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Dental caries development among African-American children: results from a 4-year longitudinal study

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Abstract

Objective—To examine dental caries development and caries risk factors among preschool African-American children from low-income families in Detroit, Michigan over a four- year window.

Methods—Data came from a representative sample of 1,021 children (zero to five years) and their caregivers in Detroit. The baseline participants in 2002–03 (W1) were reexamined in 2004–05 (W2) and 2007 (W3). Caries was measured using the International Caries Detection and Assessment System. Bivariate and multivariate analyses for repeated data were conducted to explore associations between caries increment outcomes and demographics, access to dental care, oral health-related behaviors, and social and physical environments.

Results—The mean number of new NCCL (non-cavitated caries lesions) was 2.8 between W1 and W2 and 2.6 between W2 and W3, while the mean number of new CCL (cavitated caries lesions) was 2.0 and 2.0, respectively, during the same time periods. In younger children (< three years old in W1) higher number of new NCCL than new CCL were observed in both W1–W2 and W2–W3. The risk of new NCCL was associated with child's soda intake and caregiver's age. For the risk of new CCL, significant risk factors included baseline NCCL, baseline CCL, as well as child's age. Baseline caries and child's soda intake were also associated with the risk of developing new decayed, missing, and filled tooth surfaces.

Conclusions—Higher number of new NCCL relative to CCL was developed among low-income Africa-American children during early childhood. New caries development was associated with baseline caries and child's soda intake.

Keywords

epidemiology; dental caries; child; African Americans

INTRODUCTION

The risk of dental caries is disproportionately high among minority children or those from low-income families in the United States (1). Evidence shows that behavioral and parental characteristics are major contributors to disparities in early childhood caries, which refers to

Conflict of interest

None of the authors have any financial conflict of interest with this study.

a condition of one or more tooth surfaces with non-cavitated or cavitated lesions, fillings, or missing due to caries in the primary dentition among preschool children (3). Specifically, excess burden of caries among minority children from low-income families has been attributed to sugar-sweetened beverage consumption and caregiver's fatalistic belief (4). However, individual or parental characteristics have not fully explained inter-individual variability of new caries development, highlighting the importance of taking into account environmental characteristics as these may contribute to shaping individual risk factors and behaviors (4, 5, 6). For example, the Detroit Dental Health Project (DDHP) found that social and physical environments such as neighborhood disadvantage status, along with individual-level risk factors, significantly influenced the development of new dental caries among African-American children from low-income families (4).

Despite these recent advancements of understanding caries disparities and potential causes among children with high risk of caries, little has been studied regarding detailed descriptions of dental caries by types of carious lesions (cavitated versus non-cavitated lesions) and the effects of individual, behavioral, and environmental risk factors. Thus, the aim of this secondary analysis of data from DDHP was to examine associations between new caries development and various individual-level, family-level, and environmental risk factors over four years, expanding Ismail and colleagues' earlier findings based on two-year longitudinal data (4).

MATERIALS AND METHODS

Study Population

Data for this analysis were obtained from the DDHP, a longitudinal cohort study that was designed to investigate the oral health determinants of low-income African-American children and their caregivers. The study protocol was approved by the Institutional Review Board for Health Sciences at the University of Michigan and caregivers of all participants gave written consent for inclusion in this study.

The sampling design consisted of a stratified two-stage area probability sample of households from the 39 census tracts with the highest proportion of residents living below 200% of poverty in Detroit according to the 2000 United States Census. Power calculations indicated that a sample of 1,000 eligible children completing examinations would meet precision requirements for the project. To be eligible for the study households needed to comprise at least one caregiver of a child ages zero to five years. Among 1,386 eligible families 1,021 child-caregiver pairs came to a central facility in Detroit to complete dental examinations and face-to-face interviews in 2002–03 (response rate = 74%). Details of the sampling and data collection procedures have been described in previous reports (7). W1 participants were followed up in 2004–05 (W2) and 2007 (W3). Among these 77% (n=790) and 64% (n=654) returned to complete an interview and dental examinations in W2 and W3. No significant differences were found between caregivers and children who participated in the follow-up and those who dropped out in terms of dental caries and demographic characteristics.

