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Presence of Dental Caries Is Associated with Food Insecurity and Frequency of Breakfast Consumption in Korean Children and Adolescents.

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ABSTRACT: Dental caries remains one of the most common chronic diseases affecting children worldwide with a multifactorial etiology. The objective of the study was to evaluate the association between socioeconomic status (SES), dietary intake, food insecurity (FI), and dental caries in Korean children and adolescents. The study utilized data from the 2-year Korean National Health and Nutrition Examination Survey (KNHANES) conducted with 1,559 Korean boys and 1,391 girls aged 2 to 18 years from 2012 to 2013. Fathers' education (P=0.017), mothers' education (P<0.001), and household income (P=0.049) were all significantly associated with dental caries among Korean boys. As for dietary practices, both eating breakfast (P<0.001) and frequency of eating out (P<0.001) were strongly associated with dental caries (P<0.001). Three models of FI were used and no differences were found regarding genders. In model 3, both food insecure male [odds ratio (OR)=1.682, 95% confidence interval (CI): 0.999~2.832] and female (OR=1.900, 95% CI: 1.094~3.299) subjects had higher odds of developing dental caries than food secure subjects after adjusting the confounding factors. The present study showed a strong association between FI mediated by SES and dental caries. Nutrition education programs targeting low-socioeconomic families are necessary as a tool to prevent dental caries in Korea.

Keywords: food insecurity, dietary intake, dental caries, Korean children, socioeconomic status

INTRODUCTION

Dental caries is an infectious disease with a multifactorial etiology. It is caused by the interaction of bacteria, mainly *Streptococcus mutans* (1,2). Dental caries remains one of the most common chronic diseases affecting children worldwide (3,4). Despite improved trends in reducing dental caries in developed countries, dental caries remains prevalent in the Republic of Korea as it goes through nutrition transitions. Asian and Latin American countries are reported to be the most prevalent with 60~90% of school children having dental caries (5). Korea has greatly improved through economic growth and the development of dental-medical industry. However, in comparison to other Organization for Economic Co-operation and Development countries such as the UK, The Netherlands, and Denmark where data on a five-year-old children suggest that the trend towards the reduced prevalence of dental caries has halted (6), but the prevalence of dental caries among Korean children is still high (7). Also, three out of the top ten high-frequency diseases for walk-in treatments were related to oral health (8). Dental caries has been associated with socioeconomic status (SES), dietary practices, and food insecurity (FI) (2,9,10), among other risk factors.

SES is commonly conceptualized as the social standing or class of an individual or group. In Korea, like western countries, SES is often measured as a combination of education, income, and occupation. The education system in Korea is a very competitive one in which children coming from high SES families have better chances for higher education.

A family's SES or ability to buy or consume sufficient, safe, and nutritious food to meet their dietary needs and food preferences for a healthy and active life appears to determine their dietary practices. The inability to have access to sufficient, fresh, and nutrient dense foods is associated to the family SES. The substitution to high-energy, low cost nutrient poor sugary, and fatty foods could lead to malnutrition (11). Therefore, a low-SES is often linked with poor diet, overweight, under-nutrition (4,12), and consequently, a higher prevalence of dental

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caries in children (4,10). On the other hand, the low-SES status of the family is associated to the family FI (13,14). FI is defined as limited or uncertain availability of safe and nutritious foods (13,15). Numerous studies have reported an association between FI and oral health (13,16). We used the 2-year Korean National Health and Nutrition Examination Survey (KNHANES) conducted from 2012 to 2013 to test the following hypotheses (Fig. 1): first, dental caries is associated with SES (Parents education, household income, and teeth brushing frequency). Secondly, dental caries is associated with dietary practices. Thirdly, dental caries is associated with FI.

MATERIALS AND METHODS

Data collection

This study utilized data from the 2-year Korean National Health and Nutrition Examination Survey (KNHANES) conducted from 2012 to 2013, which was obtained from KNHANES V (2012) and KNHANES VI (2013). KNHANES is conducted annually using a rolling sampling design that involves a complex, stratified, multistage, and probability-cluster survey of a representative sample of the civilian population in Korea (17). The survey was performed by the Korean Centers for Disease Control and Prevention, and the Korean Ministry of Health and Welfare with three components: health interviews, health examinations, and a nutrition surveys (18). The study was approved by both, the Institutional Review Board of the Korean Centers for Disease Control and Prevention (2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-12EXP-03-5C) and the Keimyung University Institutional Review Board (2015-01-HR-05-01). We followed the recommendations of the strengthening reporting of observational studies in epidemiology statements (19).

