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Bisphenol A Released from Resin Based Dental Sealants

Abstract

Dental sealants are used successfully to prevent occlusal caries. Modern dental sealants penetrate the pits and fissures present on the occlusal surface of molars, allowing dentists to avoid drilling into healthy enamel. Dental sealants also are able to arrest caries progression when placed onto incipient caries, preventing future invasive restorative procedures. Resin-based sealants composed of bisphenol A glycidyl methacrylate (bis-GMA) monomer use bisphenol A (BPA) during the manufacturing process. Bisphenol A has been detected at trace levels on composite resin materials including dental sealants. A variety of adverse effects associated with exposure to BPA have been reported. The US Environmental Protection Agency (EPA) established an exposure level of 50,000 ng/kg body weight/day, which is equivalent to 1,000,000 ng/day for a 6-year-old child, weighing 20 kg.

This report from the Science Institute at the American Dental Association (ADA) demonstrates extremely low BPA release of 0.09 ng associated with the application of four dental sealants. By comparing the overall daily exposure to BPA estimated at 6020 ng/day by the European Food Safety Authority associated with different sources, we found that the contribution from dental sealants is limited to 0.001% when measured after 24 hours. Further analysis reveals that the BPA exposure from dental sealants (0.09 ng) is 100x lower compared to the exposure associated with BPA present in air (8 ng/day). The current results support the data published in 2014 and 2015 issues of the ADA Professional Product Review indicating limited release of BPA from a variety of resin-based dental materials. Our conclusion is that BPA levels in 12 dental sealants evaluated in this report are far below the daily exposure level set by the US EPA. The ADA will continue to monitor dental materials periodically, addressing a variety of concerns relevant to the oral health community.

Introduction

The introduction of the bisphenol A glycidyl methacrylate (bis-GMA) resin by Dr. Raymond Bowen in the 1950s revolutionized dentistry. This resin offered a solution for direct restorations by reducing shrinkage and improving stiffness compared to methyl methacrylate. Bisphenol-A (BPA) is used during the synthesis of bis-GMA and bisphenol dimethacrylate (bis-DMA) resins.

While BPA exposure arises mainly from food and beverage containers as well as contact with thermal paper, some residual BPA is found at trace levels in the final product of resin-based dental materials. The amount of BPA released from resin-based sealants, however, is extremely low and is restricted to a thin layer at the outer surface of the restoration, which is exposed to air during polymerization.

- BPA has been detected at trace levels on dental sealants
- The US Environmental Protection Agency (EPA) established an exposure level of 50,000 ng/kg body weight/day
- BPA exposure from dental sealants is 0.09 ng and is 100x lower compared to the exposure associated with BPA present in air (8 ng/day)
- BPA levels in dental sealants evaluated in this report are well below the daily exposure level set by the US EPA

Because ingestion of BPA at certain levels poses a health risk, the US Environmental Protection Agency (EPA) set a reference exposure limit of 50,000 ng/kg body weight/day, which translates to a level of 1,000,000 ng/day for a 6-year-old child (44 lbs or 20 kg). Studies conducted at the ADA in 2013 and 2014 indicated that the level of BPA released from resin-based materials is low and far below the limit proposed by EPA. This Professional Product Review contains BPA analysis for an additional 12 dental sealants in order to provide a more complete understanding of the current US market.

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The Problem

Dental composite resin materials are manufactured using bisphenol-A (BPA), which is known to cause adverse health effects depending on the exposure level. There is a greater concern related to dental sealants since exposure will occur in young patients whose tissues and organs are still developing.

