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In-vitro comparison of bonding time and strength of adhesive pre-coated and standard metal orthodontic brackets

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ABSTRACT

Objective

To compare the shear bond strength and bond time of 3M Unitek's APC (Adehesive Pre-Coated) Flash-Free™ system applied to metal brackets.

Materials and Methods

An in vitro study was performed on 40 extracted sound human premolar teeth randomly divided into two groups (20 per group) bonded either with Adhesive Pre-Coated Flash-Free metal brackets or metal brackets coated manually with Transbond XT™ light-cure adhesive.

Bonding time was measured using a stopwatch. Thermoycling was performed on the samples (500 cycles) to simulate the oral environment between baths of 5°C and 55°C distilled water. Debonding shear bond strength measurements were performed in an Instron universal testing machine.

Results

The APC Flash-Free group bonded in significantly ($p<0.001$) less time (mean 34.06s/tooth) than the manually coated group (mean 55.14s/tooth). Shear bond strength of the manually coated group was significantly ($p<0.001$) higher (mean 13.32 MPa) than the APC Flash-Free group (mean 10.95 MPa).

Conclusion

The APC Flash-Free free system is efficient and allows for reduced chair time during the bonding appointment while attaining a mean shear bond strength of 10.95MPa, which is higher than the minimum shear bond strength of between 4MPa and 7MPa[1].

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INTRODUCTION

Since the inception of the acid etch technique described by Buonocore[2] adhesive dentistry has evolved with a multitude of adhesive products, including orthodontic adhesives.[3-5] When a bracket is bonded to a tooth, it is either bonded by manually coating brackets with adhesive or with brackets pre-coated with adhesive.[6, 7] One of the problems with manually coated brackets is the need to remove the excess adhesive flash from around the bracket prior to curing.[8, 9]

The second problem with manually coated brackets is that clinically, a common site of enamel demineralization is at the enamel-adhesive interface of the tooth surrounding an orthodontic bracket.[8-11] When the excess adhesive flash is not removed adequately, the rough adhesive surface remaining provides a site for rapid attachment and growth of oral microorganisms.[12-14] Patients undergoing orthodontic treatment, thus face a high risk of developing enamel demineralization (white spot lesions) and caries at the bracket-enamel interface.[14]

The APC Flash-Free Adhesive Coated Appliance system was developed by 3M Unitek (Monrovia, Calif) in 2013 in an attempt to eliminate flash removal.[9, 15] The technology was first applied to ceramic brackets in 2013, and in 2016 introduced to metal brackets.[9,15] The bracket base comprises a nonwoven polypropylene mesh infused with a low viscosity resin.[9,15] When applying pressure to the compressible mat, the resin is expressed in sufficient quantity to spread out and conform to the tooth surface, making uniform and consistent contact with no flash to clean-up.[15,16] The low viscosity resin is achieved by reducing the filler content of the adhesive,[17] however, Faltermeier et al.[18] have shown that a reduction in filler particles results in reduced bond strengths.

In addition, Foersch et al.[9] have demonstrated that the APC Flash-Free™ system did in fact express some flash at the bracket margins when examined microscopically. The flash ranged between 0.08 – 0.16mm, but due to the low viscosity of the resin, was shown to have a smooth surface. This was found to be a positive feature as the minute volume of flash confirms the presence of a marginal seal while the smooth surface is less susceptible to plaque accumulation.[9]

Research performed by 3M Unitek reported a reduced bonding time, adequate bond strength, and no adhesive flash clean-up when the APC system was applied to ceramic brackets.[15] In 2016 3M Unitek applied the APC

Flash-Free™ technology to metal brackets. However, after a thorough literature search, no studies could be located which evaluated the properties of the APC Flash-Free™ technology when applied to metal brackets.

The objective of this study was to determine (1) the shear bond strength (SBS) between APC Flash-Free™ adhesive coated and manually coated metal Victory Series™ (3M Unitek, Monrovia, Calif) brackets and (2) to determine whether there is a significant difference in the bond time between the two systems.

MATERIALS AND METHODS

Ethics Approval

The study protocol was approved by the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, South Africa. Ethics Reference No.: 499/2017.

