A comparison of six enamel treatment procedures for sealant bonding

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Abstract

This in-vitro study evaluated the effectiveness of six different enamel treatment procedures for bonding a dental sealant. Sixty extracted human molar teeth were separated into the following enamel treatment groups (10 teeth each): group 1 (control) — etched with 37% phosphoric acid; group 2 — air polished (air abraded) with 45 µm particles of sodium bicarbonate; group 3 — air abraded with 50 µm aluminum oxide particles; group 4 — etched with 2.5% nitric acid; group 5 — air abraded with sodium bicarbonate particles and etched with 37% phosphoric acid; and group 6 — air abraded with 50-µm aluminum oxide particles and etched with 37% phosphoric acid. The enamel treatment procedures were accomplished on intact mesial or distal surfaces. Following the enamel treatment, a sealant was bonded to the surfaces using a plastic matrix technique. After 24 hr of water storage at 37°C, the specimens were debonded using an Instron machine. The mean shear bond strengths (MPa) were as follows: group 1 — 9.19 ± 1.34 MPa; group 2 — 2.03 ± 1.67 MPa; group 3 — 1.50 ±0.93 MPa; group 4 — 4.99 ±1.26 MPa; group 5 — 11.61 ± 4.51; and group 6 — 11.14 ± 1.70 MPa. Statistical analysis using a one-way ANOVA and Scheffe F-test revealed no significant difference (P > 0.05) among groups 1, 5, and 6. However, there was a significant difference (P < 0.05) between groups 1, 5, and 6 and the other three groups (2, 3, and 4). In conclusion, 37% phosphoric acid treatment of intact enamel, or a combination of air abrasion with sodium bicarbonate or aluminum oxide followed by phosphoric acid, provides significantly higher bond strengths of a sealant material than enamel conditioning with 2.5% nitric acid or air abrasion with sodium bicarbonate or aluminum oxide. (Pediatr Dent 18:29–31, 1996)

The integrity of a dental sealant is critical to prevent caries and directly depends on proper acid conditioning of enamel.[1] It is extremely important to create and maintain a strong bond between the enamel surface and a sealant. This micromechanical bond is created by resin penetration into enamel microporosities resulting from acid conditioning.[2]

Factors that play an important role in bonding a dental sealant to an etched enamel surface are the topography of the etched enamel surface, etching time, etching agent, etchant concentration, and clean enamel, that is free of salivary contamination and dry at the time of sealant placement.[2–3]

The most effective etching agent for bonding a dental sealant to enamel is phosphoric acid (H_3PO_4) in concentrations of 30–50%, with treatment times ranging from 5 to 120 sec.[4–5] The phosphoric acid creates microporosity in the surface of enamel for the mechanical retention of a sealant through decalcification. Subsequently, dissolution and reduction in the size of the apatite crystals increases the enamel surface available for bonding.[6] Fifteen seconds of etching creates a more retentive condition than 60 sec as judged by the degree of surface irregularities.[3] Other studies also have shown equivalent bond strengths of resin materials to enamel using phosphoric acid at reduced etching times when compared to 60 sec.[7–9]

Recently, several manufacturers have developed bonding agents that purportedly bond to enamel and dentin using acids other than phosphoric acid such as maleic and nitric acids.[7, 10] Bond strengths of resin materials to dentin following these agents has been found to approach the bond strengths reported for bonding resins to etched enamel after phosphoric acid etching.[11–12]

Plaque and other debris on the surfaces of teeth may reduce the effectiveness of acid conditioning agents. Cleaning pits and fissures before sealant placement is extremely important. The typical pumice and water cleaning method may force plaque and pumice particles deeper into the pits, fissures, and grooves.[13] Cleaning or air polishing teeth before sealant application may be an effective pretreatment measure. Aluminum oxide and sodium bicarbonate have been proposed for cleaning enamel surfaces using air-abrasive techniques. Air-abrasive technology can prepare enamel and dentin for bonding, similar to etching by acidic gels and solutions.[14, 15] The action mechanism involves loosening plaque and other organic material with air abrasion and creating a roughened surface to enhance bonding of resin materials.