The present cross-sectional analysis was restricted to participants aged 2 to 18 years who completed the health examination and the nutrition survey (n=2,950; 1,559 boys and 1,391 girls). Information regarding age, educational level, and income were obtained during the health interview according to the KNHANES standard operational procedures (18).

Variables for general information of subjects

Age was categorized into three groups (2～6, 7～12, and 13～18 years). Educational level was categorized into three groups: less than high school, high school, and college or more. Height and weight measurements were performed with the participants wearing light clothing without shoes. Body mass index (BMI) was calculated as weight (in kilograms) divided by the square of height (in meters). Waist circumference was measured midway between the costal margin and the iliac crest at the end of normal expiration (20). Regular exercise was previously defined (17).

Clinical laboratory tests

Blood samples were collected after a 12-h overnight fast. The samples were properly processed and transported in cold storage to the central laboratories (Seoul Medical Science Institute and Seegene Medical Foundation, Seoul, Korea) within 24 h. Serum 25-hydroxyvitamin D (25-OH-D) levels were measured with a radioimmunoassay kit (DiaSorin Inc., Stillwater, MN, USA) using a 1470 Wizard gamma counter (PerkinElmer Finland Oy, Turku, Finland). The inter-assay variation coefficients were 7.6% and 7.2% at 14.7 ng/mL and 52.5 ng/mL, respectively (17). All clinical analyses were performed by the Neodin Medical Institute, a laboratory authorized by the Korean Ministry of Health and Welfare.

Definition of dental caries

The presence of dental caries was defined as a positive response to the following question in the health interview: "Have you been diagnosed with dental caries by a doctor?" (18).

Dietary assessment

All subjects received instructions to maintain their usual dietary habits prior to assessing their dietary intake. Daily energy intake was calculated with the 24 h recall and the Can-Pro 4.0 nutrient intake assessment software developed by the Korean Nutrition Society (Seoul, Korea) (21).

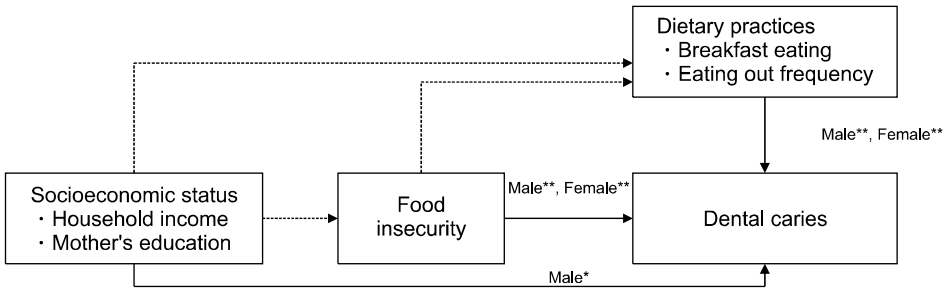

Fig. 1. Preliminary conceptual model of the relationship between socioeconomic status, food insecurity, dietary practices, and dental caries. *P<0.05 and **P<0.01.

Statistical analysis

Statistical analyses were performed using SPSS software (ver. 21, IBM SPSS Statistics, Chicago, IL, USA). Sample weights were used in all analyses to produce estimates that were representative of the Korean civilian population (22). The sample size was calculated using the G-power program version 3.1.9.2 (α=0.05, power=0.95, and effect size=0.25), and the total calculated sample size for chi-square test and analysis of covariance (ANOVA) was 317 and 400, respectively (23). The sample size was sufficient for each group since non-dental caries and dental caries groups consisted of 1,881 and 1,069 subjects, respectively. Odds ratios (ORs) and 95% confidence intervals (CIs) for having dental caries were calculated according to gender and FI, while controlling for covariates (age, household income level, frequency of teeth brushing, eat-out frequency, BMI, energy intake, and daily nutrient intakes) using logistic regression to incorporate the sample weights given the complex sample design of the survey (24). The covariates used for adjusted means were age, age, household income level, frequency of teeth brushing, eat-out frequency, BMI, energy intake, and daily nutrient intakes (protein, fat, carbohydrate, calcium, potassium, iron, sodium, phosphate, dietary fiber, vitamin C, β-carotene, and vitamin A).