Approach

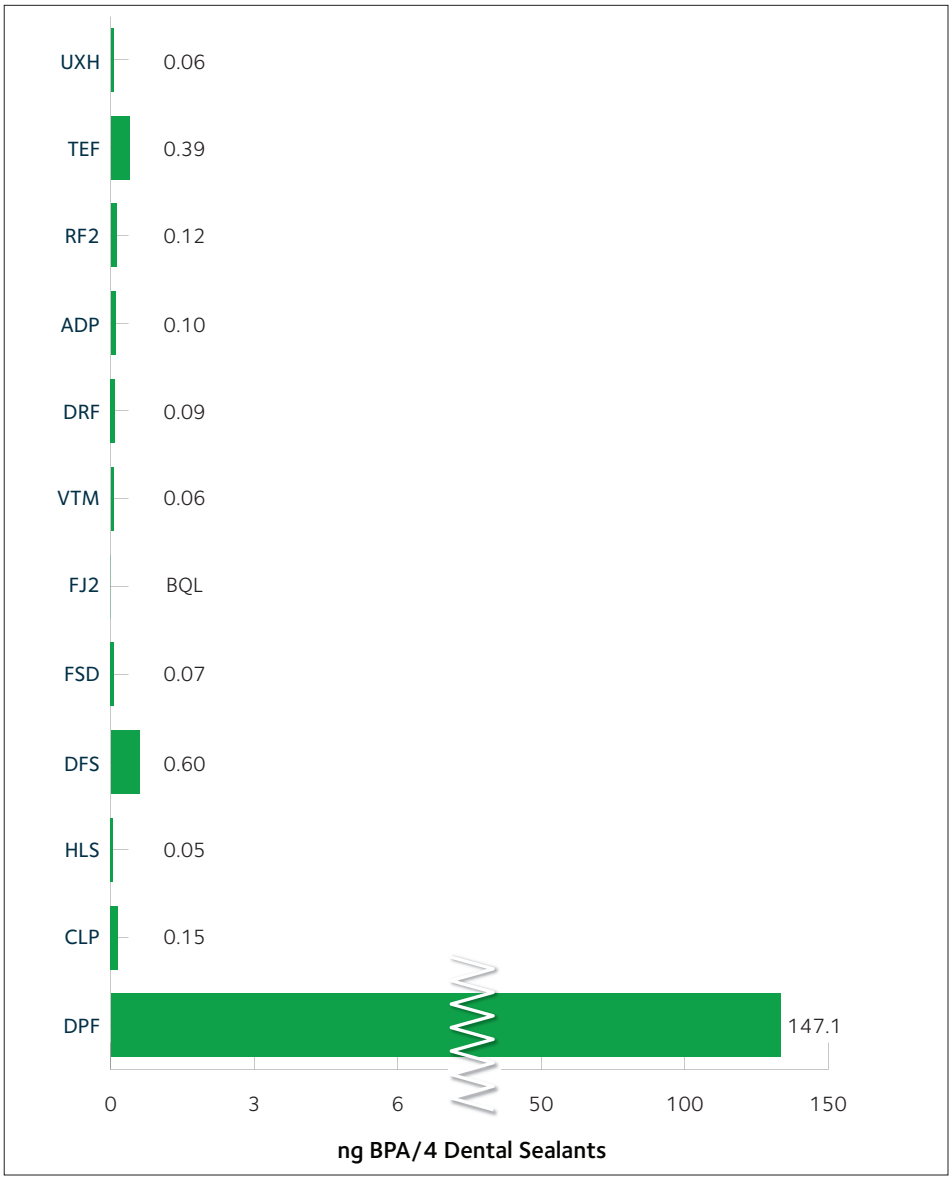
Table 1 lists 12 dental sealants that were purchased and processed at the Science Institute of the American Dental Association. The BPA was extracted from artificial saliva and acetonitrile of polymerized and unpolymerized samples. Polymerized samples were prepared in Teflon molds with a 10-mm diameter and 2-mm depth for a complete cure following the manufacturers' instructions. An Optilux 501 (Kerr Dental, USA) polymerization unit with a light radiant emittance of > 600 mW/cm^2 was used to cure the sealants. The output from the curing unit was initially measured using a spectrometer/integrating-sphere assembly with a NIST-traceable light source. This output value was then immediately compared to the output obtained from a dental radiometer (Demetron LED, Kerr Dental, USA), which was then used to continuously monitor the output of the curing unit throughout the experiment. A total of 72 samples of polymerized (24 hours) and unpolymerized (48 hours) were evaluated (n = 3).

