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Dentistry Section

Shear Bond Strength, Bonding Time and Adhesive Remnant Index of Adhesive Precoated Flash Free Adhesive System vs Conventional Adhesive System using Metal Brackets: An In-vitro Study

HRISHIKESH MADAN BORGIKAR[1], JIWANASHA AGRAWAL[2], MANISH AGRAWAL[3], SANGAMESH FULARI[4], LALITA NANJANNAWAR[5], SHRADDHA SHETTI[6], VISHWAL KAGI[7], AMOL SHIRKANDE[8]

ABSTRACT

Introduction: With advances in materials for bonding in orthodontics, errors regarding amount of adhesive to be used can be controlled. Adhesive Precoated (APC™) Brackets were introduced to reduce the step of applying conventional adhesive on base of the bracket. Moreover, APC™ Flash Free Adhesive System (FFAS) eliminated the step of removal of excessive adhesive around the brackets.

Aim: To compare Shear Bond Strength (SBS), Bonding Time (BT) and Adhesive Remnant Index (ARI) between Conventional Adhesive System (CAS) and APC™ FFAS using metal brackets

Materials and Methods: This in-vitro study was carried out in the Department of Orthodontics and Dentofacial Orthopaedics at Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Sangli, Maharashtra, India. A total of 78 teeth with metal braces were split into two groups, with 39 samples each receiving treatment with the CAS and the APC™ FFAS. Shear bond forces were applied to each sample using a universal testing machine and recorded in Megapascals (MPa) to provide an indication of SBS. Both Groups' BT was quantified in terms of seconds. The stereomicroscope indexes of Artun J and Bergland S were used to determine ARI. Microsoft Excel was used for data entry, while Statistical Package for Social Sciences (SPSS) version 24.0 was used for analysis. The normality of the data was tested using two different t-tests. In terms of mean and standard deviation, descriptive statistics were represented. A significant level of 0.05 was used.

Results: SBS values were 10.35±3.55 MPa and 11.23±3.82 MPa in CAS and FFAS respectively. No significant difference was found among the two groups ($p \leq 0.29$) in SBS. BT was significantly ($p \leq 0.001$) less in FFAS (95.54±8.72 seconds) compared to CAS (140.85±16.62 seconds). ARI was significantly ($p \leq 0.002$) less in FFAS (1.79±0.80) in comparison with CAS (1.23±0.74).

Conclusion: FFAS brackets perform better in comparison to CAS in case of BT and ARI. Both groups show no significant difference in SBS.

Keywords: Excess adhesive, Orthodontic bracket, Stereomicroscopy

INTRODUCTION

In order to achieve successful orthodontic bonding, it is necessary to take into account the tooth's surface, including its morphology and enamel preparation, the base of the individual orthodontic attachment, including its mechanical and material properties, and the bonding material, including its good SBS and material composition. The orthodontist has several different cements and resins from which to select [1].

Basic steps in direct bonding are enamel conditioning, priming the tooth surface and bonding the attachment. The bonding step consists of transfer of the bracket, positioning, fitting, removal of excess adhesive and curing. Introduction of Acid-etch technique in 1951 to bond dental restorations to teeth was an important step in history of orthodontic bonding [2]. When directly bonding brackets, most orthodontists utilise either a precoated bracket system in which the base of the bracket already has orthodontic glue applied to it, or they manually apply orthodontic adhesive to the base of the bracket. Excess glue surrounding the bracket, which physicians sometimes fail to remove entirely [3] after insertion, is a prime location for the development of mature plaque [4-6].

A little amount of adhesive around the bracket surface area is still required to guarantee that the glue will be buttered into the bracket backing during the fitting process, even if surplus adhesive (Flash) has to be removed after bracket insertion [7]. The innovative APC™ FFAS from 3M™ Unitek (Monrovia, Calif.) eliminates the requirement for flash removal during bracket placement or composite curing. The success of a bond depends heavily on the etching technique used, the adhesive's mechanical qualities, and the clinician's expertise. SBS values between 6 and 10 MPa are necessary for strong adhesion [8]. Etching time, priming time, and curing time following bracket placement make up BT. ARI was used to measure the quantity of adhesive still present on enamel after debonding, as reported by Artun J and Bergland S [9]. Ceramic brackets have been the primary focus of FFAS research in previous studies [10-13]. Only SBS, ARI, and/or BT have been evaluated independently using FFAS in metal brackets [14]. This research set out to compare FFAS with CAS in metal brackets with regards to SBS, BT, and ARI.

