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 etching significantly enhanced the long term bond of a sealant to enamel. The clinical relevance of this has not been established.

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 finish. After sectioning the tooth crowns were mounted 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 cross-head 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 followed by acid conditioning with 35% phosphoric acid 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 compressed air dried.

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 cross-head 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 followed by acid conditioning with 35% phosphoric acid 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 compressed air dried.

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 cross-head 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 followed by acid conditioning with 35% phosphoric acid 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 compressed air dried.

**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
for 30 seconds. The treated specimens were fractured through the treated surfaces and conductively coated with Au-Pd and visualized in a Jeol M edel 801 Scanning Electron Microscope at a magnification of 500X and 1000X with an acceleration voltage of 10 K.V. 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.

Discussion
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. 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 and aluminum oxide 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.

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...
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.

**References**