



ORIGINAL ARTICLE

# Enamel demineralization around two different orthodontic bracket adhesive systems: An in vivo study



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## KEYWORDS

Demineralization;  
APC Flash Free;  
Orthodontic bracket;  
Excess adhesive

**Abstract** *Objective:* To compare the enamel demineralization around the two precoated adhesive bracket systems, APC Flash-Free and APC PLUS (3M Unitek, Monrovia, CA, USA), in clinical settings.

*Material and method:* This prospective experimental in-vivo study included 40 premolar teeth, which were planned for extraction due to orthodontic purposes. They were divided into two groups (Group A; n = 20 teeth were bonded with APC Flash Free ceramic brackets and group B; n = 20 teeth were bonded with APC Plus ceramic bracket). After four weeks, the teeth were extracted, sectioned, and examined under the Scanning Electron Microscope (SEM) to evaluate the amount of demineralization from the enamel surface to the deepest point.

*Results:* Findings revealed that the mean values of demineralization under SEM were significantly higher in APC Plus compared to APC Flash Free (149.95  $\mu\text{m}$  vs. 112.96  $\mu\text{m}$ , respectively) ( $P < 0.05$ ). The difference between the two systems was mainly found in the middle part of the facial surfaces, while there were no differences between the two systems in the proximal parts.

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*Conclusion:* The enamel demineralization around APC Flash-Free adhesive bracket system was significantly less than that of APC plus Adhesive bracket system, which can be due to the absence of the caries promoting adhesive flash during tooth bonding using the flash free system.

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## 1. Introduction

The demineralization of the buccal surfaces of teeth around bonded brackets and the formation of white spot lesions (WSL's) is a persistent and prevalent issue in orthodontics (Enaia et al., 2011; Julien et al., 2013; Øgaard et al., 1988; Richter et al., 2011). The incidence of new carious lesion formation in orthodontic patients was found to be more than 45%, and the overall prevalence of caries in patients undergoing orthodontic treatment was more than 68% (Sundararaj et al., 2015). One of the contributing factors of demineralization is the surface roughness caused by remaining adhesive around the brackets, which lead to plaque accumulation (Gwinnett and Ceen, 1979; Sukontapatipark et al., 2001). While complete removal of excess adhesive around the bracket is desirable, it can be a technique sensitive and time-consuming task (Armstrong et al., 2007; Grünheid et al., 2015).

To minimize the risk of demineralization around the brackets, several innovations of the adhesive bracket system have been developed. This included incorporating anti-cariogenic compounds or nanoparticles containing anti-bacterial compounds within the adhesives to prevent the carious lesions from forming during orthodontic treatments (Borzabadi-Farahani et al., 2014; Su et al., 2010; Wang et al., 2015). Also, methods to minimize or even completely eliminate the presence of bonding adhesive flash have been developed. In 2014, 3M Unitek (3M, Monrovia, CA, USA), introduced APC Flash-Free technology. The APC Flash-Free Adhesive Coated Appliance consists of brackets with the adhesive already pre-coated on the bases, which provides a uniform and reliable layer when placed on the surface with no clean-up required according to the manufacturer's claim. This is due to the adhesive layer being incorporated within an integrated fiber matrix, which is added to the base of each bracket. At this time, the APC Flash-Free technology is only available in ceramic brackets form. Another bracket system which is developed by 3M Unitek is the APC PLUS Adhesive Coated Appliance System. This system is characterized by a color changing and a uniform coating of adhesive on each bracket, which changes into a natural tooth color after polymerization using the light cure. According to the manufacturer, this contrasting color allows for easy adhesive clean-up which results in less flash remaining on the tooth surfaces. In addition, the adhesive has incorporated fluoride, which provides advertised fluoride release over time. This fluoride-release feature may contribute to the tooth resistance to demineralization.