MATERIALS AND METHODS

This in-vitro study was carried out in the Department of Orthodontics and Dentofacial Orthopaedics at Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Sangli, Maharashtra, India. On December 13, 2019, the Institutional Ethical Committee approved the study {Letter no. BV(DU)MC&H/IEC/Sangli/Dissertation2019-20/D-33}. Study was delayed because of COVID-19 pandemic. The procedure of study was followed in conformity with the Institute's ethical standards from September 2020 to March 2021.

Teeth were obtained from a patient undergoing extraction at the Dental College and Hospital of the Bharati Vidyapeeth (Deemed to be University), Sangli, Maharashtra, India. Those utilising the 3M™ Unitek Transbond™ XT CAS for their 3M™ Unitek Victory Series low profile metal brackets served as the control group, while those using the 3M™ Unitek APC™ FFAS served as the experimental group.

Inclusion criteria: Newly extracted human premolars with intact and non carious buccal enamel surface.

Exclusion criteria: Pretreated teeth with bleaching, flurosis, restored teeth, teeth with cracks and previously orthodontically treated teeth.

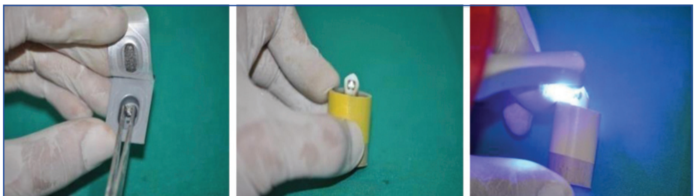
Sample size calculation: Based on an alpha significance level of 0.05 and power of 80%, 78 samples were assessed according to Grünheid T and Larson BE [15]. This in-vitro study was done using 39 human premolars in each group

Study Procedure

The teeth were thoroughly cleansed of any remaining tissue tags. When the tooth's root was firmly lodged, each tooth was placed vertically in self-cure orthodontic acrylic blocks. Oil, fluoride-free fine pumice, water, and a slow-speed handpiece were used to clean and polish the teeth's buccal surfaces before being rinsed and dried. Bonding procedure was done in four steps. Etching was done using 37% orthophosphoric acid for 15 seconds. Etched surface was painted with with 3M™ Unitek Transbond™ XT primer.

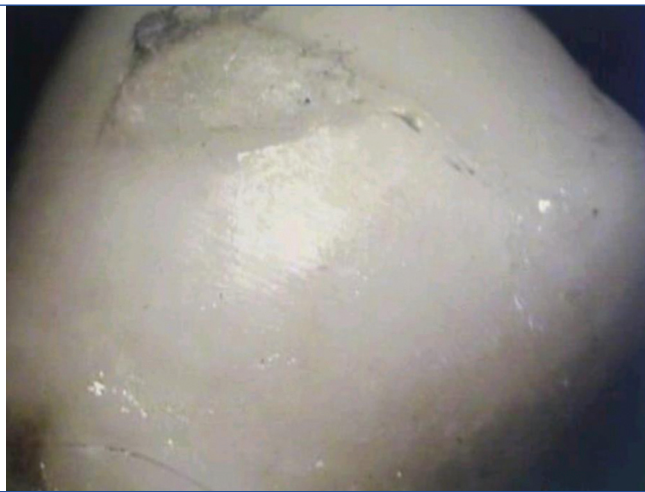
In the CAS group, a 3M™ Victory series low profile bracket system was coated with Transbond™ XT light cure adhesive paste (3M™ Unitek) and then selected at random. After applying a steady force to bond the bracket to the tooth, any extra adhesive glue or flash was scraped off with an explorer, as seen in [Table/Fig-1]. The APC™ Flash-Free Adhesive Coated Bracket was removed from its container and placed on the tooth in the FFAS group, as illustrated in [Table/Fig-2]. Light-emitting Diodes (LED) curing light at 1200-1500 mW/cm² was used for 20 seconds of curing. Occluso-gingival and mesio-distal bracket placement was optimised to the greatest extent feasible.

[Table/Fig-1]: Steps in bonding using CAS.



[Table/Fig-2]: Steps in bonding using FFAS.

