

Do enamel microabrasion and casein phosphopeptide-amorphous calcium phosphate affect shear bond strength of orthodontic brackets bonded to a demineralized enamel surface?

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ABSTRACT

Objective: To evaluate and compare the effects of enamel microabrasion, casein phosphopeptide-amorphous calcium phosphate (CPP-ACP), and their combination on the shear bond strength (SBS) of orthodontic brackets bonded to demineralized enamel surface.

Materials and Methods: One hundred human first premolar teeth were randomly allocated to one of five groups. Group I was considered as the control of other groups. For the remaining groups, demineralization was performed via solutions. In group II, brackets were directly bonded to the demineralized enamel surface. CPP-ACP was applied in group III, microabrasion was performed in group IV, and both microabrasion and CPP-ACP application were performed in group V. The specimens were tested for SBS. Bond failures were scored according to the Adhesive Remnant Index (ARI). Analysis of variance and Tukey tests were used to compare the SBS of the groups. ARI scores of the groups were evaluated with a G-test. The statistical significance was set at $P < .05$ level.

Results: Statistically significant difference was found among the five investigated groups ($F = 111.870$; $P < .001$). The SBS of groups II and IV were significantly lower than the other groups. No statistically significant difference was found among groups I (control; mean 24.1 ± 4.1 MPa), III (mean 22.0 ± 3.6 MPa), and V (mean 24.3 ± 1.9 MPa). Microabrasion and combination with CPP-ACP showed higher SBS compared to the control group. The differences between ARI scores of the groups were statistically significant ($P < .001$).

Conclusion: CPP-ACP pretreatment, microabrasion of the enamel, and the combination of these two methods improve the bonding to demineralized enamel. (*Angle Orthod.* 2012;82:36–41.)

KEY WORDS: Microabrasion; CPP-ACP; Demineralization; Brackets

INTRODUCTION

White spot lesions (WSLs) are defined as “subsurface enamel porosity from carious demineralization.” These lesions appear as milky white opacities when located at smooth surfaces.¹ In other words, an opaque

white area reflects a marked mineral loss below the outermost enamel layer.²

WSL severity and incidence were shown to increase with fixed appliance treatment.^{3–5} Gorelick et al.⁶ found that the prevalence of at least one WSL in patients who did not undergo orthodontic treatment was 24%. Mizrahi and Cleaton-Jones⁷ and Mizrahi⁸ conducted studies on school children who had not undergone orthodontic treatment. They showed that 83%–85% of them had some evidence of enamel opacities. In a later study, Mizrahi⁹ examined 527 untreated individuals and 269 orthodontic patients who completed their treatment. The prevalence of enamel opacities in untreated individuals was 84% for treatment group and 72.3% for untreated individuals. More recently, Tufekci et al.⁵ found that 11% of the control patients had at least one WSL at the start of orthodontic treatment.

Overall WSL management includes prevention and treatment methods. Prevention methods include fluoride

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toothpastes, gels, varnishes, mouth rinses, antimicrobials, xylitol gum, diet counseling, and casein derivate.¹⁰ Treatment includes topical fluoride applications, tooth whitening, microabrasion, and finally composite restorations or porcelain veneers.⁴

Daily use of casein phosphopeptide (CPP)-amorphous calcium phosphate (ACP) has been shown to increase enamel remineralization, and mineralization of artificial subsurface enamel lesions increased more than 78% compared to control samples.^{11,12} CPP stabilized ACP, and CPP-ACP clusters formed.¹³ These CPP-ACP clusters increase the plaque calcium and phosphate levels and remineralize the enamel. In a meta-analysis,¹⁴ CPP-ACP has been shown to have remineralization effects with short-term use, and according to the results of randomized clinical trials, long-term use of CPP-ACP was promising for caries prevention.

Microabrasion has been used to remove noncarious enamel defects.¹⁵⁻¹⁷ This technique has also been used for postorthodontic, demineralized white spot removal.¹⁸⁻²⁰ Murphy et al.² reported that microabrasion is an effective treatment approach for the cosmetic improvement of long-standing, postorthodontic, demineralized enamel lesions. Gelgöer et al.²¹ performed microabrasion on artificial WSLs and showed that local enamel decalcifications may be sufficiently eliminated by microabrasion, without any detrimental effect on enamel. It has been also reported that the abraded enamel surface is less susceptible to bacterial colonization and demineralization than natural nonabraded enamel.^{22,23}

The percentage of individuals with WSLs who did not undergo orthodontic treatment is also high. The likelihood of WSLs developing may get worse with the placement of fixed orthodontic appliances. Detecting WSLs during active treatment can be challenging for the clinician. The clinical crown must be free from plaque and debris, and the presence of excess gingival tissue can make recognizing WSLs difficult.⁵ In these patients, enamel pretreatments may be performed to improve the WSLs before risky fixed-appliance therapy is initiated. Recently, we compared fluoride and CPP-ACP pretreatment on the shear bond strength (SBS) of brackets bonded to demineralized enamel.²⁴ CPP-ACP pretreatment resulted in SBS values that were similar to those of the control group. In the present study, the aim is to evaluate the effects of microabrasion, CPP-ACP application, and combinations of these procedures on the SBS of orthodontic brackets bonded to a demineralized enamel surface.