Dental Caries Assessment

Four dentists with good to excellent reliability (kappa coefficients 0.59–0.82) assessed the W1 and W2 caries status of all tooth surfaces using the International Caries Detection and Assessment System (ICDAS) (8). Similar to W1 and W2, in W3, a new team of six dentists (except for two examiners from previous examinations) achieved good to excellent reliability (kappa coefficients 0.58–0.86), except for low reliability of two pairs of examiners. Training of examiners started with a two-week intensive review and repeat examinations followed by reliability assessments and reviews of findings throughout each data collection cycle. The “gold standard” was the same examiner throughout the study. The numbers of carious tooth surfaces in the primary dentition were counted for each child using the following categories: sound tooth surfaces (ICDAS 00, 10, 20), untreated non-cavitated lesions (NCCL; ICDAS 01, 11, 12, 21, 22), untreated cavitated lesions (CCL; ICDAS 03–06, 13–16, 23–26), filled lesions (ICDAS 30, 40, 50, 60, 70, 80), filled/NCCL (ICDAS 31, 32, 41, 42, 51, 52, 61, 62, 71, 72, 81, 82), filled/CCL (ICDAS 33–36, 43–46, 53–56, 63–66, 73–76, 83–86), and missing tooth surfaces due to caries (ICDAS 97). We created two count measures of new carious lesions (“new NCCL”, “new CCL”) to capture new development of NCCL and CCL in the primary dentition. Along with these two measures, to account for plausible biological reversals and reduce bias due to examiners’ misclassification, we created two summary measures of increments of caries (“new d₁₂mfs”, which captures new NCCL and new CCL and, “new d₂mfs”, which captures new CCL only) based on the ICDAS transition matrix. Details of this scoring system have been described in a previous report (9). Because there were three data collections with two-year intervals, each child had two repeated count measures of new carious lesions (e.g., new NCCL in W1–W2, new NCCL in W2–W3). Due to a majority of children without permanent teeth at W1, we only focused on the primary dentition in this analysis.

It is well established that dental caries is determined by biological, behavioral, and environmental factors over the life course (3). To capture this complex mechanism, we selected risk factors representing five major dimensions that have been related with dental caries, including demographic characteristics, access to dental care, oral health related behaviors, social environments, and physical environments. We further refined our selection by only including those significantly associated with dental caries among low-income African-American preschool children in previous studies (4, 6).

Demographic Characteristics

The study included information on household size including children (two, three to four, five or higher), age (child and caregiver), sex (child), annual household income (less than \$10,000, \$10,000 or higher), caregiver’s highest level of education (less than high school degree, high school degree, some college or higher), and caregiver’s full-time employment (yes/no).

Access to Dental Care

The study included an indicator of the current status of dental insurance (yes/no), which was reported by caregivers.

Oral Health Related-Behavioral Characteristics

Risk behaviors associated with dental caries included child's soda intake, caregiver's smoking status, and oral health fatalism at baseline. Child's carbonated sugary drink (soda) intake information during the preceding week was based on caregiver's response to Block's Kids Food Frequency Questionnaire. Weekly frequencies of soda intake were grouped into two categories (yes, no). Caregivers who reported smoking ≥ 100 cigarettes in their life and currently smoke were defined as current smokers, whereas those who have never smoked or smoked < 100 cigarettes in their life were considered as non-current smokers. Oral health fatalism was measured by asking the caregivers whether they agree or disagree with a statement that "most children eventually develop dental cavities" (10). The answers were grouped "high" (neutral, agreed and strongly agreed) and "low" (disagree and strongly disagree).

Physical and Social Environments

A sound housing condition was assessed by asking whether there were any cracks on the wall or paints peeling off walls or pipes. Social support was assessed by five questions assessing caregivers' perception of the availability (rated as yes/no) of someone they could count on to run errands, lend money, offer encouragement and reassurance, supervise their children, and lend car or offer a ride if needed. Caregivers who responded "yes" to all five areas for social support were considered having social support.

Statistical Analysis

Descriptive analysis was first conducted to summarize characteristics of the study population and new development of caries in W1–W2 as well as W2–W3. Mean numbers of new dental caries lesions were calculated for each category of the selected risk factors to examine bivariate associations. Lastly, multivariate regression analyses for repeated data of new dental caries were conducted to examine these associations while controlling for potential confounders. Because data were collected repeatedly at three time points over four years, negative binomial regression models took into account correlated data within each child (i.e., new caries in W1–W2, new caries in W2–W3) using Generalized Equation Estimation method and AR(1) covariate structure. Statistical significance of the associations was evaluated at $p < 0.05$.

