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Dental sealants and restorations and urinary bisphenol A concentrations in children in the 2003-2004 National Health and Nutrition Examination Survey

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Abstract

Background—Resin-based dental sealants and composites contain bisphenol A-glycidyl methacrylate, a bisphenol A (BPA) derivative. The authors hypothesized that a greater number of sealants or restorations would be associated with higher urinary BPA concentrations.

Methods—The authors examined urinary BPA measurements (in nanograms per milliliter) and oral examination data for 1,001 children aged 6 to 19 years from the dataset of the 2003-2004 National Health Examination and Nutrition Survey (NHANES). They categorized children into four groups according to number of occlusal sealants and number of restorations, separately. They estimated associations by using unadjusted and adjusted tobit regression models.

Results—The lowest quartile of BPA concentrations ranged from 0.3 ng/mL to 1.9 ng/mL, whereas the highest quartile ranged from 7.3 ng/mL to 149 ng/mL. In adjusted analysis, children with seven to 16 sealants had geometric mean BPA concentrations 25 percent higher than those of children with no sealants (95 percent confidence interval [CI], –14 percent to 82 percent; $P = .23$). In adjusted analyses, children with seven to 42 restorations had geometric mean BPA concentrations 20 percent higher than those of children with no restorations (95 percent CI, –6 percent to 53 percent; $P = .13$). Neither of these adjusted estimates was statistically significant.

Conclusions—Though the findings were in the direction hypothesized, the authors did not observe a statistically significant association between a greater number of sealants or restorations and higher urinary BPA concentrations. Additional studies are needed to determine the extent of oral and systemic exposure to BPA from resin-based dental restorative materials over time.

Practical Implications—Dentists should follow this issue carefully as it develops and as the body of evidence grows. There is insufficient evidence to change practice at this time.

INTRODUCTION

More than 4 million metric tons of the chemical bisphenol A (BPA) are manufactured each year globally.¹ BPA is used widely to make polycarbonate plastics such as those in hard plastic baby and water bottles and epoxy resins such as those in dental sealants and resin-based composites.² Although dental sealants and composites typically do not contain pure

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BPA as an initial chemical compound, BPA is thought to occur as a trace material resulting from the manufacturing process of bisphenol A-glycidyl methacrylate (bis-GMA) or as a byproduct of degradation of bis-GMA or other components in resin-based dental composites or sealants.^{3,4} Several studies show dental sealants or composites containing bis-GMA can leach BPA into saliva.⁵⁻⁸ Biomarker studies have shown an increase in urinary BPA concentrations after patients received bis-GMA-based dental sealants or composites that did not contain BPA as an active ingredient.^{5,7,9} Dental sealants and composites containing bis-GMA are among the most commonly used materials in children.¹⁰ For example, an estimated 16 million (27.2 percent) school-aged children have dental sealants.^{11,12} By age 13 to 15 years, more than 50 percent of children have at least one dental sealant and therefore may be at risk of exposure to BPA.¹³

BPA is a known endocrine disruptor that mimics estrogen and alters hormonal function, which can adversely affect neurodevelopment, reproductive development and metabolic processes.¹⁴⁻¹⁷ Food sources often are cited as the primary source of BPA exposure in humans; however, recent studies suggest dental materials and other nonfood sources (for example, polycarbonate plastics) may contribute to cumulative BPA exposure in humans.^{2,18} Public concern about products that contain BPA is increasing and has led to calls for BPA-free consumer products. In light of this growing concern, and given experience with public concern regarding mercury in amalgam, dentistry needs to be proactive in evaluating potential adverse effects of BPA and BPA-derived components in dental materials.

The extent to which dental sealant or restoration exposure is associated with urinary BPA exposure in American children is unknown. We sought to address this gap in knowledge by examining the association between number of dental sealants or restorations and urinary BPA concentrations in a nationally representative sample of U.S. children using the 2003-2004 National Health and Nutrition Examination Survey (NHANES). We hypothesized that a greater number of dental sealants or restorations would be associated with higher urinary BPA concentrations.