RESULTS

Table 1 shows the association of dental caries and socio-demographic variables by gender among Korean children aged 2 to 18 years. The prevalence of dental caries increased with age and no significant differences were found regarding the gender. More than 40% of female participants had dental caries compared to 32% among males. As for the SES, parents' education and household income were significantly associated with dental caries. As for the dietary practices, both eating breakfast and frequency eating out were strongly associated with dental caries (P<0.001).

Table 2 and 3 represent the means and 95% CIs between nutrition assessment (anthropometric, biochemical, and nutrient intake) and dental caries by gender. While low density lipoprotein (LDL)-cholesterol levels were much higher in subjects with dental caries than those without in both genders, dental caries was only significantly associated with male participants with a lower BMI (P= 0.036). Glucose intake and 25-OH-D were not significantly associated with dental caries in both genders. As for the nutrient intake (Table 3), fat intake was higher for those with dental caries, although it was not significantly different in both genders. The daily intake of calcium

Table 1. Demographics of Korean children aged 2 to 18 years by gender and dental caries status

Demographic group		Male			Female		
		Without dental caries (n=1,053)	With dental caries (n=506)	P-value	Without dental caries (n=828)	With dental caries (n=563)	P-value
Age group	2 to 6 years	440 (39.3%)	5 (0.3%)	<0.001	368 (47.1%)	2 (0.2%)	<0.001
	7 to 12 years	383 (37.5%)	187 (28.6%)		306 (37.4%)	229 (32.8%)	
	13 to 18 years	140 (23.2%)	314 (71.0%)		87 (15.4%)	332 (67.0%)	
Father's education level	Less high school	46 (12.8%)	31 (16.9%)	0.017	30 (12.9%)	42 (18.3%)	0.106
	High school	133 (33.8%)	93 (43.9%)		114 (40.3%)	108 (44.6%)	
	College graduate	247 (53.4%)	101 (39.2%)		168 (46.8%)	113 (37.0%)	
Mother's education level	Less high school	68 (12.2%)	52 (17.9%)	<0.001	75 (19.0%)	69 (18.9%)	0.006
	High school	218 (43.9%)	176 (58.2%)		160 (38.6%)	182 (50.5%)	
	College graduate	292 (43.9%)	103 (23.9%)		219 (42.4%)	137 (30.6%)	
Household income level	Less than $1,000/month	29 (3.3%)	32 (7.5%)	0.049	25 (3.6%)	31 (7.1%)	0.194
	$1,000~$2,000/month	117 (11.7%)	51 (12.1%)		83 (12.9%)	57 (11.6%)	
	$2,000~$4,000/month	453 (43.1%)	185 (39.4%)		344 (41.0%)	197 (38.1%)	
	More than $4,000/month	449 (41.9%)	233 (41.0%)		366 (42.5%)	275 (43.2%)	
Frequency of teeth brushing	One time/d	144 (13.9%)	58 (13.0%)	0.427	90 (11.1%)	26 (4.3%)	<0.001
	Two or three times/d	852 (79.8%)	408 (78.6%)		690 (83.2%)	464 (83.5%)	
	More than four times/d	57 (6.3%)	40 (8.4%)		48 (5.7%)	73 (12.2%)	
Food security	Secure	948 (88.3%)	419 (80.8%)	0.002	749 (91.1%)	476 (83.2%)	<0.001
	Insecure	100 (11.7%)	79 (19.2%)		70 (8.9%)	76 (16.8%)	
Breakfast eating	Yes	992 (86.6%)	402 (73.5%)	<0.001	766 (86.7%)	426 (71.2%)	<0.001
	No	122 (13.4%)	122 (26.5%)		104 (13.3%)	148 (28.8%)	
Eat-out frequency	Zero or two times/week	95 (8.3%)	6 (1.7%)	<0.001	78 (8.6%)	8 (1.4%)	<0.001
	Three or more times/week	954 (91.7%)	494 (98.3%)		748 (91.4%)	548 (98.6%)	
Regular exercise	Yes	18 (10.1%)	45 (13.2%)	0.416	9 (11.1%)	23 (4.9%)	0.022
	No	175 (89.9%)	308 (86.8%)		108 (88.9%)	372 (95.1%)	

Values are frequencies and percentages according to the presence of dental caries and the statistical differences were analyzed using the chi-square test.

