Effect of Individual or Simultaneous Curing on Sealant Bond Strength

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ABSTRACT

Purpose: The objective of this study was to assess the shear bond strength of resin sealants to saliva-contaminated and noncontaminated enamel, comparing 2 curing protocols: (1) individual light-curing of the intermediate bonding agent layer and the sealant; or (2) simultaneous curing of both materials.
Methods: Seventy-two enamel test surfaces were obtained from 24 third molars and randomly assigned to 2 groups (N=36): (A) saliva-contaminated; (B) noncontaminated. Each group was divided into 3 subgroups, according to the bonding technique: (1) Prime&Bond and Fluroshield were light cured separately; (2) Prime&Bond and Fluroshield were light cured together; (3) Fluroshield was applied alone. Shear bond strength was tested at a cross-head speed of 0.5 mm/minute.
Results: Means (MPa) were: IA-15.61(±4.74); IIA-15.71(±6.18); IIIA-13.83(±1.50); IB-24.73(±4.34); IIB-22.41(±4.16); IIIB-18.20(±3.58). Statistical analysis revealed that overall bond strength to saliva-contaminated enamel was remarkably lower ($P<.05$) than that recorded under dry conditions. In both contaminated and noncontaminated groups, significantly higher shear bond strength ($P<.05$) was observed when the bonding agent was applied underneath the sealant. Comparing the curing protocols for contaminated specimens, no statistically significant difference ($P>.05$) was observed between individual and simultaneous curing. Conversely, for noncontaminated specimens, bond strength was higher and statistically different ($P<.05$) when the materials were light cured separately.
Conclusions: Individual or simultaneous curing of the intermediate bonding agent layer and the resin sealant does not seem to affect bond strength to saliva-contaminated enamel. When dry, noncontaminated conditions are maintained, however, the intermediary and the sealing materials should preferably be light cured separately. (J Dent Child 2005;72:31-35)

KEYWORDS: BONDING AGENT, SEALANTS, SALIVA CONTAMINATION, LIGHT-CURING

Over the last 30 years, dentistry has experienced remarkable scientific advances. This is not only regarding the notable improvement of restorative materials and techniques, but also the revision of ancient concepts, which has resulted in more efficient oral health management with emphasis on prevention. Based on contemporary principles, as often as possible, noninvasive strategies have preferably been instituted rather than invasive healing treatments.[1-3] Therefore, efforts have been focused on reducing patients' risk for caries by:

1. stimulating the adoption of preventive measures;
2. highlighting the relevance of a partnership approach between patients and dentists for the ultimate success of caries control.[4]

The high susceptibility of pits and fissures to carious attack and the rapid onset of the disease at these sites soon after tooth eruption are reported by several studies.[5-7] In this context, treating caries-susceptible pits and fissures with resin sealants has been considered an outstanding adjunctive tool to oral health care strategies and fluoride therapy to decrease occlusal caries initiation and/or progression.[5-8] The sealing material acts as an effective mechanical obstacle to plaque retention, thus minimizing the harmful action of cariogenic microorganisms on enamel surface.[9,10]

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Nevertheless, the preventive benefits of such treatment rely directly upon the ability of the sealant to thoroughly fill pits, fissures, and/or anatomical defects and remain completely intact and bonded to the enamel surface for a lifetime, thus preventing caries from developing underneath the sealant.[5,6,8,11-13]

Low utilization of sealants has been attributed to lack of confidence in the bonding of sealant to enamel and to the difficulty of achieving adequate, necessary salivary control and dry field isolation.[14,15]

Recently, there has been a shift with respect to the approach for sealant therapy. It has been advocated that, for sealants to be effective, they must be allocated to children who are at high risk for occlusal caries and not be applied routinely throughout a low-risk dental practice population. Indeed, overzealous sealant application is costly and may not provide additional oral health benefits. Caries risk assessment is, therefore, an essential step to render a realistic, comprehensive treatment plan.[8,16-18]

The most appropriate moment for placement of occlusal sealants in high caries-risk patients is soon after permanent molars erupt.[17,19] Newly erupted teeth are far less mineralized than those exposed to the oral environment for years and, thus, are more prone to acid attack.[20] In addition, the period in which occlusal pits and fissures are more likely to become decayed is between the moment the tooth erupts and when it contacts the opposing occlusal surface during occlusion. Paradoxically, the possibility of failure increases for sealants placed soon after tooth eruption, when the distal marginal ridge has just cleared the soft tissue. This leaves the occlusal surface at risk for moisture and salivary contamination during the sealing procedure.[16]