Upon the extraction of dental sealants in acetonitrile or artificial saliva, liquids extracts were analyzed using a liquid chromatography-tandem mass spectrometry (LC-MS/MS) with a detection limit of ≤ 0.5 ng/mL. Prior to analysis, extracts were prepared using a liquid-liquid extraction procedure, evaporated to dryness, and reconstituted in a solution of methanol and ammonium acetate. LC-MS/MS was then performed

Table 1. Dental sealants included in the present evaluation.

Sealant, Manufacturer	Acronym
UltraSeal XT Hydro, UltraDent	UXH
Tetric Evo Flow, Ivoclar Vivadent	TEF
Revolution Formula 2, Kerr	RF2
Admira Protect, Voco	ADP
Dyract Flow, Dentsply Caulk	DRF
Vitremer, 3M ESPE	VTM
Fuji II LC, GC America	FJ2
FluoroShield, Dentisply Caulk	FSD
Delton FS+, Dentisply Caulk	DFS
Helioseal F, Ivoclar Vivadent	HLS
Clinpro, 3M ESPE	CLP
Delton Pit and Fissure Sealant, Dentisply Caulk	DPF

BPA Released from Polymerized Dental Sealants (24 hours)



▲ **Figure 1.** *BPA (ng) released from 12 polymerized dental sealants evaluated by the American Dental Association. The values reported were adjusted to reflect the release of BPA associated with four dental sealants (8 mg/sealant).*

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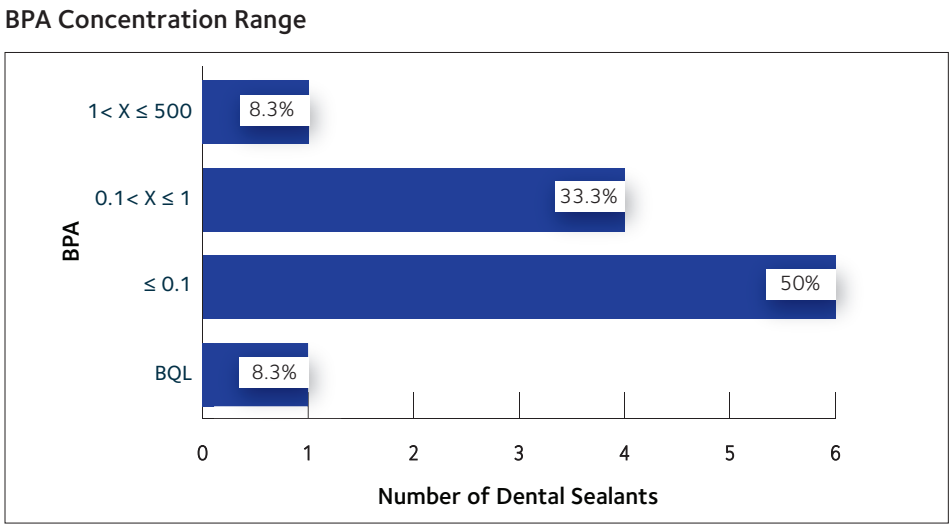

