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Effects of Enamel Fluorosis and Dental Caries on Quality of Life

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ABSTRACT

The objectives of this study were to determine the impact of enamel fluorosis and dental caries on oral health–related quality of life (OHRQoL) in North Carolina schoolchildren and their families. Students (n = 7,686) enrolled in 398 classrooms in grades K-12 were recruited for a onetime survey. Parents of students in grades K-3 and 4-12 completed the Early Childhood Oral Health Impact Scale (ECOHIS) and Family Impact Scale (FIS), respectively. Students in grades 4-12 completed the Child Perceptions Questionnaire (CPQ_{8-10} in grades 4-5; CPQ_{11-14} in grades 6-12). All students were examined for fluorosis (Dean's index) and caries experience ($d_{2-3}fs$ or $D_{2-3}MFS$ indices). OHRQoL scores (sum response codes) were analyzed for their association with fluorosis categories and sum of $d_{2-3}fs$ and $D_{2-3}MFS$ according to ordinary least squares regression with SAS procedures for multiple imputation and analysis of complex survey data. Differences in OHRQoL scores were evaluated against statistical and minimal important difference (MID) thresholds. Of 5,484 examined students, 71.8% had no fluorosis; 24.4%, questionable to very mild fluorosis; and 3.7%, mild, moderate, or severe fluorosis. Caries categories were as follows: none (43.1%), low (28.6%), and moderate to high (28.2%). No associations between fluorosis and any OHRQoL scales met statistical or MID thresholds. The difference (5.8 points) in unadjusted mean ECOHIS scores for the no-caries and moderate-to-high caries groups exceeded the MID estimate (2.7 points) for that scale. The difference in mean FIS scores (1.5 points) for the no-caries and moderate-to-high groups exceeded the MID value (1.2 points). The sum of $d_{2-3}fs$ and $D_{2-3}MFS$ scores was positively associated with CPQ_{11-14} (B = 0.240, $p < .001$), ECOHIS (B = 0.252, $p \leq .001$), and FIS (B = 0.096, $p \leq .01$) scores in ordinary least squares regression models. A child's caries experience negatively affects OHRQoL, while fluorosis has little impact.

KEY WORDS: children, adolescents, oral health-related quality of life, minimal important difference, fluoride risks, fluoride benefits.

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INTRODUCTION

Fluoride is the most effective and frequently used strategy for the prevention of dental caries (Kumar and Moss, 2008). Drinking water, dentifrices, mouth rinses, dietary supplements, and professional products all are used to deliver fluoride to the public. Exposures to these multiple sources of fluoride have led to notable improvements in the oral health of some segments of the U.S. population (Dye & Thornton-Evans, 2010) but also to an increase in enamel fluorosis (Leverett, 1982). The prevalence of decayed, missing, or filled teeth in the United States decreased from 57.3% in 12- to 15-year-old children in 1988-1994 to 50.6% in 1999-2004 (Dye *et al.*, 2007), while enamel fluorosis increased from 22.6% in 1986-1987 in the same-aged child to 40.1% in 1999-2004 (Beltrán-Aguilar *et al.*, 2010).

A number of organizations have published guidelines for fluoride use since the increase in enamel fluorosis was first observed more than 30 yr ago (Centers for Disease Control and Prevention, 2001; Hagan *et al.*, 2008; American Dental Association Council on Scientific Affairs, 2014). These guidelines seek to balance the benefits of caries prevention with the risks of fluorosis by targeting optimal fluoride exposure levels. Professional guidelines for fluoride use are based mostly on the biological consequences of fluoride exposures—namely, dental caries and enamel fluorosis. It also is important to consider the effects of these 2 clinical conditions on the psychosocial well-being of children and their families (Chankanka *et al.*, 2010).