Sample

Forty extracted human premolar teeth were collected from the Maxillofacial and Oral Surgery clinic. The sample size was guided by previously published *in-vitro* studies evaluating bonding time and bracket bond strength on extracted human teeth.[6,19-22] Any deposits on the teeth were removed with a brush or a dental scaler and rinsed under running water. The inclusion criteria for the extracted teeth were sound enamel surfaces with no carious lesions, fluorosis or cracks, no demineralisation of the enamel, and no restorations present. The teeth were randomly divided into two groups (20 per group) and stored in a 0.1% Thymol solution to inhibit any microbial growth.[23] All teeth were bonded within 48 hours of being extracted.

Brackets

Adhesive precoated brackets were introduced by 3M Unitek in 1991.[24] The brackets were precoated with a modified version of Transbond XT™ that has been developed to have reduce viscosity.[24] These earlier APC systems lessened the number of bonding steps; however, flash removal was still necessary.[25] In 2013 3M Unitek released the APC Flash-Free system which the company had developed after recognising the shortcomings of excess adhesive flash removal.[15] For the purpose of standardisation, maxillary premolar metal twin brackets (Victory Series™,3M Unitek, Monrovia, Calif) were used in this study. Twenty uncoated metal (Victory Series™) brackets in conjunction Transbond XT™ (3M Unitek, Monrovia, Calif) were used in the control group (Group 1, Transbond XT™) and twenty APC Flash-Free pre-coated metal (Victory Series™) brackets were used in the experimental group (Group 2, APC Flash-Free).

METHODOLOGY

Bonding procedure: The bonding surfaces of each tooth were polished with non-fluoridated pumice and water for 15 seconds. The surfaces were then rinsed, air dried and etched with 37% phosphoric acid (Ultraetch™, Ultradent, St Louis, MO, USA) for 30 seconds. After rinsing and drying, Transbond XT™ primer (3M Unitek, Monrovia, Calif) was applied and thinned out using a burst of air. The bonding procedure was performed by the principal investigator as follows:

- **Group 1:** Transbond XT was applied to the bracket base directly. The bracket was then placed on the tooth with firm constant pressure. The excess flash was then removed, and the bracket was corrected to the ideal occluso-gingival and mesio-distal position on the tooth.
- **Group 2:** The APC Flash-Free coated brackets were removed from their individually packaged containers and placed onto the tooth with firm constant pressure. The bracket was then corrected to the ideal occluso-gingival and mesio-distal position on the tooth.

An LED light curing unit (Woodpecker™, Model: LED.B, Woodpecker Medical Instrument Co, Guilin) was used to cure the adhesive. The light was applied for ten seconds (five seconds from the mesial and 5 seconds from the distal of the bracket) at an intensity of between 1070 mw/cm^2 and 1120 mw/cm^2.

Measurement of bond time: The bonding procedure was timed to the nearest hundredth of a second by an independent observer using a stopwatch. Timing began when the operator secured the bracket onto the bracket holding forceps and was stopped when the operator deemed the bracket to be in the correct occluso-gingival and mesio-distal position.

Thermocycling: Thermocycling tests were developed after it was noted that oral temperature changes resulted in stresses at the restorative-substrate interface.[26] It is a method of simulating oral temperature changes *in-vitro* by immersing specimens in circulating baths set at predetermined temperatures for predetermined time durations.[27] Previous studies have demonstrated that after thermocycling, a significant decrease in shear bond strength was observed.[28, 29] Bonded teeth were placed in a net which was attached to the motorised arm of a thermocycling system (Model MX07R-20-A11B, Polyscience Temperature Control Solutions™, Niles, Il). The teeth were cycled 500 times between baths of 5°C and 55°C.[30] Distilled water was used in the baths, and the exposure time in each bath was 20 seconds with a transfer time of 5 seconds between baths.[30]

Debonding procedure: The bonded teeth were secured into copper rings which were then mounted onto the clamp of an Instron™ universal testing machine (Model 3366, Instron Corp, Norwood, MA, USA). The mounted teeth were adjusted until the occlusal portion of the bracket was parallel to the shearing blade of the testing machine. The shearing blade of the Instron™ machine applied an occluso-gingival load to the bracket at a speed of 1mm per minute and SBS was recorded in Mega Pascals (MPa).

