Dental caries and fluorosis among children in a rural Georgia area

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Abstract

Purpose: This IRB-approved study compared the caries experience, fluorosis prevalence, and plaque and salivary fluoride concentrations ([F]) in middle school (MS; N=51) and elementary school (ES; N=144) children residing in nonfluoridated and fluoridated communities in rural Georgia. All participants were exposed to fluoridated water at school (0.5–1.2 ppm), some received that level at home, and others received home water with <0.1 ppm F.

Methods: Subjects' parents completed a questionnaire regarding fluoride exposure. Children were examined at school by two calibrated dentists.

Results: No significant differences were seen in DMFS+dfs between children with or without fluoridated home water, nor for those with or without fluorosis. MS children with non-fluoridated home water had lower mean salivary [F] values than MS children with fluoridated home water. No differences were found among MS and ES children in mean plaque [F] for those with or without fluorosis.

Conclusions: Home water fluorodation had little effect on the variables measured. These findings appear to be due to fluoride exposure from fluoridated dentifrices, fluoridated drinking water at school, and the fluoride "halo" effect. (Pediatr Dent 21:81–85, 1999)

The differences in the prevalences of dental caries and dental fluorosis between communities with and with out controlled water fluoridation have diminished since the late 1970s. The prevalence of fluorosis, while increasing in both types of communities, has increased to a greater extent in nonfluoridated communities.[1–3] At the same time, the prevalence of dental caries in some non-fluoridated communities has decreased to levels approximating those found in optimally-fluoridated areas.[2, 4, 5] Both of these findings point to an increased fluoride exposure in children in nonfluoridated communities.

This increased exposure comes from several sources. The use of fluoridated dentifrices is ubiquitous in the United States.[6] Several studies have documented the degree of fluoride ingestion from this source by children with developing teeth as well as by older individuals.[7, 8] Consequently, fluoride dentifrice use has been identified as a risk factor for fluorosis.[9] Dietary fluoride supplementation has also been identified as a risk factor in communities with and without water fluoridation.[10]

There is also evidence that fluoride exposure from foods and beverages has increased in nonfluoridated areas due to the consumption of products processed, canned, and bottled in larger communities.[11, 12] These larger communities are typically supplied with fluoridated water, so the products processed there reflect the fluoride content of the water used. The exposure to fluoride from such products by residents of nonfluoridated communities has been termed the "halo" or "diffusion" effect. Little is known, however, about the relationship between this effect and salivary and plaque fluoride concentrations or the prevalences of dental caries and fluorosis.

The purpose of this study was to compare the caries experience, fluorosis prevalence, and plaque and salivary fluoride concentrations in children residing in nonfluoridated and fluoridated rural communities.

Methods

This study was approved by the Medical College of Georgia Human Assurance Committee. It was conducted among children attending the sole elementary and middle/high schools in Warren County, a rural county in east central Georgia. The schools are located in Warrenton, a community served by a public water supply that is artificially fluoridated. A water sample was obtained from each school for confirmation of the water fluoride level. Some of the children lived in Warrenton; others lived in homes served by individual wells or in neighboring communities with public water supplies. One of these communities was served by a public water supply with naturally occurring fluoride at a level of 0.5 parts per million (ppm). The other was served by a nonfluoridated (<0.1 ppm) water supply. We did not obtain water samples from homes served by well water. As part of its state-wide monitoring program, however, the Oral Physiology laboratory at MCG has conducted fluoride analyses from a number of homes served by wells in that area. All analyses have determined drinking water fluoride levels to be <0.1 ppm.

Table 1. Mean (SD) DMFS and dfs Scores by School Group

Group	DMFS	dfs	DMFS+dfs
Middle School (N=51)	2.73 (4.80)	0.16 (0.84)	2.88 (4.76)
Elementary School (N=144)	1.27 (1.92)	4.11 (5.43)	5.88 (5.85)

Table 2. Mean (SD) DMFS+dfs Scores by School Group and Home Drinking Water Fluoride Concentration (*P*-values are Derived from Wilcoxon 2-Sample Tests).