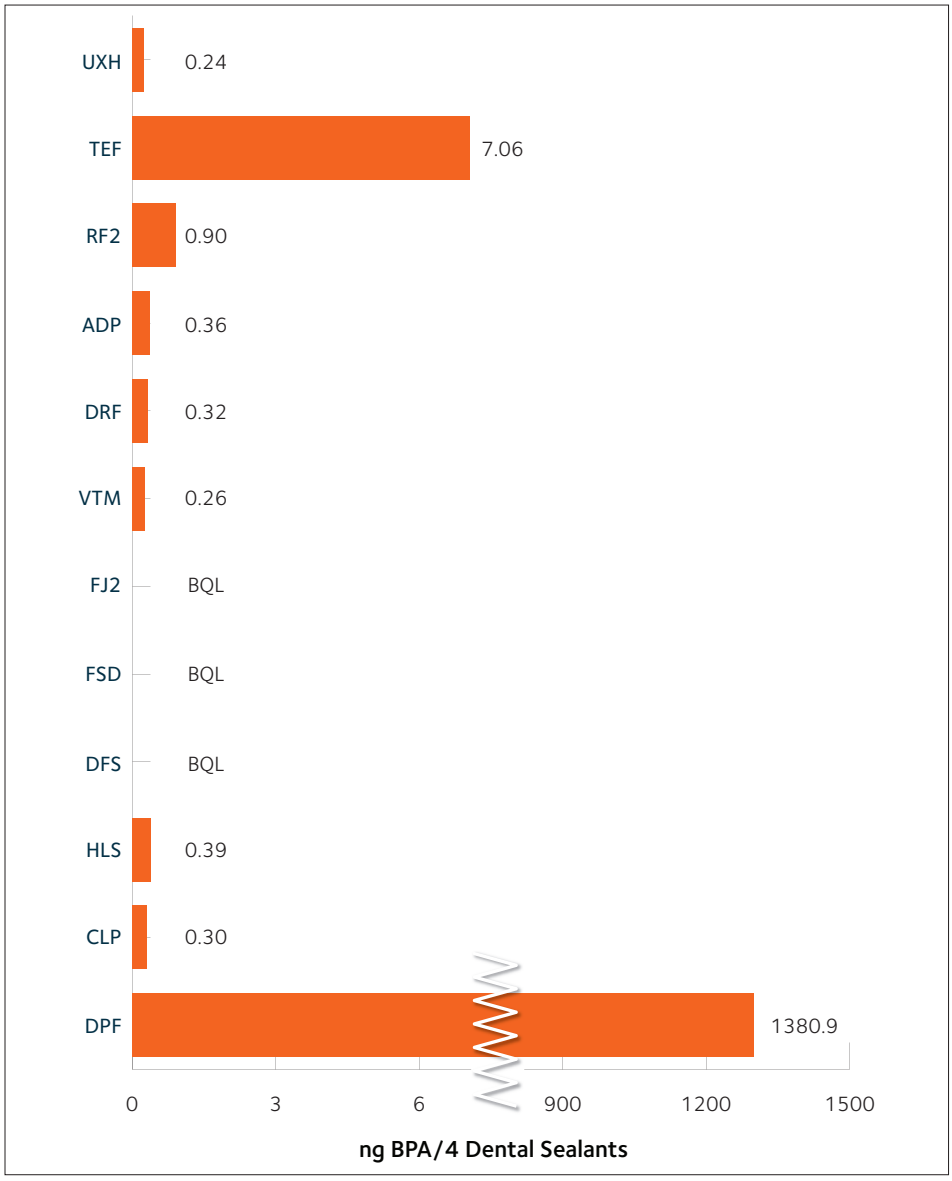

Figure 2. *Distribution of the BPA values within the polymerized groups at 24 hours. Groups were divided into 4 range of values: below quantification limit (BQL); ≤ 0.1; 0.1 < X ≤ 1 and 1 < X ≤ 500. Out of the 12 dental sealants analyzed at 24 hours, one group (8.3%) had a BPA level below the quantification limit (BQL) of the equipment, whereas six samples (50%) had BPA levels ≤ 0.1 ng and four samples (33.3%) between 0.1 < X ≤ 1 ng. The remaining sample (8.3%) from Delton Pit and Fissures (clear) had a BPA release between 1 < X ≤ 500 ng.*

on an AB Sciex API 5000 system. Liquid chromatography was performed on an ACE C18-PFP 100 x 2.1 mm column followed by tandem mass spectrometry in negative ion mode. Quality control samples and an internal standard (d16-BPA) were used throughout the analyses for accurate quantification of BPA. Similar methodology was used in previous ADA Professional Product Review analyses of the BPA release from resin-based materials. The values reported then were adjusted to reflect the release of BPA associated with four dental sealants (8 mg/sealant). The results were compared to the BPA exposure levels recommended by EPA and BPA estimated daily intake based on European Food Safety Authority limits set in 2015 for a 6-year-old child with average weight of 44 lbs (20 kg).

