The depth of cure of clear versus opaque sealants as influenced by curing regimens

Christopher Yue, DMD, MS; Daranee Tantbirojn, DDS, MS, PhD; Ronald L. Grothe, DDS, MS, MBA; Antheunis Versluis, PhD; James S. Hodges, PhD; Robert J. Feigal, DDS, PhD

ABSTRACT

Background. The authors conducted a study to test the hypothesis that light-curing regimens affect depth of cure of clear versus opaque sealants.

Methods. The authors light-cured samples of one clear and two opaque sealants at 20 seconds, 0 millimeters; 40 seconds, 0 mm; and 40 seconds, 2.2 mm (n = 5 each). They assessed the depth of cure with Knoop hardness at 0.5-mm increments five minutes and one hour after curing. The authors used analysis of variance.

Results. Curing regimens and sealant types affected the depth of cure. The clear sealant maintained a greater hardness than did the opaque sealants through a depth of 3 mm ($P < .001$). A 20-second duration reduced the depth of cure for all sealants ($P < .001$). The distance from the light source did not affect the cure depth of the clear sealant ($P = .34$), but it reduced the cure depth of the opaque sealants ($P < .05$). Sealant hardness increased significantly one hour after light curing ($P < .001$).

Conclusions. A clear sealant cured deeper than did opaque sealants. Curing duration is crucial to achieve an adequate depth of cure. A 20-second duration may not suffice. Light source distance affected the depth of cure for the opaque sealants, but not for the clear sealant with sufficient curing duration.

Clinical Implications. The authors advocate a curing duration of longer than 20 seconds to ensure thorough polymerization at the interface between the sealant and tooth. Insufficient curing could contribute to failure of the sealants, especially the opaque sealants, under clinical conditions that restrict the light tip position.

Key Words. Sealant; depth of cure; curing duration; distance; hardness; postirradiation.

JADA 2009;140(3):331-338.

Resin-based sealants placed with good technique by trained dental personnel are effective in preventing pit-and-fissure caries on at-risk surfaces.[1-3] The majority of pit-and-fissure sealants are polymerized by light-initiated reactions. The polymerization process starts when photoinitiators, most commonly camphoroquinone, absorb energy from blue light with a wavelength in the region of 470 nanometers.[4] This absorption facilitates the conversion of low-viscosity monomer units into a polymer matrix. This hardened material then forms a strong micromechanical bond to etched tooth enamel, thus physically obliterating susceptible areas of the tooth surface and preventing dental caries. Thus, the degree of conversion is a critical element in the physical properties of the resultant polymers and their bond to enamel.

The success of sealants in reducing dental caries depends directly on their retention on the tooth.[1,5] Sealants rely on their adhesive properties for retention. What

At the time this study was conducted, Dr. Yue was a pediatric dentistry resident, Division of Pediatric Dentistry, Department of Developmental and Surgical Sciences, School of Dentistry, University of Minnesota, Minneapolis. He now is in private practice, Children's Dental World, Winnipeg, Manitoba, Canada.
Dr. Tantbirojn is an assistant professor, Division of Operative Dentistry, Department of Restorative Sciences, School of Dentistry, University of Minnesota, 16-212 Moos Tower, 515 Delaware St., S.E., Minneapolis, Minn. 55455, e-mail "tant0002@umn.edu". Address reprint requests to Dr. Tantbirojn.
Dr. Grothe is a clinical assistant professor and director, Pediatric Dentistry Residency Program, Division of Pediatric Dentistry, Department of Developmental and Surgical Sciences, School of Dentistry, University of Minnesota, Minneapolis.
Dr. Versluis is a research assistant professor, Department of Restorative Sciences, School of Dentistry, University of Minnesota, Minneapolis.
Dr. Hodges is an associate professor, Division of Biostatistics, School of Public Health, University of Minnesota, Minneapolis.
Dr. Feigal is a professor, Division of Pediatric Dentistry, Department of Developmental and Surgical Sciences, School of Dentistry, University of Minnesota, Minneapolis.

often has been overlooked is that the extent of cure of a sealant will determine material properties, both in the bulk and at the interface. A high level of cure throughout the bulk of the sealant is critical, because sealant retention depends primarily on interfaces, which are at the deepest portion of the resin, the place at which it is in closest contact with the etched enamel. If the deepest portion of a sealant is not fully hardened, the micromechanical bond of the sealant could be compromised easily by physical challenges in the oral environment, resulting in loss of sealant.