METHODS

We used data from the 2003-2004 NHANES for our cross-sectional study. BPA was collected for a random subsample of the larger data set (N = 2,612), and we restricted our analysis to those with an available BPA measurement (n= 2,517), including those with values below the limit of detection (LOD) of 0.3 nanograms per milliliter (95 excluded because of missing data). We restricted the subsample to children aged 6 to 19 years (n = 1,029). BPA was not measured in children younger than 6 years. We used 19 as the upper range on the basis of the reporting by the U.S. Centers for Disease Control and Prevention (CDC), which categorizes children as those aged zero to 19 years. We further restricted our analysis sample to those for whom data were available for at least one of our dental exposures of interest (sealants or restorations); we excluded 28 owing to missing data. Our final sample was 1,001 participants.

Urinary BPA levels (in ng/mL) have been measured in NHANES since 2003. We defined quartiles of BPA on the basis of the sample of 6- to 19-year-olds in NHANES. Normality of the outcome is an assumption of tobit regression, hence we log transformed BPA when analyzing it as a continuous outcome to make it closer to a normal distribution for tobit regression analyses.

NHANES conducted an extensive dental examination in the 2003-2004 cycle. Our primary exposure of interest was number of occlusal-surface sealants observed at the dental examination, and the 2003-2004 NHANES cycle is the most recent in which these data were collected. We decided a priori to exclude nonocclusal surfaces because the size of any sealants placed on other surfaces compared with those on occlusal surfaces would tend to be small. We counted all premolar and molar occlusal surfaces but excluded teeth nos. 7 and 10 and third molars (if any). A priori, we categorized sealants as none, one to three, four to six, and seven to 16 (maximum) on the basis of the likely number of sealants to which children would be exposed.

Another potential exposure source of BPA is dental composite restorations, which often contain bis-GMA. We explored restored surfaces as a secondary exposure, because the NHANES did not collect data about the type of restoration or material used (amalgam, composite and so forth), only about whether or not a restoration was present. In contrast to sealants, we counted restorations on all surfaces (except for third molars), because the amount of material and potential for BPA exposure would be greater. We categorized restorations as none, one to three, four to six, and seven to 42.

CDC guidelines strongly encourage the inclusion of basic design variables in any analyses of NHANES. In all adjusted regression models, we included age, sex, and race or ethnicity on this basis and because these variables were considered potential confounders. We also included a socioeconomic indicator, the education level of the household reference person (typically the child's parent), as a potential confounder. We adjusted for creatinine to account for urinary dilution. There are other possible BPA exposure routes that we considered a priori as potential confounders of the association with dental sealants (or restorations) based on published literature^{19,20} and biological plausibility. These included number of restaurant meals per week, number of school lunches per week, amount of bottled water consumption, tap water source and serum cotinine concentrations (an indicator of active or passive smoking). We also considered demographic covariates (parent's marital status and country of birth), as well as the child's consumption of sugary beverages (juice, fruit drinks, soda), body mass index (BMI) category and poverty level (measured as the ratio of family income to poverty based on poverty guidelines from the U.S. Department of Health and Human Services).^{14,21}

As recommended by CDC, we used the sample weights for the BPA subsample of the 2003-2004 NHANES. We conducted all analyses with statistical software (Stata 11, StataCorp, College Station, Texas) by using survey ("svy") commands. We log transformed urinary BPA and estimated the geometric mean and geometric mean ratios, which is the ratio of the medians and a better measure than the regular mean ratio when the distribution is skewed. We fit unadjusted and adjusted multivariate tobit models to accommodate left