Our Findings

Twelve dental sealants were analyzed after 24 hours and 48 hours (Figures 1-3). The overall BPA released from polymerized dental sealants was extremely low with an average value of 12.4 ± 40.6 ng and median of 0.09 ng (IQR: 0.15 ng). The disparity between the average and median values is explained by the presence of one extreme outlier represented by Delton

Figure 3. *BPA (ng) released from 12 unpolymerized dental sealants evaluated by the American Dental Association. The values reported were adjusted to reflect the release of BPA associated with four dental sealants (8 mg/sealant).*

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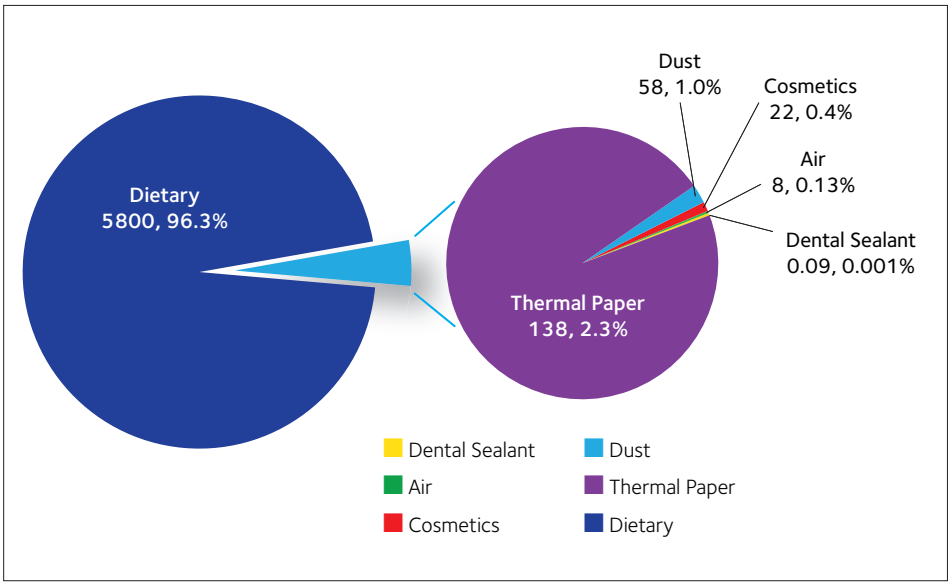
Pit and Fissures (clear) (Figure 1). To help to understand this disparity, look at the distribution of the BPA values within the polymerized groups at 24 hours (Figure 2). Out of the 12 dental sealants analyzed at 24 hours, one group (8.3%) had a BPA level below the quantification limit (BQL) of the equipment, whereas six groups (50%) had BPA levels ≤ 0.1 ng and four groups (33.3%) between 0.1 < X ≤ 1 ng. The remaining group (8.3%) from Delton Pit and Fissures (clear) had BPA release of 147.1 ng, higher than any of the other sealants (Figure 1-2). Therefore, the median value should be used to better represent the BPA release from 12 groups, minimizing the impact of one outlier.

The analysis of unpolymerized samples indicated a BPA average release of 115.9 ± 367.9 ng and median of 0.31 ng (IQR: 0.34 ng). With the exception Tetric Evo Flow (7.1 ng) and Delton Pit and Fissure Sealant, clear (1380.9 ng), BPA values from the majority of unpolymerized samples were below 1 ng (Fig. 3). The increase of BPA release observed from polymerized samples compared to unpolymerized samples confirms the hypothesis that the release is limited to non-polymerized regions of resin-based materials. Although the measurement of unpolymerized samples does not reflect the clinical scenario, it does provide an estimate of the maximum amount of BPA that could be released from dental sealants.

Clinical Relevance

The clinical relevance of BPA exposure from dental sealants should be based on three key parameters: (1) Is exposure to BPA from sealants temporary or does it continue to occur over the lifetime of the sealant? (2) How much BPA is actually released compared to the estimated daily intake? (3) How this relates to BPA levels recommended by regulatory bodies?