MATERIALS AND METHODS

The Izmir Katip Celebi University Ethics committee authorized the authors to proceed with the project

using the materials and methods described in the manuscript.

A power analysis established by G*Power Ver 3.0.10 software (Franz Faul, Universität Kiel, Germany), based on 1:1 ratio among groups, with a sample size of 20 teeth would give more than 80% power to detect significant differences with 0.35 effect size and at the $\alpha = .05$ significance level.

One hundred caries-free human first premolars, freshly extracted for orthodontic purposes, were used in this study. Teeth with cracks, enamel defects, and gross irregularities were excluded. Teeth pretreated with a chemical agent (formalin, alcohol, or hydrogen peroxide) were excluded from the study. Teeth were stored in thymol solution for no more than one month. Each tooth was vertically mounted on self-cured acrylic blocks. The buccal enamel was cleaned with scaler and polished with nonfluoridated pumice and rubber cups. The teeth were randomly divided into five equal groups of 20 teeth each, as described in the following sections.

Group I

This group was generated in order to be the control of the other groups; no enamel pretreatment was performed in this group. The buccal surface of each tooth was etched with 37% ortho-phosphoric acid (3M Dental Products, St Paul, Minn) for 15 seconds, rinsed with water for 15 seconds, and dried with oil-free air for 10 seconds until a frosty white appearance was obtained. Transbond XT primer (3M Unitek, Monrovia, Calif) was applied to the etched surface as a thin, uniform coat. Stainless steel premolar brackets (G&H Wire Company, Greenwood, Ind) with a base surface area of 10 mm² were bonded to the teeth using the standard protocols according to the manufacturer's instructions. Transbond XT composite (3M Unitek) was applied to the base of the brackets, and the brackets were positioned on the center of the buccal surfaces and pressed firmly against the tooth. The excess adhesive around the bracket was removed, and the adhesive was light cured from the mesial and distal directions for 10 seconds in each direction. A light-emitting diode unit (Elipar Freelight 2; 3M-Espe, St Paul, Minn) was used for curing the specimens.

The other four groups were the test groups, and the enamel demineralization process was performed on these groups for 3 weeks.

Group II

In this group, brackets were directly bonded to the demineralized enamel surface. The same bonding procedure was used that was explained for group I.

Group III

In this group, Tooth Mousse (CPP-ACP gel; GC Corp, Tokyo, Japan) was applied to the demineralized enamel before bonding. The agent was left undisturbed on the tooth surface for 5 minutes and then rinsed with deionized water. After 6 hours, the topical agent was reapplied to the tooth surface using the same method. This procedure was repeated 10 times for remineralization. During these cycles all teeth were stored in artificial saliva. After this step, brackets were bonded using the standard protocol.

Group IV

Microabrasion technique was adopted from the study of Gelgor and Buyukyilmaz.²⁰ Demineralized enamel surfaces were microabraded with brushes. Abrasive pad was prepared with 18% hydrochloric acid, fine-powdered pumice, and glycerine. This pad was applied with electronic toothbrushes (Braun Oral-B Plaque Control 3D; Braun, Kronberg, Germany) for 3 to 5 minutes. Then, the teeth were washed with distilled water for 1 minute.

Group V

After demineralization and microabrasion procedures, CPP-ACP application was performed as mentioned in group III. After these treatment procedures, brackets in groups II–V were placed with the same procedure as mentioned in group I.

The demineralization process, debonding procedure, and fracture analysis were the same as described in detail in a previous article.²⁴ In this article, these procedures are briefly described.

Demineralization process. In order to mimic the remineralization stage of the caries process, sequential demineralization and remineralization were performed. Each tooth was immersed in demineralization solution (pH 4.3) for 6 hours, then removed from this solution, rinsed with deionized water, and immersed in remineralization solution (pH 7.0) for 18 hours at 37°C. This procedure was repeated daily for 3 weeks. Compositions of demineralization and remineralization solutions are given in Table 1.

Debonding procedure. Each tooth was mounted vertically in a self-cure acrylic block. The blocks were placed over the base plate, and a chisel-edge plunger was mounted to the movable crosshead of a Testing Machine (Instron Corp, Norwood, Mass). Shear load was applied to the enamel-adhesive interface with a crosshead speed of 0.5 mm/min. The maximum shear force to debond the bracket was recorded in Newtons and converted to megapascals.

