Effect of air abrasion and acid etching on sealant retention: an in vitro study

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Abstract

Purpose: This in vitro study evaluated shear bond strength and analyzed, via scanning electron microscopy, enamel prepared for pit and fissure sealant placement. Various surface pretreatment methods were conducted prior to short-term (72-hour) and long-term (120-day) analysis.

Method: Six treatment groups of 14 teeth, having 28 bonding surfaces (buccal and lingual) were treated. Cylinders of Delton pit and fissure sealant were placed on the prepared buccal and lingual surfaces and light-cured for 60 seconds. One-half of each group's specimens were stored in distilled water for 72 hours and the other half were stored in water distilled for 120 days followed by thermocycling. All specimens were subjected to shear bond strength analysis as determined on an Instron testing machine.

Results: All acid treated groups were equivalent and greater than air abrasion alone after 72 hours of water storage. Scanning electron microscopy of air abraded and combination treated enamel surfaces revealed a more detailed retentive pattern in the combination treatment than in either treatment alone.

Conclusion: Based on in-vitro shear bond strength values, air abrasion with 50 micron alumina is an effective pre-etch treatment for sealant placement and in concert with phosphoric acid treatment significantly enhanced the long term bond of a sealant to enamel. The clinical relevance of this has not been established. (Pediatr Dent 21:316-319, 1999)

The retention of dental sealants, to the prepared enamel surface, is critical to the effectiveness of placement. Conditioning surface enamel with phosphoric acid is the standard method for preparing the enamel surface prior to bonding sealant materials. The etchant creates an increased surface area of irregular enamel and allows the formation of resin tags, which provides a micro-mechanical interlocking of the enamel-sealant interface.[1] The retentive condition of the etched surface, as well as the removal of surface debris influences the successful placement and longevity of dental sealants.

Various pretreatment methods have been investigated with the intent to enhance the effectiveness of etching the enamel surface. A significant advantage has been demonstrated in having a clean, debris free surface prior to etching. It has even been recommended that an increase in the amount of etchant exposure time would provide a cleaner surface.[2] 1.0N sodium hydroxide has been used to remove the organic material from the tooth surface, resulting in a more uniform etching pattern on the debris free surfaces.[3] Research has shown that air polishing teeth prior to etching results in a higher tensile bond strength of sealant.[4] The use of pumice slurry to clean the tooth prior to etching is the method most widely accepted by practitioners. Pumice does remove organic material from those areas that are accessible but not in deep pits and fissures. This method of cleaning may force pumice particles and plaque deeper into the pits and fissures.[5] It has been demonstrated that there was no significant difference in the shear bond strength of teeth pretreated with pumice and those pretreated with hydrogen peroxide.[6] In addition, recent marginal leakage studies appear to corroborate that hydrogen peroxide may indeed be an acceptable pretreatment for dental sealants.[7]

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The reintroduction of air abrasive technology (KCP 2000, American Dental Technologies, Southfield, MI) in dentistry has added a new potential method of pretreating teeth prior to placing sealants. Investigations of air abrasive techniques have suggested that this method may serve as an alternative to acid etching of enamel.[8-10] Since surface cleaning and an etching effect do occur simultaneously with this treatment, it has been suggested that this method could represent a significant time saving for practitioners. However, marginal leakage studies have shown that sealants having been prepared by air abrasion with 50 micron aluminum oxide, have higher marginal leakage when combined with the acid etch techniques. This raises a question concerning the validity of the manufacturers claim that air abrasion pretreatment alone is sufficient.[11] A combination of air abrasion and phosphoric acid etch pretreatment has been reported to create an enamel surface, whereby the bonded sealant material has demonstrated the highest shear bond strengths to intact enamel.[12]

The purpose of this in vitro study was to investigate the short-term (72-hour) and long-term (120-day) thermocycled shear bond strengths of pit and fissure sealants following various surface pretreatment methods to the enamel. These pretreatment methods are designed to clean the enamel surface and promote adhesion. A secondary purpose was to evaluate the enamel surface following air abrasion pretreatment, via scanning electron microscopy (SEM).

Methods and Materials

Shear Bond Strengths

Eighty-four recently extracted human permanent, molar teeth, stored in distilled water, were used in this study. The buccal

Table 1. 72-Hour Mean Shear Bond Strength (MPa)

Group	Pretreatment	Etchant	Mean±SD
VI	3% H_2O_2	35% H_3PO_4	20.20±5.61*
V	Air Abrasion	35% H_3PO_4	19.73±3.99*
III	None	35% H_3PO_4	17.57±4.52*
IV	Flour Pumice	35% H_3PO_4	16.98±5.43*
II	Air Abrasion	None	8.13±2.42
I	None	None	3.89±2.32

* Significant at the P>0.05 level. Groups connected by the line are not significantly different.