Daily BPA Exposure 6-year-old child (source, ng, %)



▲ **Figure 4.** *Daily BPA exposure estimated to a 6-year-old child from a variety of sources based on the European Food Safety Authority (2015). The application of four dental sealants would represent 0.001% of the estimated BPA exposure following the first 24 hours.*

Exposure to BPA from sealants occurs over a period typically limited to a couple of hours following application (mainly during the first 24 hours). During this brief period, the BPA release from four dental sealants is limited to extremely low values of 0.09 ng. By comparison, a 6-year-old child is exposed to 6020 ng/day of BPA from a variety of sources (Figure 4). The great majority of BPA comes from food and beverages (96.2%), which accounts for 5800 ng/day, followed by 138 ng/day from dermal contact with thermal paper (2.3%). Lastly, BPA exposure measures 8 ng/day from the air (0.13%) and 0.09 ng from dental sealants (0.001%). These values indicate that exposure to BPA associated to the application of dental sealants is 100x lower than the BPA exposure associated to breathing air during the same day. The EPA recommends a BPA exposure level of 1,000,000 ng/day and, since 2015, the European Food Safety Authority applied a more restricted level of 80,000 ng/day for a 6-year-old child. Both values proposed by the American and European regulatory agencies are far higher than the release we observed from the 12 dental sealants evaluated after 24 hours.

The current results indicated that the BPA release from dental sealants is limited to 0.09 ng during the first 24 hours. The exposure is 0.001% of the estimated BPA daily exposure from other sources, far below the safe level proposed by regulatory bodies. The American Dental Association Council on Scientific Affairs believes that there is no basis for health concerns related to BPA exposure from any dental material.

Continued on next page

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What is BPA? Why BPA is detected in dental materials? Where we can find BPA?

Gruninger: Bisphenol-A (BPA) is a commonly used monomer in polycarbonates and epoxy resins. BPA is not added to resin-based dental materials, it is used as starting ingredient in the synthesis of bis-GMA and bis-DMA. When combined with either chemical or light-activated initiators, these compounds bind into longer chain and cross-linked polymers that form a hard (cured) product. By controlling the amount of initiators and plasticizers, the final product also can have various levels of flexibility.

After over 50 years of use, BPA is found nearly everywhere in our environment in a multitude of products. The majority of environmental BPA exposure originates from polycarbonate plastics, epoxy resins and thermal printing paper. These BPA-derived plastic materials are extremely useful for cost-effective, durable packaging and barrier materials. Clear plastics, as well as food can liners use the polymerized products of BPA derivatives. Thermal paper used for transaction receipts uses free BPA as an acid reactant to produce images on paper under heat.

Are children who receive dental sealants at risk?

Örtengren: Twenty years ago BPA was found to have estrogen-like effects in tissue culture, which launched subsequent studies on its safety. Although most manufacturers' synthesis procedures minimize unreacted BPA, some traces of BPA will remain. This is the major source of BPA in most manufactured dental products. Another source of potential dental BPA comes from the degradation of some BPA derivatives that release BPA, such as bis-DMA through the action of salivary esterases. However, manufacturers of dental sealants no longer use bis-DMA in their formulations. There is no scientific evidence that BPA can be degraded from bis-GMA, a common monomer in resin-based dental sealants. The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) of the European Union concluded in a 2015 report that long-term oral exposure to BPA from dental materials poses a negligible health risk in humans. A review performed by the National Board of Health and Welfare in Sweden (2015) also concluded that there is no evidence that BPA released from resin-based dental materials causes any health effects. In vitro investigations on the release of BPA from resin-based materials show elution from some materials but not all. Materials containing bis-DMA and those made of polycarbonate (e.g., dentures, and brackets) may be slightly more susceptible in that respect. BPA release is at its highest during the first 24 hours following composite or sealant curing. The amount, though, is very low and decreases with time. Estimations based on BPA release in vitro showed that the BPA exposure of a 30 kg patient from composite/sealants falls well within the safety margin proposed by the EPA (50 µg/kg body weight/day) and EFSA (4 µg/kg body weight/day). The estimated release of BPA from a large composite was calculated to be 0.027% and for 12 teeth with fissure sealants 0.45% of the tolerable daily intake, according to a systematic review published by the National Board of Health and Welfare in Sweden.