Oral conditions can have a number of consequences such as pain, difficulty in chewing, embarrassment, and economic hardship (U.S. Department of Health and Human Services, 2000). These consequences have a negative impact on oral health–related quality of life (OHRQoL) when they are judged by the affected person to be of sufficient frequency, severity, or duration to be bothersome to valued aspects of their daily lives (Sischo and Broder, 2011). Most studies find that dental caries has a negative impact on OHRQoL, particularly when it is moderate to severe, goes untreated, or results in missing teeth (Barbosa & Gavião, 2008). Studies on the association between fluorosis and OHRQoL are not as numerous as for caries. In their review of 8 quantitative studies, Chankanka *et al.* (2010) concluded that severe fluorosis has negative impacts on OHRQoL but very mild to mild fluorosis has either no effect or a positive one. A qualitative study found that enamel defects bother adolescents during social interactions, but the importance of appearance and approval from others in their senses of self has more impact than the severity of the defects themselves (Marshman *et al.*, 2009).

Only a few studies have simultaneously considered the influence of dental caries and enamel fluorosis on OHRQoL. The purpose of this study is to

determine the association of enamel fluorosis and dental caries in school-aged children in North Carolina with their OHRQoL and that of their families. Our goal is to determine the relative impacts of these 2 conditions on the lives of children and provide a psychosocial perspective on the risks and benefits of population-level fluoride exposures.

MATERIALS & METHODS

Overview of Study Design

This study provides an analysis of information collected as part of a cross-sectional oral health survey of a probability sample of students and their parents conducted in North Carolina during the 2003-2004 school year. Parents of students in grades K-12 and students in grades 4-12 completed questionnaires assessing OHRQoL. Parent questionnaires were available in English and Spanish. All students received a clinical examination for enamel fluorosis and dental caries by dentists trained in survey techniques. This analysis investigates the impact of fluorosis and dental caries experience in children on OHRQoL as reported by the parent and the child. Written informed consent was provided by parents of children who participated in the survey. Approval for the study was provided by the North Carolina Division of Public Health and the University of North Carolina at Chapel Hill Institutional Review Boards for the Health and Safety of Human Subjects.

Sample Design and Selection

A probability sample of students in grades K-12 was selected from a statewide sample frame consisting of 1.2 million students. To ensure statewide representation of important population subgroups and a sufficient sample so that the primary goals of the parent study would be met, the sample frame was stratified into 16 strata as follows: grade (K-3, 4-5, 6-12), fluoride mouth rinse schools in 2002 for grades K-5, high-risk schools (with 40% or greater participating in the National School Lunch Program), and counties with a 6% or greater Latino population. Classroom units were selected from each stratum with known probability based on the stratified cluster design, which was estimated to provide about 8,000 student-parent dyads from 398 classrooms eligible for enrollment in the study.

Parent and Student Questionnaires

The 13-item Early Childhood Oral Health Impact Scale (ECOHIS) was used to assess OHRQoL for parents of students in grades K-3 (Pahel *et al.*, 2007) and the 14-item Family Impact Scale (FIS) for parents of students in other grades (Locker *et al.*, 2002). Self-perceptions of OHRQoL for students in grades 4 -12 were assessed *via* the Child Perceptions Questionnaire (CPQ)—the 25-item CPQ_{8-10} (Jokovic *et al.*, 2004) for grades 4-5 and the 37-item CPQ_{11-14} (Jokovic *et al.*, 2002) for grades 6-12. Five-level responses to items in each of the four scales were coded 0-4 and summed to provide an overall count of impacts.

The parent questionnaire also solicited information in a number of other domains, including sociodemographic characteristics of the child and family, dental knowledge and beliefs, access to dental care, and preventive exposures. Covariates were selected for the present study based on their potential for imbalances across fluorosis or caries levels and their associations with OHRQoL measures using the Wilson and Cleary (1995) model as a guide for initial selection. This model links biological factors to their functional and psychosocial outcomes, useful for studying fluorosis because it can affect appearance and have negative psychosocial effects such as embarrassment. This model also assigns a role to both personal and environmental characteristics in quality of life and thus provides a guide for selection of confounders.