The formation of WSL's on the labial surfaces of teeth have a significantly undesirable esthetic impact after orthodontic treatment (Maxfield et al., 2012). However, by reducing the amount of remaining excess adhesive around the brackets we can reduce the amount of plaque retention and accumulation

sites. This eventually may reduce the incidence of WSL's, leading to better esthetic results after orthodontic treatment. In addition, new technology has been introduced to minimize enamel demineralization during orthodontic treatment but still need more investigations (Nanoparticles in orthodontics, a review of antimicrobial and anti-caries applications, Borzabadi-Farahani A1, Borzabadi E, Lynch E.)

To the best of our knowledge, there are no in-vivo studies comparing the incidence of enamel demineralization around these two precoated adhesive systems. The aim of this clinical study was to investigate and compare the amount of enamel demineralization occurring around ceramic bonded brackets from two precoated adhesive bracket systems, APC Flash-Free and APC PLUS. The null hypothesis is that these two bracket adhesive systems have no differences in the amount of enamel demineralization around the brackets.

## 2. Materials and methods

### 2.1. Study design

This in-vivo experimental prospective double-blinded study was approved by the Ethics Committee at King Saud University, College of Dentistry Research Centre, Riyadh, Saudi Arabia (Registration number IR 0177). The study was carried out at the orthodontic clinics, King Khaled University Dental Hospital, Riyadh, Saudi Arabia. Forty premolar teeth of orthodontic patients who were scheduled to have premolars extraction as part of their orthodontic treatment were included. The inclusion criteria of this study were: (1) all included teeth must have intact buccal surfaces with no caries, fluorosis, WSLs, cracks, irregularities, abnormalities, restorations and not subjected to any materials that could affect the enamel, (2) Patients must have at least 2 premolars indicated for extraction for orthodontic treatment. An informed consent was provided and signed by all the participants before inclusion in this study.

The teeth were distributed randomly into two groups: Group A; (n = 20) premolar teeth were bonded with APC Flash Free adhesive Ceramic Brackets (APC Flash-Free Adhesive Coated Appliance System, 3M Unitek, Monrovia, CA, USA). Group B; n = 20 premolar teeth were bonded with APC Plus Adhesive Ceramic Brackets (APC PLUS Adhesive Coated Appliance System, 3M Unitek, Monrovia, CA, USA). For each orthodontic patient, equal number of brackets from both groups A and B were applied. The type of bracket system to bond the first tooth in the patient's mouth was chosen randomly using a random number generator. then going clock-wise and alternating between the 2 groups A and B. The patients were blinded to which type of bracket was bonded each of the teeth.

## 2.2. Brackets bonding procedures

All bonding procedures was done by a single experienced orthodontist under a standardized method. The surface of the enamel for each tooth was cleaned with fine pumice and rubber cup for 10 s. A 35% phosphoric acid etch (Unitek Etching Gel, 3M, Monrovia, CA, USA) was applied on the enamel surfaces for thirty seconds, and then the tooth was washed with water for three seconds and dried. A thin layer of bonding agent (Transbond XT, 3M Unitek) was coated on the etched surface with a disposable brush, then gently air-dried and light cured according to the manufacturer enclosed instructions. The brackets were positioned on the buccal surface at their proper position mesio-distally and occluso-gingivally, with a parallel angulation to the long axis of the tooth. Pressure was applied to the brackets until fully seated on the enamel surfaces. Excess adhesive around the bracket removed using a plastic instrument for teeth in-group B. Then, light curing was done for 20 s, and two elastic rings were placed over the four wings of each bracket (Fig. 1).

The patients were then instructed to avoid brushing the assigned teeth for 4 weeks, which is the time for enamel demineralization to be initiated after bonding (Øgaard et al., 1988). After 4 weeks, the brackets were debonded, and the teeth were carefully extracted by a single experienced surgeon. Any damaged tooth from extraction was excluded from this study. Then, the extracted teeth were disinfected and stored in deionized water.

## 2.3. Teeth sectioning procedures and SEM analysis

The teeth of each group were mounted in a putty material using Genie VPS Impression Putty Rapid Set (Sultan Healthcare, York, PA, USA), and sectioned with a low speed double-sided diamond disk (with a disk thickness of 0.6 mm) and continuous water irrigation (ISOMET 2000 Precision Saw, Buehler, Lake Bluff, IL, USA) (Fig. 2). Each tooth was cut bucco-lingually into three parts; P1-Proximal Mesial, M: Middle, and P2-Proximal Distal. The total of 120 sections were mounted on stubs and prepared by sputtering them with gold before the reading under the SEM.

