

Effects of procedures of remineralization around orthodontics bracket bonded by self-etching primer on its shear bond strength

Mahmoud Al-Suleiman, Nick Silikas¹ and David Watts¹

ABSTRACT

Aim: To evaluate the effect of the application of either fluoride varnish (FV) or amorphous calcium phosphate (ACP) as preventive method on shear bond strength (SBS) at the same time of their bonding *in vitro* using self-etching primer (SEP) as an agent for enamel pre-treatment FV.

Materials and Methods: Sixty human bicuspid teeth were randomly divided into five groups: G1 was rubbed by SEP for 5 s, G2 for 5 s by SEP and ACP, G3 for 10 s by SEP and ACP, G4 for 5 s by SEP and FV, and G5 for 10 s by SEP and FV. Stainless steel metal brackets were bonded. A Zwick/Roell Z200 Universal Testing Machine (Zwick GmbH and Co, Germany) with a 500 N load cell was used to test SBS. SBS values were analyzed using one-way analysis of variance (ANOVA) and Tukey's *post hoc* tests ($P \leq 0.05$). Differences in adhesive remnant index (ARI) values between groups were calculated.

Results: The mean SBS values were 10.00 ± 4.48 MPa, 5.71 ± 4.3 MPa, 7.47 ± 4.44 MPa, 4.4 ± 2.39 MPa, and 3.98 ± 0.83 MPa for groups 1–5, respectively. Significant differences in SBS values between all groups were found. The mean SBS values of groups 2, 4, and 5 were significantly lower than that of the G1. No significant difference was found between G3 and G1. Significant difference in ARI between the groups was found ($P < 0.001$) and G1 had a significantly higher ARI.

Conclusion: The results suggested that the application of ACP at the same time of using SEP for 10 s has no effect on SBS.

Key words: Amorphous calcium phosphate, fluoride varnish, prevention of demineralization, self-etching primer, shear bond strength

INTRODUCTION

Enamel demineralization is a significant problem^[1-4] and can cause major clinical complications of orthodontic treatment with fixed appliances.^[5-9] Prevalence of white spot lesions after orthodontic treatment was reported to vary from one-third up to 96% in patients undergoing fixed appliance therapy.^[5,8,9] The placement of fixed orthodontic appliances creates a favorable environment for the accumulation of microorganisms, which causes enamel demineralization or exacerbates the effects of any pre-existing caries.^[10] A positive correlation was found between caries prevalence and lactobacillus counts before debonding.^[5] The high prevalence of carious lesions might be due to the high cariogenic challenge existing in the plaque around orthodontic appliances.^[6] Remnants of bonding

materials adjacent to orthodontic appliances accelerate dental plaque accumulation.^[11-13]

Prevention of enamel decalcification and remineralization of enamel through orthodontic treatments is a critical issue. Topical fluoride in various forms (toothpaste, mouthrinse, gels, varnishes, and fluoride-releasing cements) has been used extensively in the prevention of demineralization around orthodontic brackets.^[1-4,6-8,14] The use of topical fluorides in addition to fluoride toothpaste appears to reduce the incidence of decalcification in patients undergoing orthodontic treatment with fixed appliances.^[2] A systematic review examining 90 studies concluded that the optimum results were obtained

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when orthodontic patients with fixed appliances had used daily mouth rinsing with a 0.05% sodium fluoride mouthrinse.^[1] The effectiveness of these products and methods of prevention is directly related to the patients' compliance.^[15] Patients' compliance and their cooperation in orthodontic treatment and oral hygiene are considered a problematic matter.^[16-18] Orthodontists do not implement the available evidence in order to prevent enamel demineralization during fixed-appliance treatment.^[14] Successful preventive strategies must be based on noncompliance method. The application of fluoride varnish (FV) can be considered an efficient preventive method to enhance enamel resistance against the cariogenic challenges during orthodontic therapy.^[19,20] Clinicians should consider applying FV on areas of enamel that exhibit demineralization or are at risk of demineralization in patients with poor oral hygiene.^[15,20] One topical application of FV with a high concentration can decrease enamel lesion depth adjacent to bonded brackets by about 40% for 3 months.^[20,21]

To prevent decalcification, it has been recommended to use casein phosphopeptide-amorphous calcium phosphate (CPP-ACP), which may assist remineralization and can maintain high concentration gradients of calcium and phosphate ions and ion pairs into the subsurface lesion, thus leading to high rates of enamel remineralization.^[22-25] The presence of CPP-ACP agent delays the biofilm formation and favors the nucleation and crystallization of calcium phosphates, possibly in apatitic form, in matured biofilms.^[26] The application of CPP-ACP before bonding improves the shear bond strength (SBS) to demineralized enamel.^[27] The application of teeth mousse (CPP-ACP) (TM), NaF, or TM/NaF can significantly prevent enamel demineralization when composite resin is used for bonding.^[28]