Clinical Assessments

All students received a clinical examination for enamel fluorosis and caries experience by one of nine dentists trained and standardized in survey techniques. Fluorosis was measured with Dean's (1942) classification system. Anterior (canine to canine) and posterior (premolar to second molar) permanent teeth were separately assigned a single fluorosis status score (normal, questionable, very mild, mild, moderate, or severe). Classification of each group of teeth was based on the 2 teeth most affected by fluorosis within that group or the lesser-involved tooth if 2 teeth were not equally affected.

The caries status of each tooth surface was recorded according to Radike's (1968) criteria (after drying with compressed air) and used to compute index scores for primary (d_{2-3}fs) and permanent (D_{2-3}MFS) teeth. A distinction was made in these assessments between cavitated (d_{2-3}, D_{2-3}) and noncavitated (d_1, D_1) lesions according to criteria for noncavitated lesions developed for the Iowa Fluoride Study (Warren *et al.*, 2002).

Data Analysis

The analytic sample was limited to those participants with caries and anterior fluorosis scores. Population estimates for the prevalence, extent, and severity of the 2 clinical conditions and OHRQoL were determined with PROC SURVEYFREQ and SURVEYMEANS in SAS version 9.2 to properly account for the complex survey design and to produce correct variance estimates.

Differences in OHRQoL scores and covariates (child ever had dental injury, treatment needed, unmet demand, dental home, age, sex, race/ethnicity, percentage poverty level, county urbanicity, and parental education) were accessed according to categories derived from grouping fluorosis severity scores (unaffected; questionable, very mild; mild, moderate, or severe) and the sum of d_{2-3}fs and D_{2-3}MFS scores (none = 0, low = 1-4, moderate to high ≥ 5) per analysis of variance in PROC SURVEYREG. In addition to statistical significance based on the standard criterion of $p < .05$, we examined practical significance of impacts by calculating minimal important differences (MIDs) using both distribution- and anchor-based approaches (Ellis, 2010; Taskos *et al.*, 2011; Masood *et al.*, 2012; see appendix).

Between 0% and 2.3% of values were missing for all the covariates except for parent education and poverty status, which were missing 6.5% and 24.0% of responses, respectively. We used multiple imputation of complex survey data (Fully Conditional Specification method in SAS PROC MI) to create

20 data sets with imputed values for all covariates with missing values (Berglund, 2010). The independent associations of fluorosis categories and caries index scores with OHRQoL scores were determined *via* ordinary least squares regression in SAS PROC SURVEYREG to account for the complex survey design, while controlling for covariates, and were combined through SAS PROC MIANALYZE to provide final parameter estimates for the regression models. We used a backward stepwise regression approach to develop a parsimonious model in which fluorosis and caries were forced into the model but other variables were omitted if not statistically significant at a level of $p < 0.1$. Both clinical conditions were considered simultaneously in the regression models because of the potential for one condition to confound the relationship of the other condition with the outcome. We limited all analyses to anterior fluorosis scores because of the similarity of results between anterior and posterior teeth and our desire to determine the impact of fluorosis involving the teeth with the most obvious esthetic effects.

RESULTS

Of the 7,686 students included in the sample, clinical or questionnaire information was available for 6,034 (response rate = 78.5%). Of these, 4,584 (59.6%) were included in the analytic sample because they had dental caries index scores, anterior fluorosis assessments, and parent questionnaires. The majority of the students were white (61.1%), came from families at or below 200% of the federal poverty level (56.0%), and had parent respondents with at least a high school education (89.3%). Mean age of the student sample was 11.6 yr (grades K-3 = 7.4 yr; grades 4-5 = 10.0 yr; grades 6-12 = 14.2 yr).

For this analytic sample, 71.8% of the children were unaffected by fluorosis; 24.4% had questionable (15.1%) or very mild fluorosis (9.3%); and 3.7% had mild (2.8%), moderate (0.7%), or severe (0.2%) fluorosis (Table 1). The distribution of the sample by caries categories was as follows: 43.1% with no caries, 28.6% with low caries, and 28.2% with moderate to high caries (Table 2; see Appendix Table 1 for detailed characteristics of clinical measures).