Fracture analysis. After debonding procedure, the remnant adhesive on the enamel surface was assessed

Table 1. Compositions of Demineralization and Remineralization Solutions

Demineralization Solution
2.0 mmol/L calcium
2.0 mmol/L phosphates
75 mmol/L acetate
Remineralization Solution
1.5 mmol/L calcium
0.9 mmol/L phosphates
20 mmol/L cacodylate buffer
150 mmol/L potassium chloride

under a stereomicroscope (SZ-40; Olympus, Tokyo, Japan) at 20× magnification. The Adhesive Remnant Index (ARI) was used to quantify the amount of remaining adhesive according to the following scale: 0 = no adhesive remaining on the enamel surface; 1 = less than 50% adhesive remaining on the tooth; 2 = more than 50% adhesive remaining on the tooth; and 3 = all adhesive remaining on the tooth surface.

Statistical Analysis

All statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS) software package (SPSS 15.0; Chicago, Ill). The normality test of Shapiro-Wilks and the Levene's variance homogeneity test were applied to the data. The data were found to be normally distributed, and there was homogeneity of variance among the groups. Thus, the statistical evaluation of SBS values among test groups was performed using parametric tests.

The means, standard deviations, and minimum and maximum values were calculated for all groups. The SBS values were tested with one-way analysis of variance, and multiple comparisons were assessed with Tukey's Honestly Significant Difference test. The G-test was used to determine significant differences in the ARI scores among the groups. The statistical significance level was set at $P < .05$.

RESULTS

For the SBS scores, the descriptive statistics and the multiple comparisons of five groups were given in Table 2. According to the analysis of variance, a statistically significant difference was found among the groups ($F = 111.870$; $P < .001$). Post-hoc test revealed no statistically significant differences between groups I, III, and V. The mean SBSs of these groups were 24.1 MPa, 22.0 MPa, and 24.3 MPa, respectively. Significant differences were found between groups I, III, V and groups II ($P < .001$) and IV ($P = .001$). The lowest mean SBS was found in group II (6.6 MPa), followed by group IV (16.2 MPa).

Table 2. Descriptive Statistics of the Groups and Comparison of SBS Values^a

Groups	n	Mean	SD	Min	Max	ANOVA		Multiple Comparison (Tukey HSD test)*
						(F value)	(P value)	P value
Group I	20	24.1	4.1	17.8	31.5	111.87	$P < 0.001$	A
Group II	20	6.6	3.9	1.1	16.0			B
Group III	20	22.0	3.6	17.4	29.8			A
Group IV	20	16.2	1.5	14.4	18.8			C
Group V	20	24.3	1.9	21.4	29.8			A

^a SBS indicates shear bond strength; SD, standard deviation; ANOVA, analysis of variation; HSD, Honestly Significant Difference; Group I, control; Group II, demineralization; Group III, CPP-ACP; Group IV, microabrasion; Group V, microabrasion+CPP-ACP.

* Groups with different letters are significantly different from each other.

The G-test indicated significant differences among groups regarding the fracture analysis ($P < .001$; Table 3). No enamel detachment was found for groups I, IV, and V. On the other hand, in group II most of the failures were seen at the enamel-composite interface (75%).

DISCUSSION

This study was performed to evaluate the effects of two different WSL management procedures and their combinations on the SBS of orthodontic brackets bonded to a demineralized enamel surface. According to the results of the present study, microabrasion, CPP-ACP application, and a combination thereof resulted in improved bonding to demineralized enamel. The maximum mean SBS value was obtained in the combination microabrasion and CPP-ACP group. This was followed by control and CPP-ACP groups. In other words, demineralized enamel that was pretreated with microabrasion plus CPP-ACP showed higher SBS values than undemineralized natural enamel. However, no statistically significant difference was found between these three groups.

Treatment of patients who had WSLs prior to fixed orthodontic treatment presents a challenge to the clinician and may require additional attention. These individuals may be untreated individuals or patients who had undergone appliance treatment as the first phase of their orthodontic therapy before fixed orthodontic treatment (functional appliance therapy,

rapid maxillary expansion, etc). Dixon et al.²⁵ reported five patients who had good oral hygiene before treatment and rapid demineralization during the course of functional therapy. Clinicians may help these patients and complete their treatment with several enamel pretreatment procedures. In a recent study,²⁴ we evaluated the effects of CPP-ACP and fluoride applied to demineralized enamel and compared them with a control group. In that study, higher SBS was found in the control group compared to pretreated groups. In the current study, bonding to microabraded and CPP-ACP-treated enamel resulted in higher SBS compared to natural enamel, but no statistically significant difference was found between the control and CPP-ACP-pretreated groups.