Who regulates the limits related to BPA exposure and where I can get updated information?

Gruninger: The limit on human BPA exposure is regulated by governmental agencies. These agencies publish reports with the latest research outcomes providing guidelines to ensure public safety.

- US Environmental Protection Agency (EPA)
- US Food and Drug Administration (FDA)
- European Food Safety Authority (EFSA)

What is next? Should BPA be banned from dental products?

Örtengren: Dental materials are considered as medical devices and the safety issues have a very high priority, but they are rarely made of polycarbonate or epoxy resins. Oral exposure to the limited amounts of BPA that may be released from resin-based materials is far below the limits suggested by governmental agencies and are considered to possess an insignificant risk. Therefore, development of BPA-free dental materials may not have the highest priority at present.

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Caries Workgroup, Council on Scientific Affairs

Brian Novy, Dentaquest Institute; **Doug Young,** University of the Pacific; **Margherita Fontana,** University of Michigan; **Norman Tinanoff,** University of Maryland; **Rebecca Slayton,** University of Washington

In the fall of 2013, the ADA Council on Scientific Affairs convened an expert panel to conduct a systematic review of the literature on sealants in order to update the 2008 clinical recommendations (Journal American Dental Association 2008) and generate Clinical Practice Guidelines (CPG) for their use. Both the systematic review and CPG are published in the August Journal of the American Dental Association along with a "For the Patient Page" on the topic, which dentists can use as a resource for patients.

The four most common sealant materials used in practice are resin-based sealants, glass ionomer sealants, polyacid-modified resin sealants and resin-modified glass ionomer sealants. Sealants, no matter the type, are technique sensitive. Isolation is key to the successful application of all sealants but is critical for resin sealants. To attain the desired impact, it is important to be familiar with and follow manufacturer's instructions.

Sealants provide two types of benefits: primary and secondary caries prevention. Caries risk in primary and permanent molars with sound pit and fissure surfaces has been shown to be reduced following the application of sealants in children and adolescents. Progression of early cavitated occlusal caries lesions also has been shown to be reduced in this population following the application of sealants. There is not enough data to assess the impact of sealant use in adults.

One issue that the systematic review noted is the need for an established baseline risk level for the development of pit and fissure caries or the prevention of their progression. Risk of caries development is present even for those children and adolescents who engage daily in appropriate brushing and interdental cleaning, consume a healthy diet and make regular visits to the dentist. Notwithstanding the factors minimizing their risk, these adolescents can still benefit from timely sealant application. The potential benefit from sealants is greater among children who are known to be at higher risk of caries development (whether due to lack of regular access to fluoridated water, poor oral care habits, or frequent consumption of sugar-containing drinks or snacks). In addition, the systematic review suggests that sealants are more effective in preventing pit and fissure lesions in permanent molars than fluoride varnish. More definitive studies will be required to discriminate the level of benefit among the various products on the market.

Dental sealants have a more than 40-year track record for reducing the risk of pit and fissure caries lesions in primary and permanent teeth. Nonetheless, data from the National Health and Nutrition Examination Survey (2005) and the Public Health Reports (2015) demonstrate that, while sealants may be becoming more prevalent, their use is far from universal. A goal for the new CPG is to increase sealant use in children and adolescents and stimulate additional research into the efficacy of sealants in older populations.

Links of Interest

ADA 2015 PPR Evaluation of BPA Released from Resin-Based Dental Sealants

ADA 2014 PPR Evaluation of BPA Released from Resin-Based Composite Restoratives

ADA 2016 Clinical Practice Guidelines

ADA 2016 Systematic Review

ADA "For the Patient Page"

National Health and Nutrition Examination Survey 2005

Public Health Reports 2015

CSA Statement on BPA