The SBS was measured at a crosshead speed of 1 mm/min on a universal testing equipment. To evaluate the SBS, a knife edge shaped equipment was positioned at the enamel-resin contact. By measuring the surface area of the bracket, we were able to convert the maximal force needed to de-bond it from Newtons to Megapascals (1 MPa=1N/mm²) [10]. BT was arrived at by adding etching time comprising of priming and etching, to BT, which incorporated bracket placement and curing. An outsider used a stopwatch to time BT and report the results in seconds. To determine the kind of fracture, ARI was measured using a stereoelectronic microscope. The ARI provided by Artun J and Bergland S was used to assess the quantity of adhesive remaining on the tooth after de-bracketing [Table/Fig-3] [9]. The following are some of the criteria used in the index: Adhesive removed from tooth=0. One means there is less than half the amount of glue on the tooth. More than half of the glue is still on the tooth if the number is two. Three remaining traces of glue on teeth.



[Table/Fig-3]: ARI being examined.

STATISTICAL ANALYSIS

Pilot study was done using 10 samples that were not included in the study. Power was calculated to be 80%. This in-vitro study was done using 39 human premolars in each group. Statistical analysis was performed using SPSS 24.0 (IBM Corp., USA) for Microsoft Windows. Contrasts were analysed using T- tests for each group separately. If the probability value is less than 0.05, then the result is statistically significant.

RESULTS

In the present study, 78 samples were divided equally into two groups as shown in [Table/Fig- 4]. All three parameters SBS (MPa), BT (seconds) and ARI (0-3) for 39 samples in each group are displayed in [Table/Fig-5].

S. No.	Groups	Group content
1	CAS	3M™ unitek transbond™ XT Conventional Adhesive System (CAS) usingvictory series lowprofile brackets
2	FFAS	3M™ unitek APC™ Flash Free Adhesive System (FFAS) victory series Low profile brackets

[Table/Fig-4]: Total sample distribution among each Group.

Measurement and Comparison of SBS: CAS exhibited SBS 10.35±3.55 (Mean±SD) MPa compared with FFAS having 11.23±3.82. Although the SBS of the CAS was non significant compared to the FFAS numerically but greater than 10 MPa [15], which is sufficient for orthodontic purposes. The measurements of SBS values from CAS and FFAS were statistically non-significant as shown in [Table/Fig-6].

Measurement and Comparison of BT: The BT was significantly different between CAS (140.85±16.62) and FFAS (95.54±8.72) in seconds as shown in [Table/Fig-7].

Groups	Variable	N	Minimum	Maximum	Mean	SD
CAS	SBS	39	1.73	21.42	10.35	3.55
	Etching Time	39	34.00	65.00	49.36	8.39
	Bonding Time	39	63.00	114.00	91.49	13.34
	BT	39	107.00	167.00	140.85	16.62
	ARI	39	0.00	3.00	1.79	0.80
FFAS	SBS	39	5.04	20.42	11..23	3.82
	Etching Time	39	32.00	50.00	41.56	4.30
	Bonding Time	39	40.00	74.00	54.15	6.64
	BT	39	77.00	119.00	95.54	8.72
	ARI	39	0.00	3.00	1.23	0.74

[Table/Fig-5]: Total descriptive analysis of all parameters.

Groups	Mean	SD	Difference	p-value
CAS	10.35	3.55	-0.88	0.296
FFAS	11.23	3.82		

[Table/Fig-6]: Comparison of SBS between two groups.
Independent t-test; non significant as p>0.005

Groups	Mean	SD	Difference	p-value
CAS	140.85	16.62	45.31	0.001*
FFAS	95.54	8.72		

[Table/Fig-7]: Comparison of BT between two groups.
Independent t-test; *indicates significant difference a p≤0.05

Measurement and comparison of ARI: The FFAS exhibited less ARI 1.23±0.74 compared with CAS I having 1.79±0.80. Use of flash free bracket prevents extra adhesive to be distributed compared to conventional adhesive resulting in results in minimum adhesive left on tooth surface. Flash free brackets showed less ARI as shown in [Table/Fig-8]. Distribution is shown in [Table/Fig-9].