School Group	Home Water Fluoride Level		*P* value
	0.1 ppm	0.5–1.2 ppm	
Middle School (N=51)	3.07 (4.68)	2.81 (4.85)	0.93
Elementary School (N=144)	5.81 (6.30)	4.81 (5.30)	0.43

Table 3. Mean (SD) DMFS+dfs Scores by School Group and Fluorosis Status (*P* Values are Derived from Wilcoxon 2-Sample Tests)

School Group	No Fluorosis	Fluorosis	*P* value
Middle School (N=51)	3.48 (5.21)	1.95 (3.90)	0.09
Elementary School (N=144)	6.25 (6.54)	4.70 (5.20)	0.20

Table 4. Prevalence of Fluorosis by School Group and Home Drinking Water Fluoride Concentration (*P* Values are Derived from Fisher's Exact Tests of 2 x 2 Distributions)

School Group	Home Water Fluoride Level		*P* value
	0.1 ppm	0.5–1.2 ppm	
Middle School (N=51)	21.4%	45.9%	0.26
Elementary School (N=144)	52.6%	56.8%	0.51

Parents of each participant completed a questionnaire designed to provide information on dentifrice use and home water source. The latter was determined by asking the parent whether the home was served by a well or public water supply. If a public water supply was indicated, the parent was asked to whom they paid their water bill. Parents were also asked whether their children were currently receiving daily systemic fluoride supplements.

Examinations: Examinations were conducted in the schools by two individuals (Dr. Steven Adair and Dr. Carole Hanes) using an Adec™ portable dental chair and light with #23 explorers and plain mirrors. The examiners were trained and calibrated for diagnosis of caries and fluorosis using the criteria of Radike[13] and a modification of Dean's index[2] in which the "questionable" category was collapsed into the "normal" category. Each examiner reassessed several children for calculation of intra- and interexaminer reliability.

Saliva and plaque collections: To allow calculation of the time elapsed since eating or brushing, the children were asked at what time they last ate or brushed the teeth; this was recorded along with the time of the examination. Upon completion of the caries/fluorosis examination, participants were asked to rinse for 1 min with deionized water and then to expectorate. This was done to minimize the chance of unusually high salivary or plaque fluoride concentrations resulting from recent ingestion of solid or liquid foods. Plaque was harvested from multiple interproximal and smooth surface sites by careful use of a curette. Care was taken to avoid including food particles or hemorrhage. The plaque was deposited into the well on the inside of the cap of a Beem™ (Electron Microscopy Science, Fort Washington, PA) capsule. The capsule was closed and coded with the patient's study number.

Following plaque collection, participants chewed a 1-inch square piece of Parafilm™ (American Can Company, Greenich, CT) to stimulate salivary flow. Whole saliva was expectorated for 1 to 3 min (until about 1.0 mL was obtained) into a test tube which was then capped. Plaque and saliva samples were placed on ice and transported to the laboratory for fluoride analysis. Plaque samples were dried at 95±2° C prior to analysis.

Fluoride analysis: Fluoride analyses were done using the ion-specific electrode after overnight diffusion using the HMDS-facilitated diffusion method of Taves[14] as modified by Whitford.[15] This preparative method quantitatively transfers fluoride from the sample into an alkaline trap solution of smaller volume. In this way, the fluoride concentration of the analyzed solution is well above the limit of sensitivity of the electrode which permits accurate and reproducible results (CV<6%). The trap (50 µL of 0.05 N NaOH) was buffered with 25 µL of 0.20 N acetic acid to adjust the pH to 5.0 prior to analysis. Appropriate fluoride standards (as NaF) were also diffused and analyzed. The millivolt readings of these samples were converted into concentrations of fluoride (mg/kg or mg/L) by reference to the standard curve.

S*tatistical analysis:* Nonparametric methods were used for hypothesis testing. Fisher's exact test was used for binary response data. Wilcoxon's test was used for continuous variables. Summary statistics and correlations are also reported.

Results

Consent for participation was obtained from 145 elementary school (ES) children (grades 3–5) and 55 middle school (MS) children (grades 6–8). Fifty-one MS and 144 ES children were examined. The sample sizes for saliva and plaque analyses are lower because of an inability to obtain adequate samples from some children. The male:female distributions were 50:50 for the elementary school group and 36:64 for the middle school group. The difference in these distributions was not significantly different.Interexaminer reliability for caries and fluorosis examinations was 99% and 88%, respectively. Intraexaminer reliability for the two examiners for caries was 98% and 99%, for fluorosis was 90% and 96%.

Table 5. Mean (SD) Salivary Fluoride Concentrations by School Group and Home Drinking Water Fluoride Level (*P* Values are Derived from Wilcoxon's 2-Sample tests). Data are Expressed as Parts per Million (mg/kg)

School Group	Home Water Fluoride Level		*P* value
	0.1 ppm	0.5–1.2 ppm	
Middle School (N=51)	0.014 (0.008)	0.024 (0.025)	0.07
Elementary School (N=136)	0.020 (0.017)	0.025 (0.027)	0.34

Table 6. Mean (SD) Salivary Fluoride Concentrations by School Group and Fluorosis Status (*P* Values are Derived from Wilcoxon's 2-sample Tests). Data are Expressed as Parts per Million (mg/kg)