All statistical analyses except for multivariate regression were conducted using STATA version 10 software to account for the clustering effect due to the complex sample design (11). For regression analyses, we used jackknife repeated replication method to simultaneously account for the complex sample design and repeated data within child. All analyses were adjusted with weights developed to account for unequal selection probabilities and differential non-response. A small number of missing values in risk factors (less than 4%) were imputed using the *IVEware* software (12).

RESULTS

Characteristics of the Study Population

Age and sex of children who participated in W1–W2 and W2–W3 data collections were almost evenly distributed (Table 1). A majority of caregivers were less than 34 years old and did not work full-time. Almost half reported that their annual household income was less than \$10,000 and they did not complete high school education. A majority of households consisted of more than three individuals and had dental insurance. Most caregivers held a fatalistic belief that their children eventually would develop caries, while almost half of children had soda consumption. About 60% of caregivers did not smoke at the time of the survey, and reported a good housing condition and availability of support from families and neighbors in both institutional and emotional needs. These characteristics remained consistent among those who participated in both W2 and W3 surveys, except for dental insurance. Percentage of caregivers with dental insurance decreased in W2, reflecting dental insurance coverage (mostly Medicaid) disruptions in these low-income families.

New NCCL and new CCL

The mean number of new NCCL was 2.8 between W1 and W2 and 2.6 between W2 and W3, while the mean number of new CCL was 2.0 and 2.0, respectively, during the same time period. According to the bivariate analyses, new NCCL did not vary by caries risk factors (Table 2). On the other hand, new CCL was associated with household income, caregiver's smoking status, child's sex, and child's soda consumption.

Multivariate Regression Analyses

Table 3 shows that child's soda intake and caregiver's age were significantly associated with the risk of developing new NCCL after accounting for baseline caries, potential confounders, and clustering due to repeated measures (Model 1); however, only baseline caries was significantly associated with the high risk of developing new CCL (Model 2). As seen in Table 4, child's soda intake and caregiver's age were significantly associated with a high risk of new $d_{12}mfs$. Similar to the model for new CCL, none of the risk factors except for baseline caries were associated with risk of developing new d_2mfs . Child's age was associated with lower risk of caries development, implying that older children had lower chances to develop new caries in the primary dentition due to natural tooth loss.

DISCUSSION

This large epidemiologic study found that dental caries in the primary dentition was developed during a relatively short time period among low-income African-American children, which is consistent with previous reports about rapid caries progression in the primary dentition (13, 14). Adjusting for baseline caries, demographic and neighborhood characteristics, child's soda consumption and baseline caries were significant risk factors of caries increments. In particular, soda consumption was associated with increased risk of early caries development (i.e., new non-cavitated lesions), while baseline caries was a risk factor of developing more severe caries (i.e., new cavitated lesions).

We observed that low-income African-American children from Detroit were in considerable need of treatment to restore cavitated lesions. As priority on preventive and non-invasive treatment is the principle of pediatric dental care today, our findings suggest that preschool children should be monitored frequently in order to avoid restorations (15), particularly in light of the fact that restorative treatment at an early age is a risk factor for dental anxiety disorders later in life (16) and that untreated cavitated lesions and their consequences negatively influence children's quality of life (17).

This longitudinal study confirms the existing evidence that child's soda consumption is a risk factor of early childhood caries among low-income African American preschool children (4, 6). In particular, as seen in the previous studies (18–20), soda consumption was associated with the risk of developing new NCCL and CCL together, whereas the relative risk for new CCL only was insignificant. It implies that children with high soda consumption are more susceptible with developing early lesions compared with those with low consumers, but risk of progression to CCL may not be differential between two groups.

Despite widespread fluoride availability in this community, the relationship between soda consumption and caries development continues and restricting sugar intake remains key challenge for caries prevention. Although modifying a particular behavior and belief may be difficult, efforts directed to a broad context that shape behaviors and belief system should be considered as an early childhood caries intervention. One possibility is to promote resilient parenting, which exerts positive influences on child's health despite material deprivation. As seen in the finding that capacity for resilient parenting was associated with low risk of caries development, persistent low soda consumption, and healthy weight management over four years (21, 22), addressing individual and environmental factors for resilient parenting (nonsmoking, no depressive symptoms, religiosity, social support, and sound housing conditions) may be effective in modifying child's soda consumption and caregiver's fatalistic belief, which in turn reduces risk of early childhood caries. More specifically, as evidenced in the recent randomized control trial among parents of overweight children, programs to promote parental role modeling in healthy dietary behaviors can be considered as an effective means to reduce child's soda consumption (23). Another possibility is increasing awareness through public health information about deleterious effects of consuming sugar-sweetened drinks on the dentition, while providing healthy food and drink options in schools in these low income areas.