censoring of urinary BPA measurements (NHANES assigned the 38 values below the LOD a value of 0.3 ng/mL). A tobit model accounts for values below the lower LOD by modeling a latent variable—in this case, the unobserved (true) urinary BPA level. In our adjusted model, we adjusted for urinary creatinine concentrations, age, sex, race or ethnicity, and education level of the household reference person. We evaluated confounding for all other covariates for sealants and restorations by examining their impact on coefficient values. Only the cotinine concentration category and the BMI category affected values of occlusal sealant coefficients and were included in our adjusted model. In adjusted models, we accounted for restorations when examining sealants and vice versa. In secondary analysis, we examined adjusted estimates for sealants without restorations and vice versa. To evaluate the sensitivity of our results to violations of tobit model assumptions, we compared tobit results to a linear regression with robust standard errors and with limit of detection (LOD) / 2 imputed for the values below the LOD. Because NHANES data are deidentified, the institutional review board of the University of Washington, Seattle, waived review of this study.

RESULTS

The geometric mean BPA concentration in the study sample was 2.9 ng/mL. The lowest quartile had BPA concentrations of 0.3 to 1.9 ng/mL. The highest quartile had mean BPA concentrations of 7.3 to 149 ng/mL (Table 1). A greater proportion of those in the highest quartile compared with those in the lowest quartile were male, were non-Hispanic black, were living in poverty, had serum cotinine concentrations greater than 2.0 ng/mL and were obese (Table 1).

In unadjusted analysis, children with seven to 16 sealants had geometric mean BPA concentrations 23 percent higher than those of children with no sealants (95 percent confidence interval [CI], –7 percent to 62 percent) (Table 2). In unadjusted linear regression analysis, an increase of 10 sealants was associated with geometric mean BPA concentrations that were 18 percent higher (95 percent CI, –6 percent to 49 percent). In our adjusted model, children with seven to 16 sealants had geometric mean BPA concentrations 25 percent higher than those of children with no sealants (95 percent CI, –14 percent to 82 percent). In adjusted linear regression analysis, an increase of 10 sealants was associated with geometric mean BPA concentrations that were 11 percent higher (95 percent CI, –18 percent to 52 percent). Compared to children with no restorations, children with seven to 42 restorations had geometric BPA concentrations 5 percent and 20 percent higher in unadjusted and adjusted analyses, respectively. In linear regression, an increase of 10 restorations was not associated with higher geometric mean BPA concentrations (Table 2). No test results for trend for any of the models were statistically significant. Adjusted estimates for sealants without restorations in the model (and adjusted estimates for restorations without sealants) did not alter our findings (data not shown). Tobit model results were similar to the alternative approach of linear regression with robust standard errors and LOD/ 2 imputed values (data not shown).

DISCUSSION

This is the first study in which researchers have examined the association between BPA concentrations and number of sealants and restorations in a nationally representative sample of U.S. children. Though our findings on dental sealants and restorations were in the direction hypothesized, we did not observe statistically significant associations between a greater number of sealants or restorations and higher BPA concentrations, which is likely because of the amount of background variability in BPA levels.

Our findings address a gap in knowledge regarding the link between resin-based dental materials and urinary BPA concentrations in children. We know of only one small pilot study (N = 19) aimed at examining resin-based dental materials and BPA concentrations in U.S. children. Martin and colleagues⁹ found that urinary BPA concentrations in those who received four or more sealants or composites were higher two weeks after treatment than before treatment. Findings of the largest study involving urinary BPA concentrations before and after treatment in adults with dental composites (N = 172) showed that urinary BPA concentrations remained statistically significantly elevated at nine to 30 hours after composite placement compared with pretreatment concentrations.⁷ Findings of the only other related study showed that BPA concentrations differed according to brand of sealant.⁵ Though our findings were in the same direction as those in these studies,^{7,9} we did not have data regarding the brands or ingredients of sealants used.