The variation in overall OHRQoL scores and covariates according to fluorosis and caries categories is presented in Tables 1 and 2, respectively (see Appendix Tables 2-4 for detailed information about OHRQoL scores). The mean OHRQoL scores for all scales except CPQ_{8-10} increased as the severity of fluorosis increased, but none of the differences were statistically significant (p values > 0.1) and all effect sizes were trivial (eta^2 values < 0.01). Overall scores for all the OHRQoL scales except CPQ_{8-10} were associated with caries experience at a statistically significant level. Effect sizes for the association of caries categories with FIS ($eta^2 = 0.01$) and ECOHIS ($eta^2 = 0.14$) scores suggest a small and large effect, respectively. Differences in points by caries categories for both scales also exceed the MIDs determined by using external anchors, particularly the none versus moderate-to-high caries categories (see Appendix Tables 5-9 for details).

Results of the 4 regression models (Table 3) generally confirm findings about the independent impacts of enamel fluorosis and caries experience on OHRQoL. The coefficients for the analysis of OHRQoL were inconsistent in direction and nonsignificant for the fluorosis categories (compared to none) in all 4 models. However, the sum of $d_{2-3}fs$ and $D_{2-3}MFS$ scores was positively and strongly associated with CPQ_{11-14} ($B = 0.240$, $p < .001$), ECOHIS ($B = 0.252$, $p \leq .001$), and FIS ($B = 0.096$, $p < .01$). CPQ_{8-10} values did not differ by categories of caries severity.

DISCUSSION

The primary finding in this study is that the impacts of enamel fluorosis and dental caries on OHRQoL differ markedly from each other. Fluorosis was not associated with the OHRQoL of children or their families at a statistically significant level in any of the 4 regression models. Conversely, caries experience was associated with self-perceived OHRQoL impacts for older children and child-related OHRQoL impacts as perceived by parents of children of all ages. The impact of caries affecting students in kindergarten through third grade was particularly large. Those students with dental caries classified as moderate to severe had a mean ECOHIS score 3.2 times greater than those with no caries experience (7.8 *vs.* 2.4, respectively). The effect size was large with the estimate being 5.3 times its standard deviation (Hedges' $g = 5.27$).

Differences in OHRQoL scores that represent what is important to the public can be different from those that reach statistical significance, particularly in an epidemiologic study such as this one with large sample sizes and small variance estimates. We determined MID estimates to help interpret the practical significance of OHRQoL scores. We found that differences in OHRQoL scores by fluorosis categories did not exceed MID thresholds for any of the 4 scales, while they did for parent-reported impacts of moderate to severe caries compared to none. The large unadjusted difference of 5.4 in mean ECOHIS scores for those with no caries compared to those with moderate to severe caries exceeded the MID estimate of 2.7 for that scale. The mean FIS score was 3.3 for the severe category, compared to 1.8 for those with none—the difference of 1.5 points exceeding the MID value of 1.2 calculated for this scale. Few studies have provided MID estimates for OHRQoL for children, adolescents, and their families, particularly with the scales used in our study (Foster Page *et al.*, 2010; Masood *et al.*, 2012). Interpretation of impacts from dental conditions can be improved if studies include MID estimates for comparison purposes.

We are aware of 5 other research teams that used a validated scale and multivariate analysis to simultaneously consider the association of caries and fluorosis with OHRQoL (Robinson *et al.*, 2005; Do and Spencer, 2007; Locker, 2007; Peres *et al.*, 2009; Aguilar-Diaz *et al.*, 2011). Our findings for caries are in general agreement with these other studies, none of which were conducted in the United States. They show that dental caries has a negative impact on OHRQoL, particularly when caries experience is severe and treatment rates are low. Findings related to enamel fluorosis and OHRQoL are inconsistent in these 5 studies. At a prevalence level for fluorosis found in most populations, the impact on OHRQoL was weakly negative, positive, or nonexistent. The 1 study of the 5 conducted in a high-fluoride