School Group	No Fluorosis	Fluorosis	*P* value
Middle School (N=51)	0.016 (0.01)	0.030 (0.032)	0.02
Elementary School (N=142)	0.025 (0.025)	0.023 (0.023)	0.50

Table 7. Mean (SD) Plaque Fluoride Concentrations by School Group and Home Drinking Water Fluoride Level (*P* Values are Derived from Wilcoxon's 2-Sample Tests). Data are Expressed as Parts per Million (mg/kg)

School Group	Home Water Fluoride Level		*P* value
	0.1 ppm	0.5–1.2 ppm	
Middle School (N=45)	75.67 (102.42)	44.96 (48.42)	0.45
Elementary School (N=134)	38.53 (43.13)	45.05 (57.41)	0.35

Table 8. Mean (SD) Plaque Fluoride Levels by School Group and Fluorosis Status (*P* Values are Derived from Wilcoxon's 2-Sample Tests). Data are Expressed as Parts per Million (mg/kg)

School Group	No Fluorosis	Fluorosis	*P* value
Middle School (N=45)	51.15 (77.02)	57.51 (57.02)	0.26
Elementary School (N=134)	41.37 (58.74)	43.28 (46.84)	0.53

Fifty-five percent of the elementary school subjects and 66% of the middle school subjects were determined to be receiving fluoridated water at home. Parents of six children reported use of fluoride supplements. In the following analyses, those six children were grouped with those receiving fluoridated home water. The data were also analyzed by grouping those children according to their actual home water fluoride status. The results of the second analyses did not differ in any substantive way from those presented here.

Fluoridated dentifrice use was universal. The water samples obtained from the schools each contained 0.5 ppm fluoride.

Mean DMFS and dfs indices are shown in Table 1. Differences between the middle school and elementary school groups for permanent and primary tooth caries were attributed to age. The combined DMFS+dfs indices were not significantly different, however.

DMFS+dfs indices by school group and home water fluoride level are shown in Table 2. Caries indices were slightly lower in children receiving fluoridated water at home, but the differences were not statistically significant.

Fluorosis was observed in 51% of the entire sample, 55% of the elementary school students, and 39% of the middle school students. This difference in distribution was not statistically significant (P=0.11). Almost all of the fluorosis was classified as very mild (Dean's index of 1) and was restricted to permanent teeth. Five instances of mild or moderate fluorosis were noted.

Table 3 illustrates the DMFS+dfs indices by fluorosis status for each school group. There was a nonsignificant trend toward a lower caries index in both school groups with fluorosis compared to their fluorosis-free counterparts.

Table 4 demonstrates no significant differences in fluorosis prevalence according to home water fluoride status within school groups. The fluorosis prevalence of middle school children with negligible home water fluoride, however, was about half that of their counterparts with fluoridated home water.

Table 5 shows that there were no statistically significant differences in mean salivary fluoride concentrations between elementary school or middle school children with or without fluoridated home water. There was a nonsignificant trend, however, toward lower salivary fluoride concentrations among middle school children without fluoridated home water. When examining salivary fluoride concentration by school group and fluorosis status (Table 6), a significant difference was seen in the middle school group. Fluorosis-free middle school children had a mean salivary fluoride concentration value that was almost half that of their counterparts with fluorosis. No difference was seen in the elementary school group.

No significant differences or trends were seen for plaque fluoride concentration for middle school or elementary school children by home water fluoride level (Table 7) or fluorosis status (Table 8). There were no significant correlations between salivary or plaque fluoride concentration and time elapsed since eating or brushing, which ranged from 15 min to 6 h.

Discussion

Warrenton is considered by the Georgia State Department of Human Resources to have controlled water fluoridation at 1 ppm, but our analyses of water samples collected on two separate occasions indicated a suboptimal level of fluoridation. Periodic analyses conducted by the state show values ranging

Table 9. Fluoride Concentration (ppm) and Fluoride (mg) per Serving of Some Toods Served as Components of School Lunches

Food	F Concentration	Mg F/Serving
Apple sauce	0.184	0.027
Pizza	0.712	0.112

from a low of 0.2 ppm to a high of 1.2 ppm. It is our assumption that all children in the study benefitted from fluoridated school water, though periodically at suboptimal levels. Those who lived in Warrenton and the neighboring naturally fluoridated community received fluoridated home drinking water, though occasionally at suboptimal levels. It is virtually certain that all children had, at an earlier age, received some systemic fluoride through the ingestion of dentifrice. It also seems reasonable to assume that the fluoride intake by both groups from commercially processed beverages and foods was similar, though there is some evidence of a stronger fluoride "halo" effect among the elementary school children (Tables 4 and 5). In addition, children who ate school lunches consumed some foods containing fluoride. This was confirmed by analyses of the components of several school lunches (Table 9).