Table 2. Means and 95% confidence intervals of anthropometric and biochemical parameters according to gender and dental caries status after covariate adjustment

Outcome variables	Male			Female		
	Without dental caries (n=1,053)	With dental caries (n=506)	*P*-value[1)]	Without dental caries (n=828)	With dental caries (n=563)	*P*-value
Height (cm)	164.5 (162.5~166.6)	163.9 (161.9~165.9)	0.342	155.1 (153.1~157.0)	155.3 (153.6~157.0)	0.748
Weight (kg)	58.7 (57.1~60.2)	58.2 (56.7~59.7)	0.337	50.1 (48.8~51.3)	50.2 (49.2~51.3)	0.684
BMI (kg/m^2)	21.4 (20.1~22.7)	20.6 (19.4~21.9)	0.036	20.7 (19.4~22.1)	20.8 (19.5~22.2)	0.729
Waist circumference (cm)	71.8 (70.8~72.8)	71.7 (70.7~72.6)	0.779	66.9 (65.6~68.1)	66.9 (65.7~68.1)	0.933
Glucose (mg/dL)	88.5 (85.3~91.8)	87.8 (84.7~90.8)	0.250	90.2 (87.0~93.4)	90.1 (87.3~92.9)	0.908
HbA1c (%)	5.49 (5.39~5.58)	5.52 (5.42~5.61)	0.383	5.48 (5.37~5.60)	5.48 (5.38~5.58)	0.932
LDL-cholesterol (mg/dL)	108.5 (103.0~114.1)	129.1 (125.4~132.8)	0.002	67.0 (61.9~72.2)	102.9 (102.4~103.3)	<0.001
25-OH-D (ng/mL)[2)]	16.0 (14.0~17.9)	16.3 (14.2~18.4)	0.632	16.5 (13.8~19.1)	16.1 (13.8~18.4)	0.564

BMI, body mass index; LDL, low density lipoprotein; HbA1c, glycated hemoglobin.
[1)]Adjusted for age, BMI, household income level, frequency of teeth brushing, eat-out frequency, and regular exercise.
[2)]Adjusted for seasonal variation at the sampling plus other confounding variables.

Table 3. Means and 95% confidence intervals of daily nutrient intakes according to gender and dental caries status after covariate adjustment[1)]

Outcome variables	Male			Female		
	Without dental caries (n=1,053)	With dental caries (n=506)	*P*-value	Without dental caries (n=828)	With dental caries (n=563)	*P*-value
Energy intake (kcal/d)	2,417 (1,818~3,015)	2,298 (1,701~2,893)	0.331	1,800 (1,452~2,148)	1,677 (1,384~1,971)	0.213
Carbohydrates (%)	66.4 (63.4~69.4)	65.6 (62.4~68.7)	0.489	65.9 (60.8~70.9)	65.7 (61.0~70.3)	0.884
Protein (%)	13.9 (12.3~15.4)	14.0 (12.5~15.5)	0.744	14.5 (12.2~16.8)	14.1 (12.1~16.1)	0.564
Fat (%)	19.7 (16.4~23.0)	20.4 (17.2~23.6)	0.491	19.6 (15.8~23.4)	20.2 (16.6~23.7)	0.532
24-h recall food intake (geometric mean±SE)[2)]						
Dietary fiber (g)	6.1±0.9	6.2±1.0	0.836	6.8±2.1	7.1±2.1	0.375
Calcium (mg)	536.8±85.7	560.5±81.2	0.520	374.4±67.0	355.0±53.6	0.567
Phosphate (mg)	1,234.7±144.9	1,237.4±145.5	0.963	909.1±86.3	876.3±84.3	0.504
Potassium (mg)	2,855.2±396.1	2,935.3±391.9	0.628	2,821.8±512.3	2,822.6±508.5	0.994
Iron (mg)	20.9±4.6	21.2±4.4	0.741	13.4±1.9	12.2±1.9	0.362
Sodium (mg)	4,503.4±440.6	4,306.1±447.9	0.484	2,602.4±313.6	2,732.9±306.4	0.535
Vitamin A (μgRE)	701.5±307.9	918.4±205.9	0.275	580.7±109.7	548.3±104.7	0.503
β-carotene (μg)	3,222.1±1,747.7	4,452.0±1,120.3	0.290	2,569.2±579.3	2,410.8±528.7	0.540
Total vitamin A (μgRE)	1,238.6±598.2	1,660±391.4	0.282	1,008.9±204.1	950.1±91.1	0.512
Vitamin C (mg)	86.1±13.5	64.3±14.8	0.067	119.6±29.6	140.5±29.4	0.011