Table 1. Mean Scores for Oral Health–related Quality of Life and Sample Characteristics by Enamel Fluorosis Category

Variable	Sample Size Unweighted, *n* (%)[a]	Enamel Fluorosis in Anterior Permanent Teeth[b]		
		Unaffected	Questionable, Very Mild	Mild, Moderate, Severe
Dependent variable: quality of life (mean score)[c]				
$CPQ_{8\text{-}10}$	965	13.2	12.9	11.5
$CPQ_{11\text{-}14}$	2,401	21.2	21.5	22.1
ECOHIS	1,130	4.7	5.2	5.7
FIS	3,105	2.4	2.5	3.2
Covariates (%)				
Needs treatment				
Yes	2,334 (51.2)	51.3	51.9	55.7
No/not sure	2,219 (48.3)	48.7	48.0	44.2
Ever injured				
Yes	508 (11.2)	11.4	10.7	12.0
No/don't recall	4,025 (88.7)	88.6	89.2	87.9
Unmet demand				
Yes	1,183 (26.4)	27.6	26.3	30.7
No/don't recall	3,291 (73.5)	72.3	73.6	69.2
Dental home				
Yes	3,386 (74.0)	73.5	75.3	73.2
No	1,163 (25.9)	26.4	24.6	26.7
Sex				
Male	2,150 (46.9)	46.9	45.8	47.3
Female	2,434 (53.1)	53.8	54.1	52.6
Age, yr				
5-7	540 (11.7)	11.4	9.5	5.6
8-10	1,315 (28.6)	24.9	25.8	21.5
≥11	2,728 (59.5)	63.6	64.6	72.8
Race and ethnicity				
White, non-Hispanic	2,753 (61.1)	60.9	64.0	62.1
Other, non-Hispanic	1,391 (30.8)	32.8	30.1	31.0
Hispanic	362 (8.0)	6.2	5.7	6.8
Poverty status[d]				
≤100%	945 (27.1)	26.7	27.0	26.4
101%-200%	1,008 (28.9)	29.7	28.1	32.2
201%-300%	500 (14.3)	14.7	14.1	19.1
301%-400%	264 (7.5)	8.1	7.0	6.9
>400%	766 (21.9)	20.6	23.6	15.2
Urbanicity category				
Metro	2,672 (58.2)	58.2	60.2	51.0
Nonmetro, adjacent	1,703 (37.1)	34.7	35.8	47.3
Nonmetro, nonadjacent	209 (4.5)	6.9	3.9	1.5*
Parents' education				
<High school	453 (10.5)	9.7	9.8	10.7
High school graduate	1,113 (25.9)	26.5	27.1	27.4
College	2,717 (63.4)	63.7	63.0	61.8

$CPQ_{8\text{-}10}$, Child Perceptions Questionnaire, grades 4-5; $CPQ_{11\text{-}14}$, Child Perceptions Questionnaire, grades 6-12; ECOHIS, Early Childhood Oral Health Impact Scale; FIS, Family Impact Scale.

Standard error of measurement for overall scales: $CPQ_{8\text{-}10}$: 4.44 ± 13.2; $CPQ_{11\text{-}14}$: 4.6 ± 16.0; ECOHIS: 2.7 ± 6.3); FIS: 1.2 ± 5.0); *p* values derived from analysis of variance for continuous variables and chi-square test for categorical variables based on PROC SURVEYFREQ and SURVEYMEANS.

*$p \leq .01$.

[a]$n = 4,584$. Column contains unweighted sample sizes and percentage distributions. All other numbers in the table (counts, means, percentages, *p* values) are calculated considering the complex sample design. Missing values are not imputed.

[b]Unaffected: $n = 3,316$ (71.8%); questionable, very mild: $n = 1,108$ (24.4%); mild, moderate, severe: $n = 160$ (3.7%).

[c]Average difference between adjacent levels and eta^2 value for fluorosis categories. $CPQ_{8\text{-}10}$: 0.24, <0.01; $CPQ_{11\text{-}14}$: 0.89, <0.01; ECOHIS: 0.76, <0.01; FIS: 0.34, <0.01.