Keçik et al.²⁶ found a greater SBS of fluoride and CPP-ACP-pretreated groups compared to the control group. Tabrizi and Cakirer²⁷ reported no statistically significant difference between control and CPP-ACP only or CPP-ACP plus fluoride-pretreated groups. Xiaojun et al.²⁸ reported higher SBS in the CPP-ACP-applied group in cases where light-cure adhesives were used. However, they determined that the fluoride pretreated group showed significantly lower SBS. In these studies, pretreatment procedures were performed on natural enamel.

According to epidemiologic studies, maxillary lateral incisors and mandibular first molars have highest frequencies of WSLs.^{6,9,29,30} Mandibular second premolars and maxillary canines are also commonly affected.^{29,30} Undoubtedly, the formation of WSLs in maxillary incisors and canines adversely affects esthetics. Fluoride or CPP-ACP pretreatment may be performed, but remineralization results in whiter color compared to natural enamel and appears similar to a WSL. According to Donly and Sasa,³¹ remineralized enamel does not have enamel prisms, and they are a highly dense compaction of calcium phosphate and fluoride. Enamel microabrasion is mainly used for esthetic improvement, and in orthodontics its application is limited to postorthodontic WSL removal. As remineralization process did not improve the esthetics,

Table 3. Cross-Tab and Statistical Comparison of ARI of Groups^a

Groups	0	ARI			Total	P
		1	2	3		
Group I	0	7	4	9	20	<.001
Group II	15	5	0	0	20	
Group III	5	7	5	3	20	
Group IV	0	5	7	8	20	
Group V	0	0	11	9	20	

^a ARI indicates Adhesive Remnant Index; Group I, control; Group II, demineralization; Group III, CPP-ACP; Group IV, microabrasion; Group V, microabrasion+CPP-ACP.

microabrasion and CPP-ACP application may be performed both for esthetics and remineralization.

In the present study, solely microabrasion of demineralized surfaces resulted in significantly lower SBS compared to groups where CPP-ACP application was performed. On the other hand, Sanders et al.³² reported similar SBS values for the brackets bonded to microabraded and nonabraded enamel surfaces. This may be because they used different enamel conditions and abrasive pads than were used in this study.

One of the most important aspects of microabrasion is that the abraded enamel surface is less susceptible to bacterial colonization and demineralization than natural enamel.^{22,23} Small amounts of surface enamel are removed and the surface becomes highly polished.³¹ This is because the microabrasion process compacts calcium and phosphate into an interprismatic area. The new surface characteristics may provide additional benefits to those patients who initially have WSLs without compromising esthetics.

According to Reynolds,³³ 5.9- to 7.8-MPa SBS values are adequate for orthodontic purposes. Except for the demineralization group (6.6 ± 3.9 MPa), all groups exhibited greater SBS values based on the findings of Reynolds.³³ But the values suggested by Reynolds were based on tensile strength, whereas in the present study the SBS values were evaluated.

Keles¹⁰ reported no statistically significant difference between the control and CPP-ACP-pretreated groups regarding the mode of failure. In the demineralization group, enamel cracks were seen and enamel particles were observed at the bracket base. In our previous study,²⁴ we found a statistically significant difference among groups. Similarly, in the current study, there was a significant difference among groups regarding the fracture mode. In the demineralization group, most of the fractures were at the enamel-composite interface. This finding may show the weak bonding properties of the demineralized enamel. On the other hand, in the microabrasion plus CPP-ACP group, failures were recorded as score 3 and score 4. One might think that the bond strength between the enamel and composite was strong. Although the SBS of the CPP-ACP- and combination-pretreated groups were similar, 25% of the failures were at the enamel-composite interface for the CPP-ACP-pretreated group. Only 40% of the specimen shows failures scored as 3 and 4. At this point, the bonding properties of combination group (Group V) may be thought to be superior to CPP-ACP-pretreated group. Because all failures occurred at the adhesive-bracket interface, no failure was seen at the enamel-adhesive interfaces.

According to the limitations of this in vitro study, it may be said that the bonding properties of demineralized enamel improved with microabrasion and CPP-ACP

application. According to ARI scores, none of the failures occurred at the enamel-bracket interface, as seen in group II (demineralized enamel, no pretreatment). These techniques may be used in the management of WSLs of high-risk orthodontic patients without compromising esthetics.

CONCLUSIONS

- Significantly lower SBS values were recorded for the demineralization group.
- CPP-ACP pretreatment, microabrasion of the enamel, and the combination of these two methods improve the bonding to demineralized enamel.
- CPP-ACP pretreatment is more efficient than microabrasion for bonding.
- Microabrasion and CPP-ACP pretreatment results in higher SBS values compared to the control group.

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