Mean	SD	Groups	Mean Rank	p-value
1.79	0.80	CAS	47.05	0.002*
1.23	0.74	FFAS	31.95	

[Table/Fig-8]: Comparison of ARI score between two groups.
Independent t-test; *indicates significant difference at p≤0.05

Groups	Score-0	Score-1	Score-2	Score-3
CAS	2 (5.1%)	11 (28.2%)	19 (48.7%)	7 (18%)
FFAS	5 (12.8%)	22 (56.4%)	10 (25.6%)	2 (5.2%)

[Table/Fig-9]: Distribution according to the scores.
Scores of ARI according to Artun J and Bergland S Index [9].

DISCUSSION

This study explored the differences between two different systems in SBS, BT and ARI. This is the first study evaluating all three parameters in two systems especially metal brackets.

Difference in SBS found in the present study was non significant between CAS (10.35±3.55 MPa) and FFAS (11.23±3.82 MPa). Furthermore, Akl R et al., and Guzman UA et al., reported no statistically significant differences between CAS and FFAS after 24 hours postbonding (p-value=0.574 and p=0.574, respectively) [16,17]. The difference between FFAS (10.97 MPa) and CAS (8.23 MPa) was statistically significant, as reported by Szuhanek C et al., [18]. Both methods had comparable binding strength according to Grünheid T and Larson BE [19]. According to Lee M and Kanavakis G, the SBS of the FFAS was 13.7MPa, whereas that of the CAS was only 10.8 2.0 MPa [20]. Reynolds IR suggests that the SBS values obtained in the current investigation are sufficient however this is not the case [21]. The FFAS contains a uniform layer of adhesive on non woven matrix on base of the bracket base eliminating the time to put adhesive on the base of bracket and remove excess flash after the bracket positioning. In our study, BT found was significantly different in the CAS (140.85±16.62 seconds) and FFAS (95.54±8.72 seconds). The average BT required for FFAS (19.5 seconds each tooth) was much lower than that for CAS (33.8 seconds per tooth) [22], as reported by Foersch M et al., Bonding took much less time (30.7 3.3 seconds) in the FFAS (P. 001) compared to the CAS (41.8 4.0 seconds) [20]; this difference was statistically significant. In their study, Tumoglu M and Akkurt A found that BT administered via FFAS was over 4.22 minutes shorter per patient [23]. The bonding period in the investigation was more extensive than that in the aforementioned studies. The same operator, with just two years of clinical experience, bonded all of the patients' brackets, although a more skilled dentist could have been able to do so in less time. Usage of FFAS prevents excess adhesive to flow out of expected area of base of bracket compared to CAS resulting in lesser adhesive left on tooth surface. Results of present study indicate that the FFAS (1.23±0.74) exhibited significantly less mean ARI compared with CAS (1.79±0.80). ARI evaluation according to Artun J and Bergland S criteria explored a higher number of Score-2 in CAS (48.7%) and Score-1 in FFAS (56.4%) [9]. This indicates that the tested samples in FFAS showed a greater number of bond failures occurring at the enamel to adhesive interface than CAS, which is consonant with reports by Henkin FS et al., and Lin CL et al., [24,25]. Vig P et al., suggested that bond failure at enamel to adhesive interface is favourable as clean up procedure required after debonding will be less, preventing loss of enamel surface making it less susceptible to plaque accumulation and sensitivity on exposure of the prism endings [26]. Maxfield BJ et al., explains plaque accumulation leads to demineralisation and white spot lesions [27]. Even the appearance may be unesthetic and unsatisfying. Studies by Hosein I et al., Ireland AJ et al., and Day CJ et al., suggest that production of airborne particles and inhalation of aerosols was result of more residual adhesive [28-30]. A recent study by Brown JS et al., has explored the overestimation of concentration of particulates by sampling studies that will reach the lower respiratory tract [31]. Penetration is affected by respiratory functions, e.g., nose versus mouth breathing and breathing patterns. This explores a fact that lesser the adhesive remnants better the cleanup and lesser amount of enamel loss and airborne particles. Previous comparative studies and results of present study are summarised in [Table/Fig-10] [16,17,20,32-35].