[1)]Adjusted for age, BMI, household income level, frequency of teeth brushing, eat-out frequency, and regular exercise.
[2)]Values are geometric mean±standard error, and calculated using the generalized linear model.

and dietary fibers was not different between the groups. Vitamin C intake was higher for those with dental caries, but only in female subjects.

Table 4 presents the association between food insecurity models and dental caries in both genders. Three models of FI were used and no differences were found regarding genders. Model 1 had no adjustment and both food insecure male (OR=1.796, 95% CI: 1.235~2.612) and female (OR=2.078, 95% CI: 1.395~3.098) subjects had higher odds of developing dental caries than food secure subjects. Model 2 was adjusted for age, household income level, frequency of teeth brushing, and frequency of eating out. Similar results were observed for both boys (OR=1.681, 95% CI: 1.002~2.820) and girls (OR=1.832, 95% CI: 1.052~3.190). In model 3, adjustment was made for all covariates in model 2; plus BMI, energy intake, and daily nutrient intakes (protein, fat, carbohydrate, calcium, potassium, iron, sodium, phosphate, dietary fiber, vitamin C, β-carotene, and vitamin A). Girls living in food insecure homes had higher odds of developing dental caries (OR=1.900, 95% CI: 1.094~3.299) than those living in food secure families. The same results were seen with boys living in food insecure homes compared to those living in food secure homes (OR=1.682, 95% CI: 0.999~2.832).

Table 4. Odds ratios (OR) and 95% confidence intervals (CI) of dental caries prevalence by food insecurity with and without covariate adjustment

Food insecurity	Adjusted OR (95% CI)			
	Male (n=1,559)	*P*-value	Female (n=1,391)	*P*-value
Model 1[1)]				
Food insecure	1.796 (1.235~2.612)	0.002	2.078 (1.395~3.098)	<0.001
Food secure	1.00 (Ref)		1.00 (Ref)	
Model 2				
Food insecure	1.681 (1.002~2.820)	0.049	1.832 (1.052~3.190)	0.032
Food secure	1.00 (Ref)		1.00 (Ref)	
Model 3				
Food insecure	1.682 (0.999~2.832)	0.050	1.900 (1.094~3.299)	0.023
Food secure	1.00 (Ref)		1.00 (Ref)	

Unadjusted and adjusted OR and 95% CI and statistical differences were analyzed using logistic regression without and with adjusting for covariates.
[1)]Model 1, no adjustment; Model 2, adjusted for age, household income level, frequency of teeth brushing, and eat-out frequency; Model 3, adjusted for all covariates in model 2 plus, BMI, energy intake, and daily nutrient intakes (protein, fat, carbohydrate, calcium, potassium, iron, sodium, phosphate, dietary fiber, vitamin C, β-carotene, and vitamin A).

DISCUSSION

In the present study, it was found that SES was associated with dental caries. The social economic variables used in this study were parents' educational level and household income level. The notion that parents play an important role in the preservation of healthy children's oral health is shown in this study. Moreover, we observed that children whose parents had a high educational level and a higher income had less dental caries than those of the parents with a low educational level and low-income level. These observations are in line with previous reports associating children's oral health and socioeconomic variables such as educational level (25-27) and household income (26-28) levels. This could be attributed to availability and accessibility of dental care. Therefore, low household income and low education could be related to an unavailability and inaccessibility of dental care services (29).