Saliva and moisture contamination of the etched surface before sealant placement has been cited as the most common reason for unsuccessful sealing. This is because the microporosities produced by the acid etchant on enamel become partially occluded, thereby preventing optimal resin tag formation and undermining sealant bonding.[5,11,21,22]

Hitt and Feigal (1992)[23] first reported the benefits of adding a bonding agent layer between the etched enamel and the sealant as a way of optimizing bond strength in the face of moisture and salivary contamination. Accordingly, the outcomes of several studies[13,24-28] have shown that the use of adhesive materials, along with resin sealants, improve bonding to etched enamel when dry field isolation is maintained and the etched surface is contaminated with moisture and/or saliva. Confirmed by other studies, the advantages of using bonding agents beneath sealants on saliva-contaminated enamel include: (1) reduced microleakage[13,29-31]; (2) enhanced flow of resin into fissures[32]; and (3) improved short-term clinical success.[24,27,28]

Many studies[13,25-27,31,33,34] indicate that the association of adhesive systems and pit-and-fissure sealants enhances sealant bonding to contaminated enamel surfaces. Nevertheless, the literature is still scarce on articles investigating aspects relating to the bonding technique and curing protocol. Also, there is a lack of published data addressing whether the individual or simultaneous light curing of the bonding agent layer and the sealing material affects the sealant adhesion to dry and wet enamel.

Therefore, the aim of this study was to assess in vitro the shear bond strength of pit-and-fissure sealants placed on saliva-contaminated and noncontaminated enamel, comparing 2 curing protocols:

1. individual light-curing of the intermediate bonding agent (Prime&Bond NT) layer and the resin sealant (Fluroshield; 2 cures); or
2. simultaneous light-curing of both materials together (1 cure).

METHODS

Noncarious human third molars, extracted within a 6-month period, were cleaned using a hand scaler and rotating bristle brushes with water/pumice slurry to remove deposits of calculus, plaque, or debris. The third molars were then examined under a X20 magnifier to discard those with structural defects. Twenty-four teeth were selected for the study and stored in 0.9% saline solution with 0.4% sodium azide at 4°C.

Mesial, distal, and lingual enamel surfaces were ground and flattened with no. 320- and no. 400-grit silicon carbide (SiC) papers (Buehler Ltd, Lake Bluff, Ill) in a water-cooled polishing machine (Politriz DP–9U2, Struers, A/S, Copenhagen, DK–2610, Denmark) at low-speed. Manual polishing was accomplished with no. 600-grit SiC paper to smoothen the surfaces.

To improve handling of the teeth, their roots (by the middle third) were included in hard plaster using PVC rings (21 mm diameter; 6 mm high) as molds. After setting of the plaster, the rings were removed—leaving the teeth mounted in blocks of hard plaster. The ground surfaces were cleaned for 10 seconds using dental prophylaxis cups with water/pumice slurry and a low-speed handpiece. To demarcate the bonding sites, a piece of insulating tape with a 3-mm diameter central hole, made by means of a modified Ainsworth rubber-dam punch, was attached to each surface (mesial, distal, and lingual).

The 72 demarcated surfaces were randomly assigned to 2 groups of equal size (N=36), as follows:

1. A=saliva-contaminated enamel;
2. B=noncontaminated enamel.

Each group was then divided into 3 subgroups (N=12), according to the bonding/curing protocol adopted.

A filled resin-based pit-and-fissure sealant (Fluroshield [F], Dentsply/Caulk, Milford, Del) and a single-bottle acetone-based adhesive system (Prime&Bond NT [PB], Dentsply/Caulk, Milford, Del) were used, following manufacturers' instructions.

Each demarcated enamel site was etched with a 35% phosphoric acid gel (Scotchbond etchant, 3M/ESPE, St. Paul, Minn) for 20 sec, rinsed thoroughly for 20 seconds, and dried with a mild, oil-free air stream to obtain a uniformly white, dull, chalk-like appearance. The rationale for establishing a 20-second etching time in the bonding technique was to ensure that:

1. specimens would be conditioned for at least 15 seconds;
2. etchant agent would not inadvertently be rinsed off from the enamel surface before a 15-second etching time was obtained.

For group A specimens, the etched surface was then contaminated for 20 seconds with 0.01mL of fresh human saliva, collected from a same donor, using a micropipette. The contaminated enamel was gently dried with absorbing paper for 5 seconds, and a polytetrafluoroethylene jig (3 mm high; 3 mm in diameter) was placed over the enamel site and attached using a light-curing adhesive.

For subgroup IA:

1. Prime&Bond NT bonding agent was:
   a. applied to the demarcated etched enamel site in a uniform layer;
   b. slightly thinned with a mild, oil-free air stream;
   c. light cured for 10 seconds with a visible light curing unit (XL 3000, 3M/ESPE, St. Paul, Minn) with a 450 mW/cm^2 output.
2. Fluroshield sealant was applied and light cured for 40 seconds.