In an attempt to reduce the numbers of procedural steps and chair time when bonding orthodontic brackets to enamel, the self-etching primers (SEPs) were developed. Several *in vitro* studies observed the efficacy of SEP as an agent to prepare enamel for bonding orthodontic attachments.^[29-31] Clinical failure rate of SEP was evaluated and it was concluded that using SEP in routine orthodontic clinical practices had brought about significant results.^[32-35] The results of *in vivo*, randomized cross-mouth clinical trial suggested that enamel pre-treatment with Ideal 1 SEP system (GAC Orthodontic Products) results in unacceptably high bond failure rates when compared with conventional enamel acid etching and, as such, it cannot be recommended for clinical use.^[36] However, the pre-treated enamel by SEP Transbond Plus (3M/Unitek) has resulted in acceptable SBS values for clinical use.^[37] It was suggested that the SEP should achieve adequate bond strengths when applied to dry enamel surfaces.^[38] The use of pumice prophylaxis is strongly suggested when using SEP for orthodontic bonding.^[39] Bonding systems with SEPs may offer potential benefits compared with conventional acid etchings and primers because of the fewer irreversible changes to the enamel surface.^[40,41] An *in vitro* bond strength testing of materials used

in orthodontic bonding will produce more reliable guidance for the clinical orthodontist.^[42]

The aim of this study was to evaluate the effect of the application of either fluoride varnish (FV) or amorphous calcium phosphate (ACP) as preventive method on shear bond strength (SBS) at the same time of their bonding *in vitro* using self-etching primer (SEP) as an agent for enamel pre-treatment FV.

The null hypothesis was that the application of either FV or ACP at the same time of the bonding, using SEP will have no effect on the SBS.

MATERIALS AND METHODS

The Aleppo University scientific and ethics committee authorized the authors to proceed with the project using the materials and methods described in the manuscript.

Sixty sound human premolars freshly extracted for orthodontic purposes were collected and stored in a solution of 10% formaldehyde solution (Epenhuysen Chemie B.V., Drachten The Netherlands)^[43] and then in distilled water until use. The criteria for tooth selection included an intact buccal enamel surface, not subjected to any pre-treatment by chemical agents such as phosphoric acid, hydrogen peroxide, no cracks due to the presence of the extraction forceps, and no caries. Each tooth was cleaned and polished using pumice for 10 s.^[39] Teeth were placed in acrylic boxes. A mounting jig was used to align the facial surface of each tooth in order to be as perpendicular with the bottom of the mold as possible.

The specimens were randomly divided into five groups ($n=12$):
 Group 1: Rubbed by SEP Transbond™ Plus (3M Unitek) for 5 s (control group)
 Group 2: Rubbed for 5 s by SEP 5 min after the application of ACP (TM-GC)
 Group 3: Rubbed for 10 s by SEP 5 min after the application of ACP
 Group 4: Rubbed for 5 s by SEP 5 min after the application of FV (DuraShield 5% sodium FV, USA)
 Group 5: Rubbed for 10 s by SEP 5 min after the application of FV

Application of FV or ACP (TM-GC) and SEP

A piece of wax equal in size to the base of a bracket was placed at the center of the buccal surface of each tooth as a guide for the placement of orthodontic brackets. FV or calcium phosphate was applied topically according to manufacturer's directions for use. The wax was gently removed from the teeth, and then SEP was applied to the teeth in each group according to the protocol above.

Bonding Procedure

Stainless steel metal brackets (Mini Sprint®-Brackets; Forestadent Company, Pforzheim, Germany) were used. The brackets were bonded to the teeth using a light-curing

composite (system–RMO/mono-lok2 bonding) and polymerized with a light-curing unit (BluePhase LED Ivoclar Vivadent, irradiance 380–515 nm) for 40 s. The area of the bracket base surface was 12.4 mm² as given by the manufacturer.

Debonding Strength Testing

A Zwick/Roell Z020 Universal Testing Machine (Zwick GmbH and Co, Germany) with a 500 N load cell was used to test SBS. The specimens mounted in their acrylic blocks were secured to the lower grip of the machine (fixed head). To maintain a consistent debonding force, a custom-made blade was fixed in the upper grip (movable head) connected to the load cell. The blade was positioned in such a way that it touched the bracket and the force applied to the ligature groove between the bracket base and the wings. Each tooth was oriented with the testing device as a guide so that its labial surface was parallel to the force during the shear strength test. A cross-head speed of 2 mm/min was used. The debonding forces of the brackets were recorded in N and then converted in MPa by taking into account the surface area of the bracket base.