A main strength of the current study is that it is based on a large representative sample of African-American children and their caregivers – a group that has been traditionally understudied. The results provide reliable estimates of the caries levels of highly disadvantaged children and their caregivers in the city of Detroit. However, our study has some limitations. First, the study finding may not be generalizable to other ethnic groups from families with higher socioeconomic status, although the results provide a comprehensive epidemiologic profile of dental caries in very young African-American children. Second, because the current study uses observational data, we cannot rule out the possibility that the observed associations between risk factors and dental caries are biased due to unmeasured confounders. Third, reliability in W3 was not as good as that in W1 and

W2, which could lead to greater variance of W3 caries outcomes and lower likelihood to detect statistically significant associations.

In conclusion, this study shows a great need of dental care among African American children aged less than five years in Detroit, where new caries development was associated with demographic and behavioral characteristics. More resources are therefore needed for non-operative treatment and risk reduction strategies that contemplate not only the management of traditional biological and behavioral factors but also social determinants of health. These prevention efforts should be targeted to the whole population as the largest “burden of ill health comes more from the many who are exposed to low inconspicuous risk than from the few who face an obvious problem” (24, 25).

Acknowledgments

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Table 1

Demographic, behavioral, and environmental risk factors among low-income African American children, Detroit, Michigan, 2002–2007

	W1–W2 participants	W2–W3 participants
	N (%)	N (%)
Total number of pairs of child and caregiver	790	654
Child-level demographic characteristics		
Age at W1		
0	16%	15%
1	16%	16%
2	17%	17%
3	16%	17%
4	19%	18%
5	17%	17%
Gender		
Male	50%	50%
Female	50%	50%
Family-level demographic characteristics		
Caregiver's age		
18–24	33%	34%
25–34	48%	47%
35–44	13%	13%
45+	6%	6%
Caregiver's education		
Less than high school	46%	46%
High school degree	32%	33%
>High school degree	22%	22%
Annual household income		
<\$10K	45%	36%
\$10K	55%	64%
Caregiver's full-time employment		
Yes	32%	38%
No	68%	62%
Household size ^a		
Two	17%	17%
Three or four	49%	50%
Five or more	34%	33%
Access to dental care		
Dental insurance		
Yes	75%	43%
No	25%	57%
Oral health-related behaviors		

	W1–W2 participants	W2–W3 participants
	N (%)	N (%)
Child's soda intake		
Yes	57%	61%
No	43%	39%
Caregiver's oral health fatalistic belief		
Yes	77%	72%
No	23%	28%
Caregiver's current smoking status		
Yes	42%	35%
No	58%	65%
Physical and social environment		
Crack in a wall		
Yes	35%	37%
No	65%	63%
Social support in 5 areas		
Yes	66%	66%
No	34%	34%

Notes: we assessed all risk factors except for caregiver's education, household size, and crack in wall at each of three surveys. We measured these three measures only at W1.

^a Household members also include children.

Table 2

Mean number of new untreated non-cavitated (NCCL) and new untreated cavitated lesions (CCL) and standard errors (S.E.) in primary dentitions by demographic, behavioral, and environmental risk factors among low-income African American children, Detroit, Michigan, 2002–2007