For subgroup IIA:

1. The bonding agent was applied and gently air-thinned with no light curing.
2. The pit-and-fissure sealant was immediately applied over the bonding agent layer.
3. Both materials were light cured together in one 40-second curing cycle.

For subgroup IIIA, the pit-and-fissure sealant was:

1. directly applied to the demarcated etched enamel site;
2. light cured for 40 seconds.

The tested adhesive system and the sealant were carefully applied to the tooth surface with disposable brush tips to avoid excess and pooling of adhesive along the insulating tape's edges, which could compromise the distribution of tensions during the shear testing and, hence, the validity of results.

Group B specimens were treated strictly following the same guidelines as described for group A specimens, except for the salivary contamination.

Once the bonding procedure was completed, the polytetrafluoroethylene jig was sectioned longitudinally with a scalpel blade, opened, and carefully removed together with the insulating tape used to demarcate the bonding area—leaving a sealant cylinder (3 mm × 3 mm) adhered to the tooth surface.

After 24-hour storage in distilled water at 37°C, shear bond strength was determined using a knife-edge blade in a universal testing machine (Mod. MEM 2000, EMIC Ltda, São José dos Pinhais, PR, Brazil) running at a crosshead speed of 0.5 mm/minute with a 50 kgf load cell. Shear bond strengths were recorded in Kgf and converted into MPa. Means and standard deviation were calculated, and data were analyzed by 2-way ANOVA using a factorial design with saliva contamination and curing protocol as independent variables. Multiple comparisons were done using the Scheffé statistical test at a 0.05 significance level.

RESULTS

Shear bond strength means and standard deviations for saliva-contaminated and noncontaminated groups are displayed on Table 1.

Overall, the results showed that bond strengths to saliva-contaminated enamel were remarkably lower (P<.05) than those recorded under dry, noncontaminated conditions.

In both contaminated and noncontaminated groups, the use of an intermediate bonding agent layer underneath the sealants resulted in a significantly higher (P<.05) shear bond strength than the sealant alone.

Comparing the curing protocols in the noncontaminated specimens, a higher bond strength was observed, as was a statistically significant difference (P<.05) when the adhesive system and the resin sealant were light cured separately. Conversely, the saliva-contaminated group's results showed no statistically significant difference (P>.05) between individual and simultaneous light curing of the bonding agent intermediary layer and the sealant.

DISCUSSION

The retention of resin sealants is a micromechanical process established by the infiltration and further polymerization of the sealant into the microporosity network created by the acid etchant on the enamel surface.[35] Because of the high enamel reactivity induced by the acid etching, even minute exposures to saliva, as brief as 1 second, are reported to be enough to create a pellicle that occludes many of the micropores.[36] This leads to an ultrastructural alteration of etched enamel morphology[21,30,36] and precludes the formation of the resin tags responsible for mechanical adhesion.[21,36]

Therefore, when resin tag formation is disturbed by inadvertent contact with moisture and/or saliva during the sealing procedures, poor adhesion and sealant failure should be expected.[21,23,24,36]

Studies have shown that bond strength between the resin sealant and the contaminated surface can be dramatically decreased.[13,23,25,26,34,37-39] These outcomes agree with those of the current investigation, in which the overall bond strength to saliva-contaminated enamel was markedly lower than that recorded under dry, noncontaminated conditions. This study compared 2 curing protocols (individual vs simultaneous light curing of the bonding agent layer and resin sealant) under dry and contamination conditions—with the latter simulated by contamination of specimens with saliva from a volunteer donor. Reportedly, the use of fresh whole human saliva for artificially contaminating the etched enamel test specimens is a convenient method.[22,36,37]

Over the last decades, the application of an intermediate bonding agent layer underneath the sealant has been widely suggested. The findings of several studies[13,23-28] have shown that the use of adhesive systems, along with resin sealants, may be a valuable and adjunctive approach to improve bonding to etched

Table 1. Shear Bond Strength Means (MPa) to Contaminated and Noncontaminated Enamel

Groups/ Subgroups	(I) Sealant + bonding agent (individual cure)	(II) Sealant + bonding agent (simultaneous cure)	(III) Sealant
A (with salivary contamination)	15.61±4.74 d	15.71±4.18 d	13.83±1.50 e
B (without salivary contamination)	24.73±4.34 a	22.41±4.16 b	18.20±3.58 c

*Same letter indicates statistical similarity.

enamel under dry and contaminated conditions. Accordingly, the results of this research revealed that, in contaminated and noncontaminated groups alike, applying a bonding agent intermediary layer prior to sealant placement resulted in significantly higher shear bond strength.