Table 2. 120-Day Thermocycled Mean Shear Bond Strength (MPa)

Group	Pretreatment	Etchant	Mean±SD
V	Air Abrasion	35% H_3PO_4	17.92±3.44*
III	None	35% H_3PO_4	11.95±2.49**,†
VI	3% H_2O_2	35% H_3PO_4	11.32±3.41**,†
IV	Flour Pumice	35% H_3PO_4	9.97±1.01**,†
II	Air Abrasion	None	9.17±2.90†
I	None	None	All failed

* Indicates a significant difference between groups at the P<0.05 level. ** Indicates a significant difference within groups for storage times at the P<0.05 level. † Groups connected by the line are not significantly different.

and lingual enamel surfaces of these teeth were prepared by wet grinding on a water-cooled, abrasive wheel (Ecomet III, Buehler Ltd., Lake Bluff, IL) to produce parallel and flat bonding surfaces. These surfaces were finished to a 600-grit surface by use of silicon carbide paper.

The molar teeth, with the flat ground surfaces, were divided into six groups of 14 teeth with a total of 28 bonding surfaces for each surface treatment group.

Group I: No surface pretreatment or etchant was performed on this treatment group. The buccal and lingual enamel surfaces were rinsed for 30 seconds with tap water and compressed air dried. This group was used as the no treatment control.

Group II: Both treatment enamel surfaces were air abraded with two, five second blasts of 50 micron, alpha alumina (aluminum oxide) particles at 80 psi from a distance of three millimeters, using the KCP 2000 unit (American Dental Technologies, Southfield, MI). These surfaces were rinsed for 30 seconds with tap water and dried with compressed air. No etchant was used for the samples in this treatment group.

Group III: A 35% phosphoric acid etchant (Tooth Conditioner Gel, Caulk Dentsply, Milford, DE) was applied to the enamel surfaces of the specimens in this treatment group for 30 seconds, as recommended by the manufacturer. The etched surfaces were rinsed for 30 seconds with tap water and dried with compressed air.

Group IV: This group's treatment enamel surfaces were cleaned with fluoride-free flour pumice, using a rubber prophy cup for fifteen seconds. The surfaces were rinsed for 30 seconds with tap water and compressed air dried. A 35% phosphoric acid etchant (Tooth Conditioner Gel Caulk Dentsply, Milford, DE) was then applied for 30 seconds, as recommended by the manufacturer. The etched surfaces were rinsed for 30 seconds with tap water and dried with compressed air.

Group V: Both treatment enamel surfaces were air abraded with two, five second blasts of 50 micron, alpha alumina (aluminum oxide) particles at 80 psi from a distance of three millimeters, using the KCP 2000 unit (American Dental Technologies, Southfield, MI). These surfaces were rinsed for 30 seconds with tap water and compressed air dried. A 35% phosphoric acid etchant (Tooth Conditioner Gel, Caulk Dentsply, Milford, DE) was applied for 30 seconds, as recommended by the manufacturer. The etched surfaces were rinsed for 30 seconds with tap water and dried with compressed air.

Group VI: The buccal and lingual treatment surfaces for this group were prepared by rinsing with 3% hydrogen peroxide for one minute. These surfaces were rinsed for 30 seconds with tap water and compressed air dried. A 35% phosphoric acid etchant (Tooth Conditioner Gel, Caulk Dentsply, Milford, DE) was applied for 30 seconds, as recommended by the manufacturer. The etched surfaces were rinsed for 30 seconds with tap water and dried with compressed air.

A light-cured pit and fissure sealant, Delton, (Dentsply Preventive Care, York, PA) was then bonded on each of the buccal and lingual enamel surfaces for all treatment group specimens using a cylinder-shaped plastic matrix.

The cylinders of sealant were 3.65 mm in diameter and approximately 2 mm in length. These sealant cylinders were visible light-cured for 60 seconds. Seven teeth from each treatment group were randomly selected and stored in distilled water at 37° C for 72 hours. All teeth specimens were then mounted in 1-inch phenolic rings with acrylic. Shear bond strengths of the enamel sealant interface were determined in an Instron testing machine (Model 1123, Instron Engineering Company, Canton, MA) equipped with a chisel shaped fixture at a crosshead speed of 5 mm/min. The amount of force required to debond the cylinder was measured and calculated in megapascal units (MPa). The remaining seven teeth from each group were also stored in distilled water at 37° C for 120 days and following storage, the samples were thermocycled between water baths of 5° C and 55° C for 800 cycles with a dwell time of 60 seconds. These teeth were similarly mounted and debonded. The mean shear bond strengths were calculated (in MPa) for each treatment group of samples. The data were subjected to a two-way ANOVA, with the variables of surface pretreatment and storage time, in order to determine if significant differences existed between the treatment groups. A Tukey's post hoc test was used for multiple pairwise comparisons. Each bonded assembly was evaluated under a 20X power dissecting microscope to determine the mode of failure at the bonded interface.