The 2003-2004 NHANES did not have data regarding time of dental sealant or restoration placement, duration of exposure, or composition of dental sealants or restorations. It is possible that BPA exposure varies according to age because of sealant or restoration placement patterns, or because of lifestyle or developmental factors that may influence BPA concentrations. In post-hoc analysis we examined age as an effect modifier, but the interaction was not statistically significant (data not shown). The temporal relationship of the associations cannot be inferred from this cross-sectional analysis. We do not know whether urinary BPA concentrations increased after sealant or restoration placement, nor do we know the timing or sources of other BPA exposures. Though most sealants contain bis-GMA,³ our analysis likely included sealants with no BPA derivatives, a fact that would have biased our estimates toward finding no association. Inference from our findings regarding restorations is limited because we had no data about type of restoration and some restorations (such as amalgam) contain no BPA derivatives. These data are 10 years old, and laboratory methods have changed over time; studies using current methods are needed.

Prevalent sealant and composite exposure may be linked to higher urinary BPA concentrations through leaching of BPA, which is hypothesized to occur from degradation of components of dental sealants or composites over time.²² The findings of two retrospective studies in Korean children provided support for the degradation hypothesis, showing that greater prevalent exposure to bis-GMA-based dental sealants or composites was associated with statistically significantly higher BPA concentrations in saliva and urine.^{23,24} In contrast, Kingman and colleagues⁷ found no association between number of preexisting composites and urinary BPA concentrations in adults, which suggests that degradation of composites may not pose a problem. Our findings do not confirm or refute

the possibility that degradation of dental sealants or restorations increases BPA concentrations.

We had considerable background variability in our measure of BPA, which may obscure associations because BPA from other sources is difficult to control. Recent studies suggest that greater exposure to bis-GMA-based dental composite is associated with worse psychosocial function and adverse reproductive development; however, there was no biomarker measure of BPA in these studies.^{22,25} Given that considerable numbers of dental sealants and composites are placed in children during in a period of ongoing neurological and reproductive development, studies need to quantify the extent to which resin-based dental materials contribute to BPA exposure.

CONCLUSIONS

Our findings add to a small, important and growing body of knowledge of childhood exposure to BPA from resin-based dental materials. The findings of this study do not provide convincing evidence that the presence of more sealants is associated with higher levels of BPA—but nor does it provide convincing evidence to the contrary, because the nonstatistically significant trend is in the direction of an association. Our findings suggest that careful attention should be paid to this issue in the future.

ABBREVIATION KEY

bis-GMA	Bisphenol A-glycidyl methacrylate
BMI	Body mass index
BPA	Bisphenol A
CDC	Centers for Disease Control and Prevention
LOD	Limit of detection
NHANES	National Health and Nutrition Examination Survey

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Table 1

Summary study sample characteristics in quartiles of urinary bisphenol A (BPA), 2003-2004 NHANES.

CHARACTERISTIC	NO.	QUARTILE			
		1 (n = 266)	2 (n = 252)	3 (n = 254)	4 (n = 257)
Child's Urinary BPA Concentration (ng/mL), Range	1,001	0.3-1.9	2.0-3.9	4.0-7.2	7.3-149
Child's Sex, Percentage					
Female	1,001	56.1	49.7	44.3	46.6
Male		43.9	50.3	55.7	53.4
Child's Age in Years, Percentage	1,001				
6-11		46.8	42.2	42.9	40.5
12-19		53.2	57.8	57.1	59.5
Child's Race or Ethnicity, Percentage	1,001				
White, non-Hispanic		59.1	65.9	71.2	60.2
Black, non-Hispanic		9.1	14.8	17.6	18.2
Mexican American		18.6	12.8	7.2	9.2
Hispanic, other race		5.4	3.5	1.7	4.2
Other		7.6	2.9	2.3	8.2
Ratio of Family Income to Poverty, Divided into Quartiles	952				
< .92 (greater poverty)		13.8	14.9	17.7	24.7
.92-1.76		25.2	21.2	23.3	21.6
1.77-3.42		20.2	38.0	25.3	24.5
> 3.42 (above poverty)		40.8	25.9	33.7	29.2
Parent's Education Level, Percentage	958				
Less than grade 9		10.0	4.2	5.8	6.5
Grade 9 to 12; no high school diploma		12.7	11.3	15.7	15.7
High school graduate, general educational development (GED) diploma or equivalent		26.2	28.4	21.0	27.1
Some college or associate's degree		26.7	37.9	37.5	34.4
College graduate or above		24.3	18.2	20.0	16.2