The JEOL JSM-6360LV scanning electron microscope (SEM) (JEOL, Tokyo, Japan) was operating at 20 kV and  $\times 100$  magnification. The depth of demineralization was measured from the enamel surface to the deepest point in microns for each section, using image analysis software (SMile View<sup>TM</sup>,



**Fig. 1** Upper right first premolar bonded with group A brackets and lower right first premolar bonded with group B brackets.

JEOL Ltd, Tokyo, Japan). The reader of the samples under SEM was blinded to which sample he is reading.

## 2.4. Statistical analysis

A pilot study was performed on 8 teeth (4 teeth for each group) to calculate the sample size and power, assuming means of 109.4  $\mu\text{m}$  for APC Flash Free group, 214.3  $\mu\text{m}$  for APC Plus group and a common SD of  $\pm 100.6 \mu\text{m}$ , a sample size of 20 per group was found to be sufficient to obtain a type I error rate of 5% and a power higher than 90%. All Statistical analyses were conducted using SPSS version 22.0 statistical software (SPSS Inc., Chicago, IL, USA). The mean, standard deviation, median, and range were calculated for the descriptive analysis. Statistical significances were measured using non-parametric Mann-Whitney *U* test with *P* values of less than 0.05 considered statistically significant.

## 3. Results

A summary of the depth of demineralization results for both groups are shown in Table 1 and Fig. 3. The overall mean value of enamel demineralization depth for all three measured sections was 112.96  $\mu\text{m}$  for APC Flash Free, while the overall mean value of enamel demineralization depth for APC Plus was 149.95  $\mu\text{m}$  (Figs. 4 and 5). This difference was statistically significant ( $P < 0.05$ ) between the two groups according to Mann-Whitney *U* test. The middle parts of teeth bonded with APC Flash Free brackets shows a statistically significant less enamel demineralization compared with teeth bonded with APC Plus brackets with the mean value of enamel demineralization 108.75  $\mu\text{m}$  and 201.05  $\mu\text{m}$ , respectively ( $P = 0.006$ ).

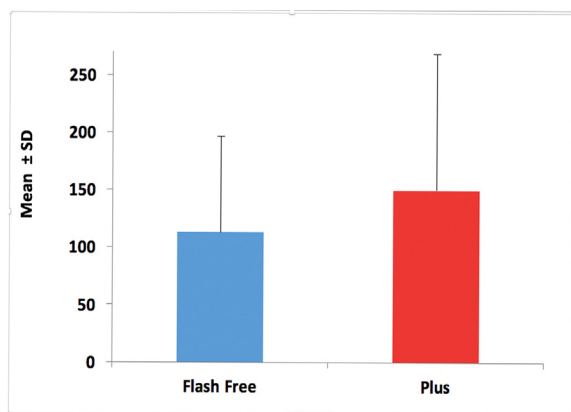
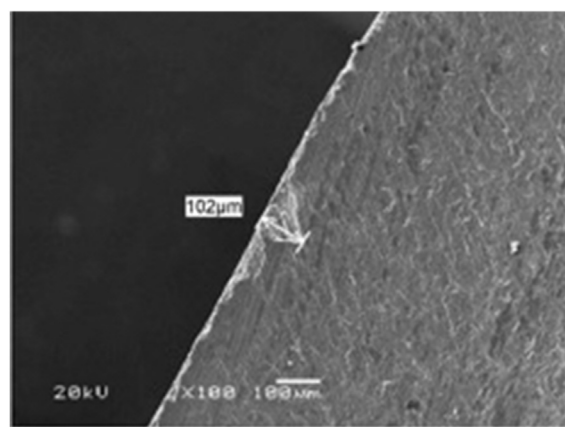
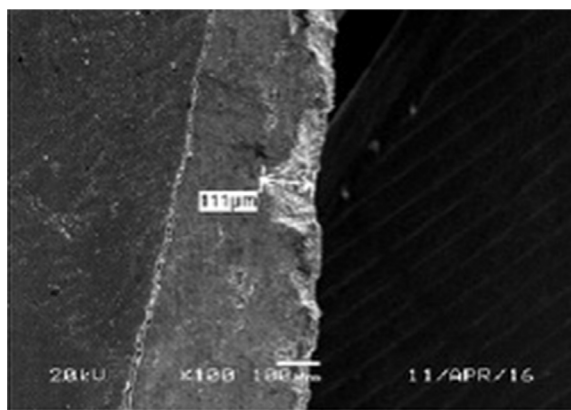