Scanning Electron Microscopy

An additional molar tooth was prepared for scanning electron microscopy by preparing enamel surfaces from the same tooth by wet grinding to a 600 grit finish. After sectioning the tooth into two specimens, the enamel was prepared by air abrasion, and followed by acid conditioning with 35% phosphoric acid

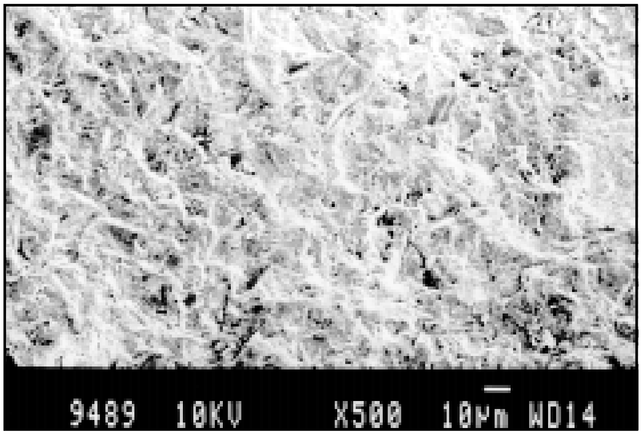

Fig 1. SEM showing enamel surface with air abrasion surface pretreatment.

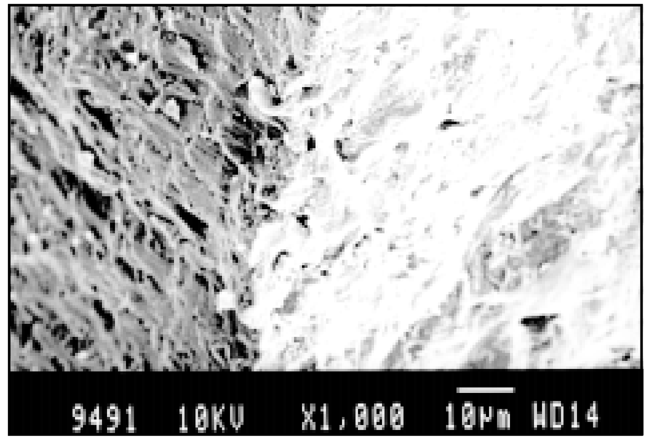

Fig 2. SEM showing fractured enamel surface with air abrasion surface pretreatment.

for 30 seconds. The treated specimens were fractured through the treated surfaces and conductively coated with Au-Pd and visualized in a Jeol Model 801 Scanning Electron Microscope at a magnification of 500X and 1000X with an acceleration voltage of 10 KV. Representative images were recorded from each specimen with Polaroid film.

Results

Shear bond strength was significantly affected by the surface pretreatment and storage time factors evaluated. After 72 hrs. of water storage, all of the acid treated groups, regardless of pretreatment, generated equivalent mean shear bond strengths ($P>0.05$). These values were notably greater than the use of air abrasion alone and the no treatment control (Table 1). Following 120 day storage and thermocycling, the mean shear bond strength of groups II, III, IV, and VI were not significantly different from each other ($P>0.05$). The bond strength of group V was significantly greater than each of the other groups ($P<0.05$). There was a significant reduction in shear bond strengths from the 72 hour values compared to the stored and thermocycled values for Groups III, IV, and VI ($P<0.05$) (Table 2).

Figures 1 and 2 show the SEM of the surface and fracture site prepared by air abrasion, with the same surface pretreatment as Group II. The air abraded surface reveals an irregular surface clearly degraded by the air abrasion process but without microscopic topographical features. Figures 3 and 4 show the SEM of the combination preparation of air abrasion in conjunction with acid etching with 35% phosphoric acid for 30 seconds, the same surface pretreatment as Group V. This surface again demonstrates the macroscopic surface irregularities and topography created by air abrasion, as well as microscopic irregularities generated from the demineralized ends of the enamel rods created by the etching process.

Disscussion

The results of the 72-hour storage time found no significant differences in shear bonding strength between those treatment groups that were etched with 35% phosphoric acid, regardless of the surface pretreatment. This result may be attributed to the artificial removal of organic material and fluoride rich surface layer, and to the cleaning of the enamel surface as created by grinding of the bonding surfaces to a flat, uniform surface. This artificially created enamel surface does not reflect the actual clinical pit and fissure topography to which the sealant would be placed.