[d]Percent of federal poverty level.

Table 2. Mean Scores for Oral Health–related Quality of Life and Sample Characteristics by Dental Caries Category

		Dental Caries Experience in Primary and Permanent Teeth[b]		
Variable	Sample Size Unweighted, *n* (%)[a]	None	Low	Moderate, High
Dependent variable: quality of life (mean)[c]				
$CPQ_{8\text{-}10}$	965	12.9	13.3	13.0
$CPQ_{11\text{-}14}$	2,401	20.3	21.7	22.6*
ECOHIS	1,130	2.4	4.0	7.8***
FIS	3,105	1.8	2.7	3.3***
Covariates (%)				
Needs treatment				
Yes	2,334 (51.2)	44.9	52.6	60.9
No/ Not sure	2,219 (48.3)	55.0	47.3	39.0***
Ever injured				
Yes	508 (11.2)	9.2	13.5	11.9
No/ Don't recall	4,025 (88.7)	90.7	86.4	88.0**
Unmet demand				
Yes	1,183 (26.4)	23.5	29.3	31.5
No/don't recall	3,291 (73.5)	76.4	70.6	68.4***
Dental home				
Yes	3,386 (74.0)	74.2	72.1	75.4
No	1,163 (25.9)	25.7	27.8	24.5
Sex				
Male	2,150 (46.9)	47.7	45.1	44.6
Female	2,434 (53.1)	52.2	54.8	55.3
Age, yr				
5-7	540 (11.7)	11.1	8.3	12.5
8-10	1,315 (28.6)	20.9	21.6	34.5
≥11	2,728 (59.5)	67.8	70.0	52.8***
Race and ethnicity				
White, non-Hispanic	2,753 (61.1)	64.8	61.4	57.2
Other, non-Hispanic	1,391 (30.8)	29.3	32.8	35.7
Hispanic	362 (8.0)	5.8	5.7	7.0**
Poverty status[d]				
≤100%	945 (27.1)	20.5	28.9	34.3
101%-200%	1,008 (28.9)	28.1	27.6	33.2
201%-300%	500 (14.3)	15.8	15.7	12.1
301%-400%	264 (7.5)	9.1	7.4	6.2
>400%	766 (21.9)	26.3	20.3	14.1***
Urbanicity category				
Metro	2,672 (58.2)	61.5	56.3	55.8
Nonmetro, adjacent	1,703 (37.1)	32.3	38.1	37.7
Nonmetro, nonadjacent	209 (4.5)	6.0	5.5	6.4
Parents' education				
<High school	453 (10.5)	7.9	9.1	13.3
High school graduate	1,113 (25.9)	22.8	28.2	31.0
College	2,717 (63.4)	69.2	62.5	55.6***

$CPQ_{8\text{-}10}$, Child Perceptions Questionnaire, grades 4-5; $CPQ_{11\text{-}14}$, Child Perceptions Questionnaire, grades 6-12; ECOHIS, Early Childhood Oral Health Impact Scale; FIS, Family Impact Scale.

p values derived from analysis of variance for continuous variables and chi-square test for categorical variables based on PROC SURVEYFREQ and SURVEYMEANS.

*$p \leq .05$. **$p \leq .01$. ***$p \leq .001$.

[a]$n = 4{,}584$. Column contains unweighted sample sizes and percentage distributions. All other numbers in the table (counts, means, percentages, *p* values) are calculated considering the complex sample design. Missing values are not imputed.

[b]None: $n = 1{,}972$ (43.1%); low: $n = 1{,}284$ (28.6%); moderate, high: $n = 1{,}328$ (28.2%).

[c]Average difference between adjacent levels and eta^2 value for caries categories. $CPQ_{8\text{-}10}$: 0.50, <0.01; $CPQ_{11\text{-}14}$: 1.09, <0.01; ECOHIS: 2.63, 0.14; FIS: 0.63, 0.01.