The mean DMFS+dfs index for middle school children (2.88) was consistent with national data for the southeastern United States, as was the DMFS index for the elementary school group (1.27, Table 1).[16] The substantially higher mean dfs index in the elementary school group (4.11 vs. 0.16, Table 1) contributed to the higher combined caries score in those children.

The prevalence of fluorosis observed among all study participants was 51%. This figure is higher than prevalence rates for optimally-fluoridated and fluoride-deficient communities reported by Leverett[2] and Szpunar and Burt,[3] but comparable to the 54% prevalence reported by Williams and Zwemer[17] for children residing in another county in Georgia. There was a nonsignificant trend toward a higher prevalence of fluorosis in the elementary school group (55%) than in the middle school group (42%). This difference suggests that the elementary school group was exposed to higher levels of fluoride during the development of the dentition.

The home water fluoride level had no significant effect on mean caries index or fluorosis prevalence for either school group. This could be explained by several factors. The water fluoride level of the homes using fluoridated community water was periodically low, and only 0.5 ppm at the time of the study. Second, all children potentially received a topical exposure to this level of fluoridated water at the schools, through the drinking water and foods prepared at school. Third, all respondents reported using a fluoridated dentifrice. Fourth, canned and bottled beverages and foods for use in both types of homes likely were similar in fluoride content. There was a distinct trend, however, toward a lower fluorosis prevalence among middle school children from homes without fluoridated water (Table 4). The fluorosis prevalences among elementary school subgroups were about equal, however. Perhaps the elementary school children received more fluoride from other sources during the period of dental development which could have blurred differences between those with or without fluoridated home water. Virtually all the fluorosis was of the very mild and mild types, and was restricted to permanent teeth.

Home water fluoride status was not significantly related to salivary fluoride concentration among middle school children, although children in that school group from homes with fluoridated drinking water had somewhat higher salivary fluoride concentrations. A similar but much weaker trend was seen among elementary school children. The salivary fluoride concentrations found in this study were comparable to others reported in the literature.[18] It has been proposed that the fluoride concentration in ductal saliva (and presumably whole saliva after rinsing the mouth with deionized water), like plasma, is a marker for the long-term exposure to fluoride.[19] If true, our data suggest that middle school children from nonfluoridated homes were exposed to less fluoride over some time period prior to or during the study.

As might be expected, middle school children with fluorosis had a lower mean DMFS+dfs score than their counterparts without fluorosis. This difference did not reach statistical significance, but it may indicate that exposure to fluoride sufficient to create very mild or mild fluorosis can impart an additional caries-protective benefit. Among elementary school children a similar, but much weaker, trend was observed. Middle school children with fluorosis had a significantly higher mean salivary fluoride concentration which might indicate a higher level of exposure to fluoride during permanent tooth formation, and probably a higher level of fluoride exposure shortly before the time of the study. Mean salivary fluoride concentrations in the elementary school children with or without fluoridated home water were nearly identical and midway between the mean salivary fluoride concentrations for the middle school subgroups (Table 6).

The middle school group showed some trends and differences between those with or without home water fluoride and those with or without fluorosis. For example, compared to middle school children with fluoridated water, those without fluoridated water had a lower prevalence of fluorosis (Table 4), a lower mean salivary fluoride concentration (Table 5), and a higher mean plaque fluoride concentration (Table 7). Much weaker trends or no differences were seen between the various elementary school subgroups. One explanation for these differences between the middle school and elementary school children is the presence of a stronger fluoride diffusion effect in the younger children, including a higher level of fluoride ingestion from dentifrices at a younger age. Consumption of canned and bottled soft drinks in infancy may have been a more common practice among the elementary school children at that age. The displacement of water from the diet by other beverages has been documented in older children.[11, 12] Ershow and Kantor have also shown the predominance of beverages other than tap water in the diets of infants and young children.[20]

Conclusions

The results of this study with elementary and middle school children in rural Georgia indicated that:

1) the home water fluoride concentrations (0.1-0.2 vs 0.5-1.2 ppm) were not significantly associated with caries experience,

2) mean salivary fluoride concentrations were significantly higher among middle school chldren with fluorosis compared to those without fluorosis;
3) there was a statistically non-significant trend toward a lower dental caries experience among children with enamel fluorosis;
4) these trends appear to be due to fluoride exposure from the use of fluoridated dentrifrices, the fact that the school drinking water was fluoridated (although not consistently at an optimal concentration), and the fluoride "halo" or "diffusion" effect.

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