S. No.	Author and Year	Place	Sample size	Materials	Parameters	Conclusion
1	Akl R et al., (2022) [16]	Lebanon	186 premolars	Metal APC™ Flash-Free Adhesive System (FFAS), the APC™ pre-coated adhesive system and a conventional uncoated system.	SBS and ARI	Mean SBS between FFAS and CAS metal brackets is non significant, the bond failure of the APC™ Flash-Free metal system is highest at the bracket-adhesive interface and with the highest percentage of teeth having more than 50% residual composite on the enamel after debonding.
2	Guzman UA et al., (2013) [17]	MS,USA	90 recently extracted bovine permanent mandibular incisors	Precoated and conventionally bonded orthodontic brackets	SBS and ARI	The immediate bonding strength of the precoated brackets during the first day does not appear to be a major advantage over the conventional bracket systems but less adhesive on the tooth after debonding is an advantage of precoated brackets

3	Mahmoud E et al., (2017) [32]	Romania	80 teeth	Opal adhesive (Opal bond MV composite and Opal seal), Avex brackets, 3M™ Adhesive (Transbond light cure adhesive paste and Transbond™ XT) and Unitek miniature twin metal brackets.	SBS and ARI	Using the adhesive and bracket from the same manufacturer may increase SBS and decrease the quantity of ARI.
4	Bhattacharjee D etal., (2021) [33]	Jharkhand, India	120 humanteeth	Orthodontic brackets bonded with a self- etching primer system, and conventional acidetching priming system	SBS, ARI andBT	The SBS of SEP is comparativelylesser than the conventional acid etching technique, BTand ARI are at similar level.
5	Lee M and Kanavakis G (2016) [20]	New York, USA	36 Humanteeth	APC™ Flash- Free Adhesive Coated ApplianceSystem; Clarity advanced Ceramic Bracket pasted manually; and 3M™ APC™ PLUS Adhesive prepasted brackets bonded with the extrudedflash Removed	BT, SBS andARI	Compared withother methods of bonding, theAPC™ Flash- Free Adhesive Coated Systemcan potentially reduce BT while increasing SBS
6	Vorachart W et al.,(2022) [35]	Thailand	90 extracted maxillary premolars	Metal brackets, Transbond PLUS Color Change and APC™ FF	SBS and ARI	SBS and ARIboth lesser in APC™ flash free brackets and TP brackets. SBSincreased gradually in APC™ FF Group.
7	Essop R et al., (2022) [34]	Pretoria	40 extracted sound human premolar teeth	3M™ Unitek's APC™ (Adehesive Pre-Coated) Flash-Free™ system and manually applied adhesive system	SBS, BT	APC™ fash free system allows reducedBT and sufficient shear bond strength
8	Present study	Maharashtra, India	78 extracted human premolars	Transbond™ XT CAS and APC™ Flash Free Adhesive System (FFAS)	SBS, BT and ARI	Significantly reduced BT and ARI was detected in APC™ flash free system but non Significant difference in SBS was found in both Groups.

[Table/Fig-10]: Comparative studies from the literature [16,17,20,32-35].

Limitation(s)

Present in-vitro study was done on human premolars. Thus, generalisation of results in clinical procedures should be done with caution. As the both adhesive systems belong to same manufacturer variability is limited. Thermocycling was not considered that could help in betterment of simulation in clinical process. High cost of FFAS should be considered. Future studies are required to evaluate relation between factors affecting SBS, BT and ARI in adhesives by different manufacturers and coloured adhesive system using metal brackets.

CONCLUSION(S)

While bonding metal brackets, no significant variation in SBS was discovered between the two adhesives. The chances of bracket failure are lesser in APC™ FFAS according to absolute numbers. FFAS reduced time consumed by picking and holding bracket for application of adhesive, as well as and more important the removal of flash which in conventional system increases the chair side time. This led to less BT in FFAS. FFAS resulted in less ARI compared to conventional system. This prevents enamel loss and smoother surface post debonding. APC™ FFAS performs well on base of all three parameters compared to CAS.

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PARTICULARS OF CONTRIBUTORS:
1. Postgraduate, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Sangli, Maharashtra, India.
2. Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Sangli, Maharashtra, India.
3. Professor, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Sangli, Maharashtra, India.
4. Associate Professor, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Sangli, Maharashtra, India.
5. Associate Professor, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Sangli, Maharashtra, India.
6. Associate Professor, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Sangli, Maharashtra, India.
7. Assistant Professor, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Sangli, Maharashtra, India.
8. Assistant Professor, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth (Deemed to be) University Dental College and Hospital, Sangli, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Hrishikesh Madan Borgikar,
Haripriya, Vidyanagar, Jath. Sangli, Maharashtra, India.
E-mail: borgikarhrishikesh@gmail.com

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