The effectiveness of acid conditioning with phosphoric acid was not as clear after storage of the samples for 120 days and thermocycling. Water storage and thermocycling could slightly reduce the shear bond strength of the sealant to the enamel due to the high thermal coefficient of the resin sealant or due to the low modulus of elasticity. However, a recently published study showed no difference in enamel bond strengths between the 24-hour non-thermocycled and three month, thermocycled specimens of five adhesive systems.[13] This might suggest that extended water storage may have an effect on the sealant itself by the uptake of water resulting in a degrading of the physical characteristics of the sealant material. This could lead to a reduction in bond strength.

The results of this study, indicating a beneficial synergy of the combination of air abrasion and phosphoric acid conditioning are in agreement with previous work using both sodium bicarbonate[4] and aluminum oxide[12] as the air abrasive medium. The ineffectiveness of air abrasion alone in generating high bond strength of resin to enamel shown in this study was consistent with the findings of other authors measuring resin to enamel bonds.[4]

It was unexpected that there was a significant decrease in the shear bond strength for all of the groups that did not receive air abrasion as a pretreatment. One clue regarding this observation may be gathered from the surfaces visualized via scanning electron microscopy. The surface receiving air abrasion only exhibits a change in the flat surface with an increase in surface irregularities. This may be caused by the air abrasion leading to perhaps some mechanical retention as reflected in the high bond strength, when compared to the untreated control specimens. In the specimen, which received both air abrasion and acid etch, macro surface irregularities from the abrasion, as well as micro-irregularities from the acid conditioning are apparent. The greater surface area created by the more macroscopic pattern created by air abrasion may have facilitated the maintenance of the high shear bond strengths observed after storage and thermocycling. This observation may also have been influenced by variations in the experimental specimens, such as differing fluoride content.

The results of this in vitro study may not be transferable to other pit and fissure sealants. Chemical or physical degradation of the sealant could have contributed to the bond strength

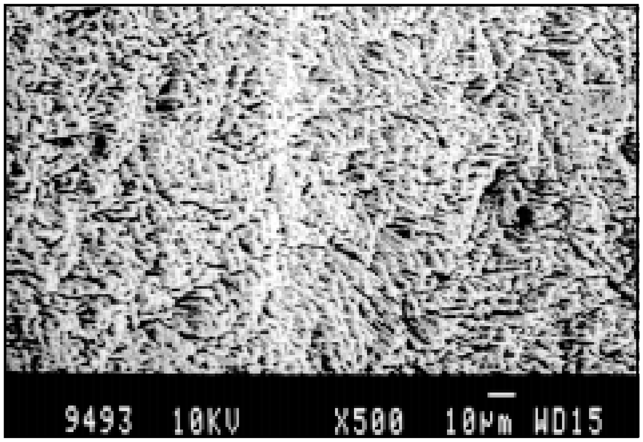

Fig 3. SEM showing enamel surface with air abrasion and phosphoric acid etch surface pretreatment.

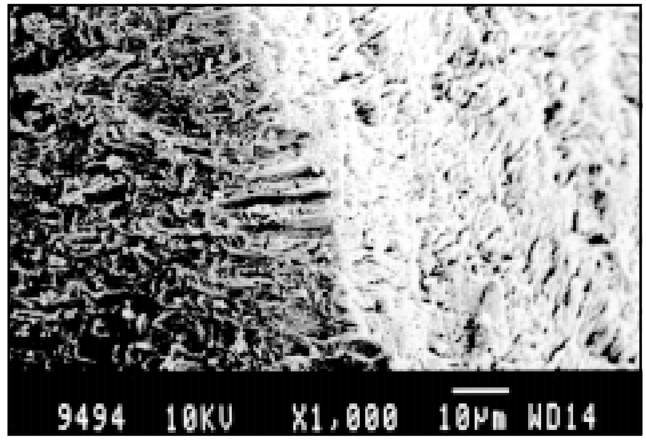

Fig 4. SEM showing fractured enamel surface with air abrasion and phosphoric acid etch surface pretreatment.

relationships in this study and the seemingly beneficial effects of the combination of air abrasion and acid etch conditioning may be specific to this particular sealant. In addition, this study was conducted on prepared enamel and the interaction of the treatments used in this study on uncut enamel may differ.

Conclusion

1. Based on shear bond strength values, the air abrasion achieved with air abrasion with 50 micron aluminum oxide is an effective pretreatment for sealant placement and in combination with 35% phosphoric acid treatment significantly enhanced the short and long term bond of a sealant to enamel.
2. Air abrasion alone is not sufficient for promoting a high bond strength of a sealant to enamel.
3. Air abrasion in concert with acid conditioning generated high immediate (72 hour) and stable long term (120 day) bond strengths with the sealant used in this study, possibly based in part on the increased surface area for bonding created by air abrasion.
4. Further research including the use of other sealant formulations is needed to better understand this phenomenon.

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