	New NCCL			New CCL		
	W1 – W2	W2 – W3	W1 – W2	W1 – W2	W2 – W3	W1 – W2
Total	2.75 (0.06)	2.62 (0.06)	2.01 (0.08)	2.03 (0.26)		
Child-level demographic characteristics						
Age at baseline						
0	1.77 (0.24)	4.23 (0.72)	1.31 (0.27)	2.16 (0.32)		
1	3.49 (0.32)	3.41 (0.55)	2.04 (0.11)	2.61 (0.56)		
2	4.22 (0.41)	2.61 (0.34)	2.73 (0.27)	2.63 (0.09)		
3	2.91 (0.07)	2.08 (0.26)	1.80 (0.15)	1.50 (0.19)		
4	2.26 (0.22)	1.95 (0.22)	2.05 (0.34)	1.47 (0.30)		
5	1.88 (0.18)	1.40 (0.28)	2.08 (0.10)	1.84 (0.36)		
Gender						
Male	2.78 (0.02)	2.72 (0.24)	2.14 (0.06)	1.85 (0.28)		
Female	2.72 (0.10)	2.52 (0.12)	1.88 (0.22)	2.21 (0.25)		
Family-level demographic characteristics						
Caregiver's age						
18–24	2.60 (0.03)	2.75 (0.06)	2.23 (0.22)	1.99 (0.37)		
25–34	2.71 (0.02)	2.57 (0.03)	1.87 (0.23)	2.03 (0.30)		
35–44	3.04 (0.41)	2.64 (0.39)	2.01 (0.39)	1.86 (0.05)		
45+	3.27 (0.13)	2.27 (0.0005)	1.91 (0.16)	2.72 (0.19)		
Caregiver's education						
Less than high school	2.64 (0.003)	2.63 (0.22)	2.16 (0.08)	1.89 (0.29)		
High school degree	2.87 (0.26)	2.83 (0.37)	2.13 (0.48)	2.28 (0.31)		
>High school degree	2.80 (0.12)	2.28 (0.14)	1.51 (0.60)	1.97 (0.08)		
Annual household income						
<\$10K	2.82 (0.09)	2.53 (0.001)	1.96 (0.40)	2.36 (0.24)		
\$10K	2.69 (0.02)	2.68 (0.10)	2.05 (0.18)	1.82 (0.28)		
Caregiver's full-time employment						

	New NCCL			New CCL		
	W1 – W2	W2 – W3	W1 – W2	W1 – W2	W2 – W3	W1 – W2
Yes	2.82 (0.001)	2.78 (0.12)	1.74 (0.09)	1.83 (0.06)		
No	2.72 (0.09)	2.51 (0.03)	2.14 (0.05)	2.18 (0.46)		
Household size						
Two	2.64 (0.37)	2.68 (0.11)	1.96 (0.005)	1.96 (0.15)		
Three or four	2.70 (0.13)	2.65 (0.01)	1.89 (0.04)	1.98 (0.11)		
Five or more	2.88 (0.15)	2.56 (0.11)	2.21 (0.16)	2.15 (0.68)		
Access to dental care						
Dental insurance						
Yes	2.87 (0.13)	2.67 (0.13)	2.08 (0.05)	2.13 (0.29)		
No	2.39 (0.11)	2.59 (0.20)	1.81 (0.19)	1.96 (0.24)		
Behavioral characteristics						
Child's soda intake						
Yes	2.85 (0.29)	2.59 (0.01)	2.44 (0.04)	2.15 (0.30)		
No	2.60 (0.48)	2.45 (0.05)	1.44 (0.08)	1.72 (0.29)		
Oral health fatalistic belief						
Yes	2.80 (0.09)	2.64 (0.07)	2.22 (0.06)	2.17 (0.10)		
No	2.57 (0.05)	2.58 (0.37)	1.31 (0.48)	1.69 (0.60)		
Caregiver's current smoking status						
Yes	2.82 (0.33)	2.73 (0.15)	2.36 (0.04)	2.49 (0.30)		
No	2.70 (0.33)	2.56 (0.19)	1.76 (0.20)	1.76 (0.26)		
Physical and social environment						
Crack in a wall						
Yes	2.86 (0.09)	2.64 (0.30)	1.98 (0.07)	2.48 (0.19)		
No	2.69 (0.13)	2.61 (0.27)	2.03 (0.16)	1.77 (0.28)		
Social support in 5 areas						
Yes	2.66 (0.01)	2.51 (0.12)	2.00 (0.03)	1.78 (0.06)		
No	2.92 (0.15)	2.85 (0.05)	2.04 (0.17)	2.56 (0.67)		

Notes: Numbers in bold indicate that bivariate associations between mean caries outcomes and risk factors were statistically significant at p<0.05 level.

We performed the independent t-test for the risk factor with two categories and F-test for that with three or higher categories.