While no statistical significant association was observed between the father's education level and dental caries of female children (P=0.106), there was a direct correlation between the parents' education level and the presence or absence of dental caries among boys. These findings support previous reports presenting the socioeconomic level of parents as an important predictor of caries presence among children (30,31). Both, low income and low parental educational level were related to an increased presence of caries. Dental caries is a multifactorial disease preventable by oral hygiene education and frequency of teeth brushing, among others. Table 1 shows a direct correlation between frequency of teeth brushing and the presence or absence of dental caries among girls. However, our sample did not stratify the children in age groups. Psychosocial changes or desire for independence may cause adoption of health-compromising eating behaviors.

The relationship between poor eating habits and dental caries in children has been reported (32,33). Our results are in agreement with other studies associating skipping breakfast with dental caries (32,33). Parents, especially mothers, play a major role in shaping the children's food habits (34). Among other factors, we think that the association of dental caries and skipping breakfast is mainly due to SES and maternal nutrition education. However, a food frequency questionnaire was not administered in our study to identify lacking food items in the Korean children's diet. Nevertheless, no association was found between 25-OH-D and dental caries despite reports associating vitamin D with the prevention of dental caries (35-37). However, the mechanism in which vitamin D intake may relate to dental caries is not fully known. We can hypothesize that the fact that vitamin D helps strengthening teeth's resistance to bacteria by helping to absorb calcium and phosphate could be a mechanism by which it reduces dental caries. In addition, it has also been suggested that concentrations of 25-OH-D between 75~100 nmol/L may reduce the risk of dental caries (38). This may be attributed to milk intake. Frequent milk consumption increases 25-OH-D (39). In addition, researchers have found that people with poor oral health in the form of periodontal disease are almost twice as likely to have heart disease mediated with high cholesterol levels (40,41). We think that the significant correlation observed between LDL-cholesterol and dental caries (P=0.002) in our study is mediated by the existing association between improper oral health and LDL-cholesterol (42).

It is generally accepted that the more sugar a population consumed, the greater the prevalence of dental caries (43). However, we did not find any association between

sugar intake and dental caries and could not conclude to a linear relationship. In addition, access to fluoride and oral healthcare despite diets high in sugar could contribute to low caries rates (44-46). Moreover, our finding is in line with a cross-sectional analysis of dietary data by Gibney who observed an inverse relationship between the intake of free sugars and the intake of fats (47). On the other hand, the association of dental caries with fat intake, consequently resulting in a higher BMI is not clear as controversial reports exist. Some researchers observed that obese children had more caries than children in the normal weight groups (48,49); others found no significant difference among different BMI groups (50). The results of this study showed an association between dental caries and lower BMI among male children. This is supported by the results of a report by Yang which showed that underweight 8-year-old children in Qingdao (China) were more likely to have more dental caries (5). This observation might be due to FI mediated by SES of the parents (parents' educational level and household income level) (Fig. 1). Other reports also suggested that poor nutrition could increase susceptibility to dental caries due to altered saliva composition and impaired secretion (4,51). Therefore, dietary practices link dental caries to FI.

In the three models presented in Table 4, we found that FI was significantly associated with dental caries. This observation is consistent with previous reports associating poor oral health with FI (13,16,52). We found two possible explanations. First, SES mediated FI. Our study showed an association between SES and dental caries, especially with the mother's educational level. Children's diet is often linked to the socioeconomic position of the parents (34). In agreement with previous studies, parental low income and low level of maternal education are associated with a higher prevalence of dental caries (13, 27,34). Second, food insecure children may live in homes where fluoride and oral healthcare and hygiene are lacking. Our study showed an association between teeth brushing frequency and the prevalence of dental caries among girls. Studies have reported that low-education and low-income families do not pay enough attention to dental care measures (27,53).

This study had several limitations. First, a food frequency questionnaire was not used. A food frequency will allow determining specific foods responsible for dental caries. Foods eaten in food insecure homes are often associated with the SES of the family. It is then likely that food insecure households may live in food deserts (13,54) or have poor diet (2,4,11). Second, the age of the subjects studied was wide ranging (2 to 18 years old). It is generally accepted that while older children often make their own choices (55), parents have more influences on younger children's eating patterns (56).

In conclusion, the present study showed a strong association between FI mediated by SES and dental caries. Nutrition and oral hygiene education should be targeted to low-income families. Preventive measures showed great success in reducing the prevalence of dental caries in some countries like Denmark, where 98% of children visit a dental clinic for regular check-ups up to the age of 18 years (27).

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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