The purpose of this study was to evaluate the bond strengths of a sealant material to enamel after using a variety of abrasive enamel cleaning procedures and acid conditioning agents.[16-17] An additional objective of this study was to determine if a combination of air abrasive techniques and acid treatment enhances the bond strength of a sealant material to enamel.

Methods and materials

Shear bond strength

Sixty extracted human molar teeth stored in tap and refrigerated water were used in this laboratory study. The unprepared mesial or distal proximal surface of each tooth was used for the bonding procedures. The teeth were first cleaned with a slurry of pumice and water using a prophylaxis cup in a low-speed handpiece. Following the prophylaxis procedure, the teeth were rinsed with water and air dried. The teeth were then divided into six groups of 10 teeth each. The treatment groups were as follows:

Group 1: A 37% orthophosphoric acid solution (3M Etching Liquid, 3M Dental Products Division, St Paul, MN) was applied to intact mesial or distal surfaces of teeth with a disposable brush for 15 sec. The teeth were rinsed with water for 15 sec using a dental syringe and thoroughly dried with oil-free compressed air. This group represents the conventional enamel conditioning procedure.

Group 2: Enamel surfaces were air polished (air abraded) with 45-µm particles of sodium bicarbonate for 60 sec using a Prophyjet® (Equipment Division, Dentsply International, York, PA). The teeth were then rinsed with water for 15 sec and dried thoroughly.

Group 3: Enamel surfaces were air abraded with 50-µm particles of aluminum oxide for 60 sec using an intraoral microetcher (Model er/erc, Danville Engineering Inc, Danville, CA). The teeth were then rinsed with water for 15 sec and dried thoroughly.

Group 4: A 2.5% solution of nitric acid (Quikseal™ Nitric Acid Conditioner, Chameleon Dental Products, Kansas City, KS) was applied to the enamel surfaces with a small brush and agitated on the surface for 60 sec. The teeth were then thoroughly air dried (no water rinse).

Group 5: Enamel surfaces were air abraded with 45-µm particles of sodium bicarbonate for 60 sec, rinsed with water for 15 sec, and thoroughly air dried. A 37% solution of phosphoric acid (3M Etching Liquid) was then applied for 15 sec. The teeth were rinsed with water for 15 sec and thoroughly air dried.

Group 6: Enamel surfaces were air abraded with 50-µm particles of aluminum oxide particles for 60 sec, rinsed with water for 15 sec, and thoroughly air dried. A 37% solution of phosphoric acid (3M Etching Liquid) was then applied for 15 sec. The teeth were rinsed with water for 15 sec and thoroughly air dried.

The teeth in groups 1, 2, 3, 5, and 6 were washed with an air-water spray from a dental syringe for at least 15 sec, and then thoroughly dried with compressed air. Group 4 was not washed with water but only air dried. Occlusal sealant (3M Concise™ White Sealant, 3M Dental Products Division, St Paul, MN) then was applied to the prepared enamel surfaces of all groups using a cylinder-shaped plastic matrix. The cylinders of Concise were 3.66 mm in diameter and approximately 2.0 mm in length.

Shear bond strengths were evaluated using an Instron testing machine (Model 1123, Instron Engineering Company, Canton, MA). The amount of force required to debond the cylinders was calculated and measured in megapascals (MPa). The mean and SD were calculated for each group of specimens. The data were subjected to a one-way ANOVA to determine if significant differences existed among the groups. A post-hoc Scheffe F-test was used for multiple pairwise comparisons between groups.