Table 3

Estimated relative risk (RR) and 95% confidence interval (CI) from multivariate negative binomial regression models for new NCCL and new CCL in primary dentition among low-income African American children, Detroit, Michigan, 2002–2007

	New NCCL		New CCL			
	RR	95% CI	RR	95% CI		
Baseline NCCL	1.02	0.98	1.06	1.21	1.12	1.29
Baseline CCL	1.02	0.99	1.05	1.17	1.09	1.26
Child's age	0.74	0.66	0.83	0.79	0.69	0.90
Child's sex (female vs. male)	0.81	0.60	1.08	1.00	0.66	1.50
Caregiver's age	1.03	1.01	1.05	1.01	0.97	1.04
Caregiver's education (high school degree vs. < high school)	1.16	0.71	1.88	1.49	0.80	2.77
Caregiver's education (> high school vs. < high school)	0.97	0.59	1.60	1.12	0.52	2.40
Annual household income (\$10K+ vs. <\$10K)	1.04	0.70	1.55	1.26	0.72	2.22
Caregiver's full-time employment (yes vs. no)	1.11	0.77	1.59	0.81	0.53	1.23
Household size (3–4 vs. 2)	1.04	0.70	1.54	0.99	0.53	1.88
Household size (5 or more vs. 2)	0.95	0.60	1.51	1.08	0.50	2.30
Dental insurance (yes vs. no)	1.30	0.89	1.88	1.12	0.68	1.86
Child's soda consumption (yes vs. no)	1.51	1.07	2.13	1.45	0.97	2.17
Oral health fatalistic belief (yes vs. no)	1.20	0.78	1.84	1.22	0.77	1.94
Caregiver's smoking status (yes vs. no)	1.00	0.69	1.46	1.39	0.87	2.20
Crack in wall (Yes vs. no)	1.08	0.77	1.51	1.33	0.85	2.06
Social support in 5 areas (Yes vs. no)	0.83	0.57	1.21	0.71	0.44	1.13

Notes: Numbers in bold indicate statistical significance at p<0.05 level.

Table 4

Estimated relative risk (RR) and 95% confidence interval (CI) from multivariate negative binomial regression models for new d₁₂mfs and new d₂mfs in primary dentition among low-income African American children, Detroit, Michigan, 2002–2007

	New d ₁₂ mfs ^a		New d ₂ mfs ^a	
	RR	95% CI	RR	95% CI
Baseline NCCL	1.10	0.92 1.31	1.44	1.28 1.62
Baseline CCL	1.15	1.02 1.30	1.12	1.01 1.24
Child's age	0.57	0.43 0.75	0.68	0.57 0.82
Child's sex (female vs. male)	1.18	0.59 2.38	1.32	0.80 2.18
Caregiver's age	1.04	0.99 1.10	1.01	0.97 1.05
Caregiver's education (high school degree vs. < high school)	1.13	0.44 2.89	1.14	0.61 2.15
Caregiver's education (> high school vs. < high school)	1.11	0.29 4.28	1.08	0.45 2.57
Annual household income (\$10K+ vs. <\$10K)	1.03	0.38 2.75	0.94	0.49 1.82
Caregiver's full-time employment (yes vs. no)	0.73	0.33 1.62	0.68	0.41 1.14
Household size (3–4 vs. 2)	0.85	0.30 2.46	0.76	0.33 1.74
Household size (5 or more vs. 2)	1.13	0.37 3.47	1.00	0.40 2.55
Dental insurance (yes vs. no)	1.27	0.53 3.07	0.91	0.50 1.68
Child's soda consumption (yes vs. no)	2.42	1.15 5.08	1.61	0.85 3.06
Oral health fatalistic belief (yes vs. no)	2.12	0.90 5.03	1.56	0.91 2.67
Caregiver's smoking status (yes vs. no)	1.04	0.49 2.21	1.06	0.62 1.79
Crack in wall (Yes vs. no)	2.03	0.93 4.46	1.63	0.89 2.99
Social support in 5 areas (Yes vs. no)	0.74	0.30 1.78	0.90	0.52 1.56

Notes: Numbers in bold indicate statistical significance at p<0.05 level.

^aNew d₁₂mfs = number of new non-cavitated lesions + number of new cavitated lesions + number of new fillings + number of new missing teeth due to caries; New d₂mfs = number of new cavitated lesions + number of new fillings + number of new missing teeth due to caries.