CHARACTERISTIC	NO.	QUARTILE			
		1 (n = 266)	2 (n = 252)	3 (n = 254)	4 (n = 257)
Parent's Marital Status, Percentage	966				
Married		69.5	70.8	64.7	66.2
Widowed/Divorced/Separated		17.6	13.4	19.0	19.9
Never married		10.0	11.6	12.2	11.7
Living with partner		3.0	4.2	4.1	2.1
Child's Serum Cotinine Concentration (ng/mL), Percentage	920				
< .015		18.2	17.8	18.2	8.3
.015-1.99		70.8	71.3	65.4	67.7
> 2.00		11.1	10.9	16.4	24.0
Child's Body Mass Index, Percentage	994				
Normal (< 25)		83.1	75.7	76.3	76.3
Overweight (25-29.9)		11.5	17.7	12.5	14.2
Obese (≥ 30)		5.5	6.6	11.2	9.5
Child's Urinary Creatinine Concentration (mg/dl), Mean	999	79.4	122.2	152.4	180.0
Child's Number of Dental Sealants (Occlusal Surfaces), Percentage	1,000				
Zero		61.2	57.9	61.7	58.0
One to three		18.5	18.0	19.6	18.7
Four to six		14.2	18.5	14.1	12.5
Seven to 16		6.1	5.6	4.6	10.8
Child's Number of Restored Surfaces, Percentage	1,001				
Zero		52.1	48.9	48.7	46.9
One to three		16.8	21.3	17.2	24.7
Four to six		10.6	11.3	10.3	8.8
Seven to 42		20.5	18.4	23.8	19.7

* NHANES: National Health and Nutrition Examination Survey.

Table 2

Unadjusted and adjusted geometric mean ratios of urinary bisphenol A levels, according to sealant and restoration exposure.

TREATMENT EXPOSURE	NO.	BPA GEOMETRIC MEAN (WEIGHTED)	UNADJUSTED BPA GEOMETRIC MEAN RATIO (95% CONFIDENCE INTERVALS)	P VALUE	ADJUSTED BPA GEOMETRIC MEAN RATIO (95% CONFIDENCE INTERVALS)	P VALUE
Sealants						
Zero	661	3.54	n = 1,000 1.00 (reference)		n = 873 1.00 (reference)	
One to three	151	3.75	1.06 (0.86, 1.30)	0.57	1.05 (0.88, 1.27)	0.55
Four to six	124	3.35	0.95 (0.76, 1.19)	0.62	0.95 (0.76, 1.18)	0.61
Seven to 16	64	4.34	1.23 (0.93, 1.62)	0.14	1.25 (0.86, 1.82)	0.23
Restorations						
Zero	501	3.42	n = 1,001 1.00 (reference)		n = 873 1.00 (reference)	
One to three	185	4.14	1.21 (0.95, 1.54)	0.11	1.22 (1.01, 1.48)	0.04
Four to six	102	3.42	1.00 (0.77, 1.29)	0.99	1.09 (0.82, 1.45)	0.53
Seven to 42	213	3.61	1.05 (0.78, 1.42)	0.71	1.20 (0.94, 1.53)	0.13
Sealants (10-unit change)			1.18 (0.94, 1.49)	0.15	1.11 (0.82, 1.52)	0.47
Restorations (10-unit change)			0.99 (0.80, 1.23)	0.95	1.06 (0.90, 1.26)	0.45

* Adjusted for child's age, sex, race or ethnicity, urinary creatinine and serum cotinine concentrations, body mass index, parent's education status, and number of sealants (for restoration estimates) or restorations (for sealant estimates).