Additional components of dental sealants, such as titanium dioxide, influence the shade and opacity of the material. Opaque sealants can be seen more easily during clinical application and monitoring.[6] Unfortunately, the addition of opaquer may influence light penetration as a result of increased reflection and scattering, thus preventing a more thorough cure through the depth of the sealant. Incomplete curing of resin-based material can result in increased water absorption, deterioration of mechanical properties, softening of the polymer matrix and decreased wear resistance, all of which can lead to clinical failure.[7] Therefore, improving the clinical success of dental sealants requires improvements in techniques as well as in materials.

Sufficient light needs to penetrate the bulk of the sealant to adequately initiate the polymerization reaction of light-cured sealants. Factors that affect light penetration include curing time, light intensity, distance of the light source, sealant shade and thickness of the material.[8-10] Depth-of-cure measurements can be used to determine the effectiveness of light curing. Therefore, it is important to establish the depth of cure for different sealant materials to determine which are less technique-sensitive and which have a higher chance of success in the face of normal variation in clinicians' use and in the accuracy of light-curing methods.

Because the physical properties of resin-based materials increase proportionally with the extent of cure or degree of conversion, one can estimate the extent of cure throughout the bulk of the resin (depth of cure) by measuring hardness.[11] A good correlation between microhardness and degree of conversion within each type of resin-based dental material is well-established for a broad range of conversion levels.[12-14] Investigators can use this method to determine the depth of cure of a sealant, which is a reflection of clinical performance. Although numerous studies have examined the microhardness of resin-based materials,[8-10,15,16] no studies, to our knowledge, have compared sealants with different opacities and curing techniques regarding the depth of cure.

We conducted this study to determine whether any differences in depth of cure resulted from the type of sealant (clear or opaque) or curing regimen in terms of curing duration and distance from the light source. We used microhardness measurement as a surrogate for degree of conversion. The findings will help clinicians choose techniques or materials that can improve the clinical success of dental sealants.

MATERIALS AND METHODS

The overall experimental design consisted of subjecting three commercial pit-and-fissure sealants with various opacities to three curing regimens. The sealants were Delton LC Opaque (Dentsply International, York, Pa.), Delton LC Clear (Dentsply International) and Clinpro Sealant (3M ESPE, St Paul, Minn.). Clinpro Sealant is opaque pink when applied to the tooth surface and changes to an opaque light yellow when exposed to the light. The table describes the composition of these sealants. The three curing regimens were as follows:

- 20-second cure at a distance of 0 mm from the surface of the sealant to the light tip;
- 40-second cure at a distance of 0 mm from the surface of the sealant to the light tip;
- 40-second cure at a distance of 2.2 mm from the surface of the sealant to the light tip.

Most manufacturers recommend a 20-second curing duration. The 2.2-mm distance represents clinical conditions in which anatomical access constrains where the light-curing tip is placed.

The investigator (C.Y.) prepared 45 plaster molds (Die-Keen Green, Heraeus Kulzer, South Bend, Ind.), each with a rectangular slot (1.6 × 1.6 mm) (Figure 1, page 334). The length of the slot was approximately 20 mm. The top of the slot was covered with a black-painted glass slide to ensure that light entered the slot only from the open end. After injecting uncured sealant into the slot, the

ABBREVIATION KEY. ANSI/ADA: American National Standards Institute/American Dental Association. **Bis-GMA:** Bisphenol A glycidyl dimethacrylate. **ISO:** International Organization for Standardization. **KHN:** Knoop hardness number. **NA:** Not applicable. **TEGDMA:** Triethylene glycol dimethacrylate.