A suitable explanation for such performance would be that the currently available single-bottle adhesives, particularly acetone- and ethanol-based systems, have great ability to flow deeply into capillary like spaces of the etched enamel surface—thereby ensuring optimal resin tag penetration and enhanced adhesion.[27] Additionally, the composition of the latest generation of adhesive agents may be particularly adequate for enamel bonding in the presence of contamination.

Current bonding agents have a more hydrophilic nature than resin sealants and may somehow displace the saliva/moisture from enamel surface—thus permitting the hydrophilic monomer to infiltrate into the enamel porosities. It has been advocated that solvents such as ethanol and acetone (present in Prime&Bond composition) are able to remove any residual moisture from the etched enamel, carrying the resin monomers into close adaptation with the surface.[25,31] The hydrophilic monomers present in these one-bottle adhesives increase the surface wetting and resin penetration.[31]

When using adhesive systems and sealants together, it is important to provide sufficient air thinning of the bonding agent coat. It is widely acknowledged that the bonding agent layer's thickness can affect adhesion quality.[40] Forces created during the shrinkage process tend to pull the adhesive away from tooth substrate. Therefore, the thinness of the adhesive would help to minimize its dimensional changes during polymerization.[41] In this study, irrespective of the experimental condition (with or without saliva contamination) and the curing protocol (individual or simultaneous light curing), the bonding agent was slightly thinned with a mild air stream, as recommended by the manufacturer.

An earlier investigation[42] compared microleakage of sealants placed with single curing of the bonding agent and the sealant together (1 cure) and individual curing of each (2 cures) under dry and contaminated conditions. The authors concluded that curing the bonding agent and the sealant together did not decrease the previous reported beneficial effect of the tested adhesive system on reducing sealant sensitivity to contamination.

Accordingly, this study's findings revealed that, among the specimens contaminated with saliva after acid etching, the curing protocol did not appear to affect boding (ie, the bond strengths recorded did not differ statistically, regardless of curing the bonding agent alone or together with the sealant). Conversely, among noncontaminated specimens, shear bond strength was significantly higher when intermediary and sealing materials were light cured separately but concurrently.

Indeed, the authors can only theorize about the possible explanations for such different behaviors. Applying sealant without previous light curing of the intermediate bonding agent layer results in a high-viscosity 'adhesive-sealant' mixture. Although there are no reported data to support this suggestion, it may be speculated that, for the noncontaminated specimens, the absence of moisture limited the interdiffusion of acetone (solvent present Prime&Bond composition) within the enamel microporosity network, which might have affected the infiltration of the "bonding agent-sealant" mixture. Upon polymerization, resin tags of insufficient number and length were formed, thereby yielding lower bonding of the sealant to enamel.

Regarding the specimens contaminated with saliva, the assumption may be raised that, due to the highly hydrophilic nature of acetone-based adhesive systems, the moisture of the enamel facilitated resin infiltration. This somehow counterbalanced the high viscosity of the unpolymerized "adhesive-sealant" mixture. Consequently, under wet conditions, no significant difference was observed between bond strengths obtained with separated or single curing of the intermediary and sealing materials.

In many reported studies documenting the advantages of associating adhesive systems with resin sealants, the intermediate bonding agent and the sealant were cured simultaneously.[25,27,28,31] Nevertheless, the literature is scarce on published data supporting this curing protocol's advantages. Moreover, to the best of the authors' knowledge, there are no studies currently available that address which curing protocol—separate or single curing of the materials—would yield the best bonding performance. The long-term implications of a single cure on the quality and longevity of the adhesion obtained should also be investigated. The lack of reported studies testing the same methodology and materials that the authors tested was definitely a hindrance to stating a reliable comparison with outcomes of previous studies.

It is important to emphasize that this study does not suggest that improper technique for sealant placement can be advocated. Even when stringent moisture control procedures are attempted during sealant application, however, etched enamel contamination can occur. It is the authors' expectation that this study's findings may help improve clinician confidence in sealant success, even when application circumstances are far less than ideal.

CONCLUSIONS

Based on this study's findings and within the limitations of an in vitro investigation, the following conclusions can be drawn:

1. The application of a bonding agent intermediary layer prior to sealant placement resulted in significantly higher shear bond strength in the contaminated and noncontaminated groups alike.
2. Individual or simultaneous curing of the intermediate bonding agent layer and the resin sealant does not seem to affect the bond strength of saliva-contaminated enamel.
3. When dry, noncontaminated conditions are maintained, however, the intermediary and the sealing materials should preferably be light cured separately but concurrently.

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