[d]Percent of federal poverty level.

Table 3. Ordinary Least Squares Linear Regression of Enamel Fluorosis in Anterior Teeth, Dental Caries Indices, and Other Covariates on Mean Scores for Oral Health–related Quality of Life

Variables	$CPQ_{8\text{-}10}$[a]	$CPQ_{11\text{-}14}$[b]	ECOHIS[c]	FIS[d]
Quality-of-life mean score (SE)	13.0 (0.591)	21.3 (0.469)	4.87 (0.207)	2.52 (0.120)
Fluorosis (ant)				
Unaffected	Reference	Reference	Reference	Reference
Questionable, very mild	0.373 (0.912)	–0.079 (0.947)	0.248 (0.443)	0.179 (0.215)
Mild, moderate, severe	–1.085 (1.754)	–0.726 (1.746)	0.438 (0.925)	0.625 (0.666)
Caries experience				
dfs + DMFS	0.038 (0.076)	0.240 (0.085)***	0.252 (0.030)***	0.096 (0.032)**
Need treatment				
Yes (*vs.* no/not sure)	2.319 (0.754)**	2.006 (0.746)**	0.849 (0.402)*	0.868 (0.193)***
Ever injured				
Yes (*vs.* no/don't recall)	—	3.510 (1.331)**	2.936 (0.789)***	1.673 (0.383)***
Unmet Demand				
Yes (*vs.* no/don't recall)	1.940 (1.277)	2.654 (0.935)**	3.101 (0.598)***	2.473 (0.246)***
Dental home				
Yes (*vs.* no)	—	–2.485 (1.004)*	0.811 (0.481)	—
Sex (male)	—	–2.898 (0.748)***	—	–0.377 (0.192)*
Age (yr)	—	–1.171 (0.205)***	0.446 (0.181)*	—
Race and ethnicity				
Hispanic	Reference	—	—	—
White, non-Hispanic	0.952 (1.537)	—	—	—
Other, non-Hispanic	3.444 (1.583)*	—	—	—
Poverty status[e]				
≤100%	Reference	—	Reference	Reference
101%-200%	–2.419 (1.629)	—	0.138 (0.631)	–0.844 (0.338)*
201%-300%	–3.185 (2.122)	—	–0.558 (0.587)	–1.509 (0.326)**
301%-400%	–3.958 (2.016)*	—	–0.840 (0.687)	–1.786 (0.342)***
>400%	–5.654 (1.849)**	—	–0.964 (0.630)	–1.736 (0.309)***
County urbanicity				
Nonmetro, nonadjacent	—	Reference	Reference	—
Nonmetro, adjacent	—	2.743 (1.405)	–1.295 (1.023)	—
Metro	—	3.649 (1.380)**	–1.787 (0.987)	—
Parents education				
<High school	Reference	Reference	—	Reference
High school graduate	1.327 (1.695)	–2.035 (1.409)	—	–0.796 (0.519)
College	2.445 (1.734)	–2.003 (1.364)	—	–0.591 (0.520)

ant, anterior teeth; dfs, decayed, filled primary tooth surfaces; DMFS, decayed, missing, filled permanent tooth surfaces.
Dashes (—) indicate that variables were not included in final model because p value > .1.
*$p \leq .05$. **$p \leq .01$. ***$p \leq .001$.
All models estimated according to procedures for multiple imputation of complex survey data.
[a]Child Perceptions Questionnaire, grades 4-5 (n = 966).
[b]Child Perceptions Questionnaire, grades 6-12 (n = 2,406).
[c]Early Childhood Oral Health Impact Scale (n = 1,130).
[d]Family Impact Scale (n = 3,221).
[e]Percent of federal poverty level.

area of a Mexican state (drinking water fluoride concentration = 3.38 ppm) found a strong impact of moderate to severe fluorosis on OHRQoL in eight- to ten-year-old children. Our study of children, representative of a broad age range and with both child and parent perspectives, adds to the evidence about the impacts of fluorosis.