**Fig. 2** Tooth mounted, prepared for sectioning Procedures, and cross-sectional part of the tooth structure.

**Table 1** Comparison of the depth of demineralization between the two different types of orthodontic brackets adhesive systems and three tooth surface locations.

|                            | Flash Free (A)<br>Mean $\pm$ SD<br>Median (range) | APC Plus (B)<br>Mean $\pm$ SD<br>Median (range) | <i>P</i> |
|----------------------------|---|---|----------|
| DOD <sup>a</sup> – overall | 112.96 $\pm$ 83.45<br>80 (25–403)                 | 149.95 $\pm$ 118.64<br>122.5 (32–680)           | 0.010    |
| DOD – P1-Proximal Mesial   | 122.85 $\pm$ 87.11<br>96 (32–335)                 | 117.50 $\pm$ 58.15<br>114 (32–232)              | 0.675    |
| DOD – M: Middle            | 108.75 $\pm$ 90.40<br>76 (25–403)                 | 201.05 $\pm$ 165.56<br>135.5 (70–680)           | 0.006    |
| DOD – P2-Proximal Distal   | 107.30 $\pm$ 75.56<br>82 (39–357)                 | 131.30 $\pm$ 93.24<br>109.5 (34–457)            | 0.234    |

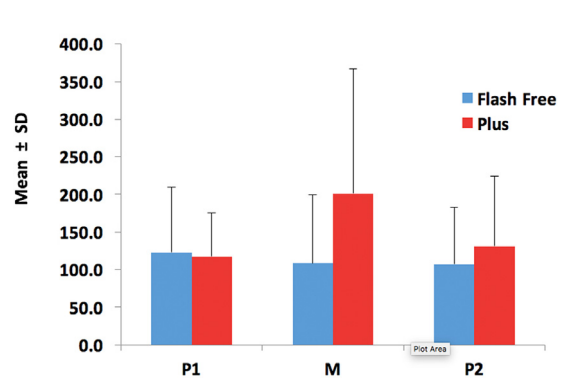
<sup>a</sup> DOD: Depth of demineralization ( $\mu\text{m}$ ).

**Fig. 3** Comparison between APC Flash Free and APC Plus in the aspect of SEM depth of demineralization.**Fig. 5** APC Flash Free (A) Specimen under SEM.**Fig. 4** APC Plus (B) Specimen under SEM.

However, there is no significant difference between the two groups in the two proximal parts (P1 and P2) in the aspect of enamel demineralization (Fig. 6).

#### 4. Discussion

Enamel demineralization has a high prevalence among orthodontic patients with fixed orthodontic appliances (Benkaddour et al., 2014; Julien et al., 2013; Lucchese and

**Fig. 6** Comparison of different parts of tooth structure between APC Flash Free and APC Plus.

Gherlone, 2013). Eliminating or reducing the risk of enamel demineralization along the perimeter of orthodontic brackets is a continuous and an ongoing struggle for clinicians and patients alike. In an attempt to prevent enamel demineralization around fixed orthodontic brackets, several improvements and innovations have been developed over the past few years. Most of these attempts studied the effect of fluoride releasing agents around orthodontic brackets (Nascimento et al., 2016; Oz et al., 2017). However, the recent development in the APC Flash Free bracket adhesive system attempts to reduce

the risk of WSL's by eliminating the excess adhesive around the bracket that can remain after flash removal.