Statistical Analysis

Based on previous studies[6, 9, 16, 31] the expected shear bond strength of the manually coated brackets was 10.4 MPa with a standard deviation of 1.39. A 15% increase or decrease in shear bond strength of the preloaded appliance would therefore be regarded as clinically significant. Based on this, a sample of 20 teeth per group would have a 90% power to detect a 15% change when testing at the 0.05 level of significance.

Descriptive statistics, including the mean, standard deviation, minimum, and maximum values, were calculated for each group tested. The two-sample t-test was used to test for differences between groups and

any statistical interaction between the different adhesives used. The Shapiro-Wilks test was used to test the normality of the distribution of Shear Bond Strength and Bond Time. All statistical calculations were performed at the 95% confidence interval.

RESULTS

Bond Time

The mean bond time of brackets in Group 1 (Transbond XT™) was 55.14s (min: 49.12, max: 59.46, SD: 3.14). Brackets in Group 2 (Flash-Free) were bonded in a mean time of 34.06s (Table 1). According to the two-sample t-test, the time-saving effect of Group 2 (Flash-Free) (21.01s per bracket) was found to be statistically significant ($p<0.001$).

Table1: Descriptive Statistics - Bond Time (in seconds).

Group	*n	Mean	**Std Dev	Minimum	Maximum
Group1 (Transbond XT)	20	55.14	3.14	49.12	59.56
Group 2 (APC Flash-Free)	20	34.06	4.73	19.65	42.48

*Number in sample
** Standard deviation

Shear Bond Strength

The mean SBS of the brackets in Group 1 (Transbond XT™) was 13.32 MPa (min: 9.23, max: 15.67, SD: 1.72). The mean SBS of the brackets in Group 2 (Flash-Free) was 10.95 MPa (min: 6.19 MPa, max: 16.7 MPa, SD: 2.29) (Table 2). According to the two-sample t-test, Group 1 (Transbond XT™) brackets bonded with a significantly higher shear bond strength than brackets in Group 2 (Flash-Free) ($p<0.001$).

Table 2: Descriptive statistics - Shear Bond Strength (*MPa).

Group	**n	Mean	***Std Dev	Minimum	Maximum
Group 1 (Transbond XT)	20	13.32	1.72	9.23	15.67
Group 2 (APC Flash-Free)	20	10.95	2.29	6.19	16.70

*Megapascal
**Number in sample
*** Standard deviation

DISCUSSION

The objective of this study was to evaluate the shear bond strength (SBS) and bond time of a flash free pre-coated bracket adhesive system (APC Flash-Free, 3M Unitek, Monrovia, California).

This in vitro study demonstrated a statistically significant decrease in bonding time when using the pre-coated APC Flash-Free™ system [Figure 1]. This was expected since two steps (adhesive application and excess adhesive flash removal) are eliminated from the bonding procedure. The flash-free system took, on average, 21 seconds less to bond per tooth. This agrees with the results of Lee and Kanavakis[6] , Foersch et al.,[9] and Grunheid and Larson.[17] The percentage reduction in bond time per tooth reported by Foersch et al.[9] was 58%, Lee and Kanavakis[6] 74%, and Grunheid and Larson[17] – 37%. In this study the percentage reduction in bond time per tooth using the flash-free system was 62%. This equates 8.75 minutes when bonding 25 teeth. However, in a systematic review and meta-analysis, Alakttash et al.[32] reported that there was no clinical significance regarding bonding time between pre-coated and manually coated brackets.[32]

In this study, the ideal bracket position was marked on each tooth. This step was performed to eliminate the time taken to position each bracket at the correct height and mesio-distal position. Due to variations in tooth morphology, positioning the bracket ideally without prior marking could result in unreliable recorded bond times. It should be considered that the brackets of the flash-free system are sealed individually in a light resistant package and the handling of this packaging during the bonding procedure could possibly affect the overall bond time. In this study the time taken to open the package was not considered when measuring bond time.