The widespread prevalence of dental caries is well documented. This study provided first-time estimates for the prevalence of enamel fluorosis among all school-aged children in North Carolina. The prevalence of any fluorosis was 28.1% based on our analytic definition that included the "questionable" category and only 12.9% when defined by the convention used in national surveys, which omits that category (Dean, 1942). Both these estimates are lower than national estimates of 33.4% for children 6 to 11 yr of age and 40.6% for those 12 to 15 yr of age from about the same period (Beltrán-Aguilar *et al.*, 2010). The prevalence of fluorosis at a level considered by Chankanka *et al.* (2010) to be noticeable by the public in our sample was only 3.7%, compared to 12.2% for 12- to 15-yr-olds nationally. The prevalence of dental caries was twice that of fluorosis (56.8% *vs.* 28.1%), and what we classified as moderate to severe

caries occurred 7.6 times more often (28.2% *vs.* 3.7%) than the most severe category of fluorosis. More children are affected by dental caries than with fluorosis, and it has more negative effects on OHRQoL.

The high prevalence of dental caries compared with enamel fluorosis and its negative impacts on OHRQoL have implications for developing strategies to improve population oral health. This study suggests that if a person-centered approach is used in helping to establish policies for optimal fluoride exposures, then we would weigh a reduction in the risks for dental caries more than an increase in risks for fluorosis. Such an approach would favor less conservative dosage schedules. It would support, for example, the recent guidelines from the American Dental Association that recommend that all children have their teeth brushed with fluoridated toothpaste beginning as soon as the first tooth erupts (American Dental Association Council on Scientific Affairs, 2014). Individual perceptions of clinical conditions vary, however, and further study is needed to provide comprehensive information for a population-based risk assessment for fluoride exposure levels that includes a psychosocial perspective (Marshman *et al.*, 2009).

Strengths and Limitations

Results of this study are based on a large sample with a good response rate, representative of a statewide population of school children and their parents. Even with this large sample, the number of respondents with mild, moderate, or severe fluorosis was small, affecting the precision of estimates for the association between fluorosis in its severest forms and OHRQoL scores. Mean OHRQoL scores generally were larger in the most severe category compared with the other categories in the unadjusted analysis, but differences did not achieve statistical or practical significance.

The only condition other than fluorosis or caries that we controlled for in our analysis was dental injuries. The fluorosis-OHRQoL and caries-OHRQoL associations might be confounded by other unobserved clinical conditions, such as tooth exfoliation and eruption, malocclusion, and enamel defects other than fluorosis. Some of the domains in the OHRQoL scales might not be valid for measuring the impacts of fluorosis. Krisdapong *et al.* (2012) have dealt with this source of bias by querying respondents about the condition-specific source of impacts being reported.

OHRQoL scores reported by students in grades 4 and 5 using the $CPQ_{8\text{-}10}$ scale were unaffected by fluorosis or caries. These weak associations could be attributable to a number of factors, including the developmental stage of these children, a low prevalence of disease, low impacts of disease, access to treatment, or difficulties that young children might have in understanding and reporting oral health outcomes, some of which can lead to poorer psychometric properties for the $CPQ_{8\text{-}10}$ compared with the other scales (Jokovic *et al.*, 2004). The causal model for the relationship between clinical conditions and QoL is likely complex and can be affected by a number of individual and environmental characteristics (Wilson and Cleary, 1995; Barbosa and Gavião, 2008). We did not examine potential mediators or effect modifiers in this study, which might help clarify relationships.

CONCLUSIONS

Using a population- and person-centered perspective, we conclude that dental caries in school-aged children in North Carolina is a much bigger public health concern than enamel fluorosis. The prevalence of fluorosis is less than caries, and it had no impact on the OHRQoL of children or their families. Dental caries had a negative impact on OHRQoL for the majority of students and their families. The public appears to evaluate the practical significance of the biological risks and benefits of fluorides differently. MID estimates can help interpret the importance that the public places on fluorosis and caries and add an important perspective in establishing policy on population exposures to fluorides.

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