Results

Shear bond strengths

The results of this study are presented in the Table. The mean shear bond strength of group 1 (9.19 ± 1.34 MPa), enamel conditioned with 37% H_3PO_4, was not significantly different ($P > 0.05$) than the bond strengths

Table. Mean bond strengths (MPa) sealant to enamel

Group	*Treatment*	*Mean*	*SD*
5	Na Bicarbonate + 37% H_3PO_4	11.61	4.51
6	Al_2O_3 + 37% H_3PO_4	11.14	1.70
1	37% H_3PO_4	9.19	1.34
4	2.5% HNO_3	4.99	1.26
2	Na Bicarbonate	2.03	1.67
3	Al_2O_3	1.50	0.93

Groups connected by line are not different at the 5% significance level.

of group 5 (11.61 ± 4.51 MPa) and group 6 (11.14 ±1.70 MPa), which were air abraded with sodium bicarbonate and aluminum oxide, respectively, prior to etching with the 37% H_3PO_4. The bond strengths of groups 1, 5 and 6 were significantly ($P < 0.05$) higher than the other three groups (groups 2, 3 and 4) in this study.

The bond strength of group 4, which involved enamel conditioning with 2.5 % HNO_3 followed by air drying, was 4.99 ± 1.26 MPa. This value was not significantly different ($P > 0.05$) than the bond strength for group 2 (2.03 ± 1.67 MPa) in which the enamel surfaces were only air abraded with sodium bicarbonate.

The two groups that produced the lowest bond strengths were group 2 (2.03 ± 1.67 MPa) and group 3 (1.20 ± 0.93 MPa). The enamel in these groups was air abraded with sodium bicarbonate and aluminum oxide, respectively. There was not a significant difference ($P > 0.05$) between these two groups.

Discussion

Acid conditioning of enamel with phosphoric acid has been the routine treatment procedure prior to placing a dental sealant. Recently, several newer acid conditioning agents have been introduced to the profession for bonding resin materials to both enamel and dentin. In addition, air-abrasion techniques are being investigated in adhesive dentistry procedures to promote adhesion of resin materials.

The results of this study indicate that 37% H_3PO_4 is much more effective in producing high bond strengths of sealant materials to enamel than 2.5% HNO_3. The bond strength of Concise sealant to intact enamel using 37% H_3PO_4 was 9.19 ± 1.34 MPa compared with 4.99 ± 1.26 MPa for the 2.5% HNO_3. There was a statistically significant difference ($P < 0.05$) in these bond strengths.

Air abrasion with either sodium bicarbonate or aluminum oxide alone produced low bond strengths of the sealant to enamel. The bond strength of Concise sealant to enamel air abraded with sodium bicarbonate was 2.03 ± 1.67 MPa and the bond strength using aluminum oxide air abrasion was 1.50 ± 0.93 Mpa. The highest bond strengths of the sealant material to intact enamel was observed with the combination of either air abrasion with sodium bicarbonate or aluminum oxide followed by 37% H_3PO_4. The bond strengths were 11.61 ± 4.51 MPa and 11.14 ± 1.70 MPa, respectively. However, these bond strengths were not significantly different ($P > 0.05$) than the 37% H_3PO_4 used alone (9.19 ± 1.34 MPa).

The results of this study suggest an advantage in using air abrasive techniques on enamel prior to acid conditioning for bonding. Higher bond strengths of a dental sealant were achieved to intact enamel surfaces using either air abrasion with sodium bicarbonate or aluminum oxide followed by acid conditioning with phosphoric acid. While these bond strengths were not statistically ($P > 0.05$) higher than phosphoric acid used alone, the clinical performance of sealants placed using air-abrasive techniques in combination with phosphoric acid conditioning may be improved.

Conclusions

1. Acid conditioning of intact enamel with 37% phosphoric acid produces significantly ($P < 0.05$) higher bond strengths of a sealant material to enamel than conditioning the surface with 2.5% nitric acid or air abrasion of enamel with either sodium bicarbonate or aluminum oxide.
2. Lower bond strengths occurred in enamel treatment groups that were air abraded as compared to acid treated groups.
3. A combination of enamel air abrasion with either sodium bicarbonate or aluminum oxide followed by phosphoric acid conditioning produced the highest bond strengths of a sealant material to intact enamel surfaces, but not significantly greater than the bond strengths of acid alone.

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