The surfaces of the teeth were then examined with a stereomicroscope (Meiji Techno, Japan, Saitama, Japan) at 7× magnification to evaluate the mode of failure and enamel fracture. Adhesive remnant index (ARI) scores were recorded for each specimen to determine the mode of failure. The ARI scale ranges from 0 to 3 and the scores were classified as:

- 0: No adhesive is remaining on the enamel surface,
- 1: Less than half of the adhesive is remaining on the enamel surface,
- 2: More than the half of the adhesive is remaining on the enamel surface, and
- 3: The entire adhesive is remaining on the enamel surface.

Statistical Analysis

A one-way analysis of variance (ANOVA) and Tukey's *post hoc* test at a level of confidence ($P < 0.05$) was used to statistically analyze the SBS results. Differences in ARI values were calculated by Kruskal–Wallis test, and Mann–Whitney *U* test was used to determine which group in fact differs.

RESULTS

The mean shear bond (MPa), standard deviation, and minimum/maximum values for each group are shown in Table 1. The mean SBS of G1 (control group) was 10.00±4.48 MPa, G2 was 5.71±4.37 MPa, G3 was 7.47±4.44 MPa, G4 was 4.4±2.39 MPa, and G5 was 3.98±0.83 [Figure 1]. When the means of SBS were compared using one-way ANOVA, significant differences were found to exist between the groups ($F=5.61$, $P=0.001$). Multiple comparison [Tukey's honestly significant difference (HSD) test] [Table 2] showed that the mean bond strength findings of groups 2, 4, and 5 were significantly lower than those of the control group. However, no significant difference was found to exist between G3 and the control group.

The results of the ARI testing are recorded in Table 3. Kruskal–Wallis test showed that there was a significant difference in ARI between the groups ($P < 0.001$). Subsequently, Mann–Whitney test showed that G1 was found to have a significantly higher ARI score than all groups: G2 ($P=0.001$), G3 ($P=0.005$), G4 ($P < 0.001$), and G5 ($P=0.001$). Groups 2 and 3, 2 and 4, 2 and 5, 3 and 4, 3 and 5, and 4 and 5 did not differ in ARI scores ($P=0.229$, $P=0.66$, $P=1.00$, $P=0.105$, $P=0.229$, and $P=0.66$, respectively). Additional computation of Pearson correlation coefficients (0.543) showed strong correlation between bond strength and ARI scores within or across all groups ($P < 0.001$).

DISCUSSION

The hypothesis that there would be no difference in mean SBS between groups whether FV was used at the same time of the application of SEP in different times (5 s and 10 s) or an SEP only was used was not accepted. This was partially accepted only when the calcium phosphate was used at the same time of the application of SEP for 10 s. The results of Kimura's study suggested that there was no difference in bond strength of orthodontic brackets to enamel treated with FV or not when he applied the FV 10 days before the etching materials.^[44] The application of FV does not affect the bond strength of orthodontic brackets to enamel with conventional or SEP systems.^[44] The application of a CPP-ACP containing remineralizing paste (TM) for 60 min daily for 7 days before

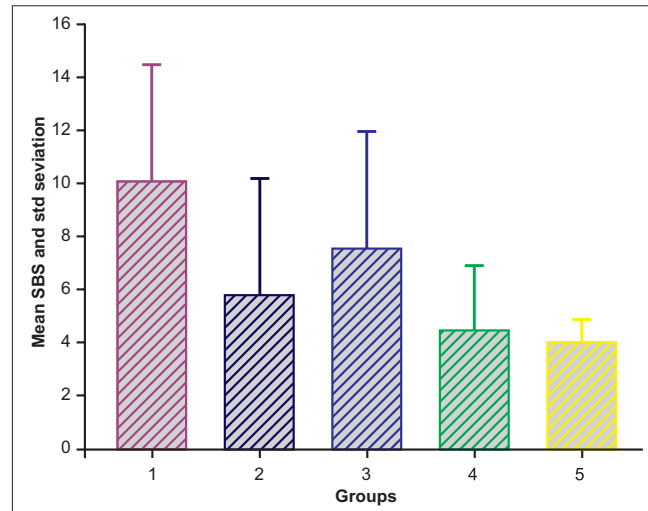


Figure 1: Bar chart diagram showing the mean SBS values for all four groups tested (1 = G1 SEP 5 s; 2 = G2 SEP 5 s and ACP; 3 = G3 SEP 10 s and ACP; 4 = SEP 5 s and FV; 5 = SEP 10 s and FV)

Table 1: Shear bond strength findings (mean, standard deviation, maximum, and minimum)

Groups	n	Mean	Minimum	Maximum
Control 5 s SEP only	12	10.01 (4.48)	6.17	19.01
Calcium phosphate 5 s SEP	12	5.71 (4.37)	3.40	19.07
Calcium phosphate 10 s SEP	12	7.47 (4.44)	2.83	16.52
Fluoride varnish 5 s SEP	12	4.40 (2.39)	1.83	8.07
Fluoride varnish 10 s SEP	12	3.98 (0.83)	2.48	5.24