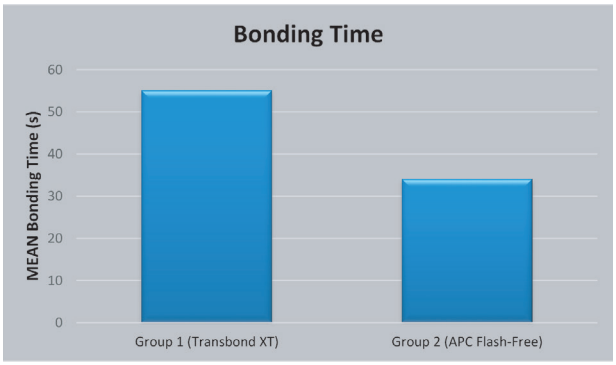

Figure 1: Comparison of bonding time.

Thermocycling is a method of simulating changes in oral temperature which occurs during routine function. This is achieved using circulating baths set at predetermined temperatures. Previous studies have demonstrated that after thermocycling, a significant decrease in shear bond strength was observed.[28, 29] In addition, none of the earlier investigators evaluating the APC Flash Free™ adhesive systems SBS had performed thermocycling on their samples.[6, 9, 16]

In this study the mean shear bond strength of Group 2 (Flash-Free) (10.95 MPa) was significantly lower than that of Group 1 (Transbond XT™) (13.32 MPa) ($p<0.001$) [Figure 2]. These results conflict with the results of Lee and Kanavakis[6], where greater shear bond strengths were achieved with the flash free system compared to manually coated brackets. However, Lee and Kanavakis[6] compared ceramic flash free brackets to conventionally bonded metal brackets in their study, and the sample was not subjected to thermocycling.

In addition, the bond strength achieved by Lee and Kanavakis[6] using the flash-free coated ceramic bracket was less than the bond strengths reported by Reddy et al.[33] and Uysal et al.[34] who investigated manually coated ceramic brackets. Lee and Kanavakis[6] reported a mean shear bond strength of 13.37 MPa for their flash-free sample which was comparable to the mean shear bond strength achieved on conventionally bonded metal brackets (13.32 MPa) in the present study. This was unexpected since previous studies have demonstrated that ceramic brackets bond with greater shear bond strengths than metal brackets.[33, 34] This could possibly

be explained by the debonding method used by Lee and Kanavakis[6] in which a tensile shearing force was applied to the bracket whereas in the present study a compressive shearing force was used.

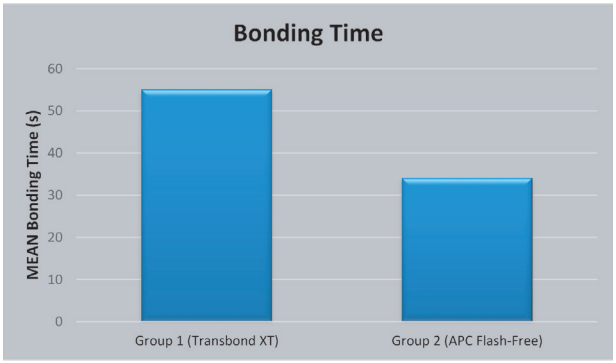

Figure 2: Comparison of shear bond strength.

According to Reynolds, the minimum shear bond strength required for clinical success should be in the range of 6 to 8 MPa.[1] Despite the lower bond strength of the flash free adhesive bracket system compared to conventionally bonded brackets in the present study and in the research by Lee and Kanavakis[6], the APC Flash Free™ bracket system bonded with sufficient strength for clinical use when integrated on either metal or ceramic brackets. In addition, Alakttash et al.[32] reported no difference of pre-coated brackets over manually coated bracket systems regarding the clinical failure rate of brackets.

CONCLUSION

- This study demonstrated that the APC Flash-Free system applied to metal brackets produced shear bond strengths adequate for clinical use.
- The APC Flash-Free™ system is a convenient bonding method which could potentially save significant chair time.

Conflict of interest

None declared.

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