Previous studies showed that one of the significant risk factors for enamel demineralization during orthodontic treatment was the rough surface left by excess adhesive around orthodontic brackets (Gwinnett and Ceen, 1979; Sukontapatipark et al., 2001; Weitman and Eames, 1975). In this APC Flash Free introduced system, the manufacturer claims no excess adhesive around the bracket. This claim was supported by a recent study in which the investigators compared the APC Flash Free system with the APC Plus system of brackets. They concluded that the APC Flash Free system facilitated a smoother marginal surface around the bracket, which clinically might reduce the amount of plaque accumulation (Foersch et al., 2016). Even though the pink color was added to APC Plus adhesive in order to enhance the visibility when removing excess adhesive, a recent study concluded that the addition of the pink color failed to significantly reduce the amount of excess adhesive around the bracket when compared with non-colored adhesives (Armstrong et al., 2007).

In our current study there was a significant difference between APC Flash Free and APC plus in the amount of demineralization around the bracket, these results might be due to the lesser amount of bacterial colonization around the APC Flash Free due to the lesser amount of excess adhesive and the smoother marginal surface of the adhesive. Despite the ability of APC Plus to release fluoride, the results of the current investigation suggest that the impact of excess adhesive around the bracket on the demineralization of enamel outweigh the ability of the adhesive to release fluoride. However, the results of this study were obtained within 4 weeks of bonding, further studies with a longer period of time might be needed in the future.

In this investigation the tooth was cut bucco-lingually into three different parts to have three readings covering most of the tooth surface around the bracket, to evaluate the mesial and distal areas adjacent to the bracket in addition to the middle of the tooth. Comparing the three areas between the two different bracket systems revealed that the middle part of the tooth structure showed the most significant difference between the two groups. This finding is similar to the observation by Khalaf with the middle part of the teeth showed more demineralized enamel (Khalaf, 2014). This propensity might be attributed to the typical projection of the bracket wings occluso-gingivally, increasing the difficulty of removing excess adhesive in the middle area behind these wings compared to the mesial and distal areas.

A limitation of this study was not including stainless steel brackets, as it is the more commonly used bracket material. However, ceramic brackets were used in this clinical study taking into account that only ceramic brackets are available with flash free adhesives in the market at the time of this publication. Although the type of material – either ceramic or stainless steel - doesn't have a significant influence on the accumulation of plaque around the bracket (Anhoury et al., 2002), only ceramic brackets were used in this study to decrease the variability when comparing the adhesives systems.

In addition to the decreased potential for demineralization, the APC Flash Free system allows for shorter chair-side times spent during bonding appointments. This is due to the flash free characteristic of this system, which leads to the elimination

of the time spent on flash clean-up (Foersch et al., 2016; Grunheid et al., 2015). This time saving advantage in addition to the potential to decrease WSL's during orthodontic treatments might increase the acceptance rates and usage of this system by orthodontics and patients in the future. It is prudent of clinicians to ensure that every effort is done to remove all adhesive flash around the brackets during bonding, or use a flash-free system when available. Up to our knowledge, this is the first in-vivo investigation studying the impact of recently marketed APC Flash Free system on the demineralization around the bracket. Nevertheless, the typical orthodontic treatment takes more than a year, and a longer clinical trial is needed to investigate and compare the effects of using a flash-free bracket adhesive system on the incidence of WSL's in patients in active treatment or at debanding. Also, a study comparing both flash-free ceramic adhesive systems with its stainless-steel counterpart is needed, as it is the more widely used bracket material overall.

## 5. Conclusion

Enamel demineralization around APC Flash Free adhesive bracket system was significantly less than that of APC Plus Adhesive bracket system within the first four-weeks of application. This finding can be attributed to the absence of the adhesive flash remnants during tooth bonding when using the flash free system. A study of a longer duration is needed to examine the differences occurring during conventional orthodontic therapy.

## Conflicts of interest

The authors declare that there are no known conflicts of interest.

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