Table 2: Comparing shear bond strength findings between the groups by one-way ANOVA ($P < 0.05$) and multiple comparison (Tukey's HSD test)

Groups	Mean difference	Std. error	Sig.	95% confidence interval	
				Lower bound	Upper bound
Control/cal. 5 s SEP	4.29500*	1.47567	0.040	0.1331	8.4569
Control/cal. 10 s SEP	2.53500	1.47567	0.432	-1.6269	6.6969
Control/FV 5 s SEP	5.60333*	1.47567	0.003	1.4415	9.7652
Control/FV 10 s SEP	6.02250*	1.47567	0.001	1.8606	10.1844
Cal. 5 s SEP/cal. 10 s SEP	-1.76000	1.47567	0.755	-5.9219	2.4019
Cal. 5 s SEP/FV 5 s SEP	1.30833	1.47567	0.901	-2.8535	5.4702
Cal. 5 s SEP/FV 10 s SEP	1.72750	1.47567	0.768	-2.4344	5.8894
Cal 10 s SEP/FV 5 s SEP	3.06833	1.47567	0.244	-1.0935	7.2302
Cal. 10 s SEP/FV 10 s SEP	3.48750	1.47567	0.141	-0.6744	7.6494
FV 5 s SEP/FV 10 s SEP	0.41917	1.47567	0.999	-3.7427	4.5810

* $P \leq 0.05$ **Table 3: ARI scores**

Groups	ARI				Total
	0.00	1.00	2.00	3.00	
Control group	1	5	5	1	12
Calcium phosphate 5 s SEP	8	4	0	0	12
Calcium phosphate 10 s SEP	5	7	0	0	12
Fluoride varnish 5 s SEP	9	3	0	0	12
Fluoride varnish 10 s SEP	8	4	0	0	12

etching did not affect SBS to enamel for either the total etch (Single Bond) or SEP adhesives.^[45] The findings suggest that the SBS of resin to enamel using self-etching priming adhesive may be decreased if the enamel is treated with CPP-ACP (TM).^[46] Baysal and Uysal evaluated the effect of CPP-ACP application on the SBS of orthodontic brackets bonded to demineralized enamel surface and concluded that pretreatment of enamel with CPP-ACP improves the SBS.^[27] This is not in agreement to the finding of this study where the application of (TM) did not affect SBS when brackets were bonded to normal enamel.

Taking into account that the minimum accepted SBS value for clinical using was 6 MPa,^[42,47-49] the results of this study show that the application of calcium phosphate (TM) as preventive material for enamel demineralization at the same time of the use of SEP for 5 s or 10 s can be used clinically. In addition, the application of SEP for 10 s has resulted in higher SBS when compared to its application for 5 s.

Several studies evaluated the role of fluoride in enamel decalcification prevention. The protective effects of F^- on the reduction of enamel decay have also been observed. It has been confirmed that F^- reduces the solubility of calcium hydroxyapatite, balances the rates of demineralization and remineralization, and has an antimicrobial feature as well.^[50-53]

In order to prevent enamel demineralization, FV and calcium phosphate were applied before bonding in areas around the orthodontic brackets. This application had limited the etching areas and eased the removal of the composite remains

after bonding, where these remains should be accumulated above the applied preventive materials. This has resulted in protected and smooth enamel surfaces compared with conventional bonding methods and topical application preventive materials. The suggested technique of applying of FV or calcium phosphate, SEP, and bonding should give us the following advantages: decreased dental plaque accumulation around orthodontic brackets,^[11] delayed biofilm formation, and antimicrobial^[54] and enamel remineralization^[13,19,20] roles of fluoride, calcium, and phosphate ions.^[22,25]

The failure at the enamel–adhesive interface decreases the probability of enamel damage by reducing the required mechanical removal of the residual adhesive after debonding.^[55] The results of the current study showed reduction in the ARI values when the calcium phosphate was applied before the application of SEP. This has been shown to have no effect on shear bond findings. This technique has a clinical application as a preventive method in minimizing the enamel damage after treatment.

The reduced SBS values obtained in the current study, which are unacceptable values for clinical use, after application of FV can be explained by the contamination of bonding area by varnish. However, we can use FV immediately after bonding as a demineralization agent, an antibacterial agent, and to reduce in *Streptococcus mutans* counts in the dental plaque.^[15,19,20,53]

CONCLUSIONS

1. The application of ACP (TM) around bonding area with SEP for 10 s did not affect SBS
2. The application of FV around bonding area with SEP for 5 and 10 s affected SBS.

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