Dental Caries and Dental Fluorosis Among Schoolchildren Who Were Lifelong Residents of Communities Having Either Low or Optimal Levels of Fluoride in Drinking Water

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Abstract

Objective: *This paper reports findings for dental caries and dental fluorosis in 8–10- and 13–16-year-old schoolchildren who were lifelong residents of communities having either naturally occurring low (Broken Bow and Holdrege, NE; <0.3 ppm) or optimal (Kewanee, IL; 1 ppm) levels of fluoride in drinking water.* ***Methods:*** *Findings are reported for participants who received both dental caries and dental fluorosis examinations (n=495). The DMFS and TSIF indices, respectively, were used to assess dental caries and dental fluorosis.* ***Results:*** *The mean DMFS score adjusted for age, sealant presence, and fluoride use was significantly lower in Kewanee (1.8) than was the adjusted mean caries score in either Holdrege (2.9) or Broken Bow (3.6). Adjusted mean DMFS scores in Broken Bow and Holdrege were not statistically different. The mean percent of fluorosed tooth surfaces per person, adjusted for age and use of dietary fluoride supplements, was similar in the three communities (approximately 15%); more than 80 percent of tooth surfaces in all participants were fluorosis-free.* ***Conclusions:*** *Findings from the present study suggest that water fluoridation still is beneficial and that dental sealants can play a significant role in preventing dental caries. In addition, findings from this survey appear to support the premise that the difference in dental fluorosis prevalence between fluoridated and nonfluoridated communities has narrowed considerably in recent years. [J Public Health Dent 1998;58(1):28-35]*

Key Words: dental caries, dental fluorosis, mottled enamel, fluoride, water fluoridation.

Over the past few decades, a substantial decline in dental caries has occurred among children in the United States and several other industrialized countries (1-6). Fluoride has been recognized as the single most influential factor responsible for the observed decline in caries in children as well as adults (7-9). Beginning in the 1980s, growing concern has been voiced regarding the effect on dental fluorosis of increased consumption of fluoride from a number of sources in both fluoridated and nonfluoridated communities (2,10-12). Although dental fluorosis remains more prevalent in fluoridated than nonfluoridated communities, it has increased proportionally more in nonfluoridated than fluoridated communities over the past five or six decades (11,13).

In April 1980 and 1985, staff of the National Institute of Dental Research (NIDR) conducted cross-sectional surveys of dental caries and dental fluorosis among schoolchildren residing in seven communities in western Illinois that had optimal or above-optimal concentrations of naturally occurring fluoride in their drinking water. In 1982, a similar survey of dental caries and dental fluorosis was carried out in a group of communities in Iowa that had negligible levels of fluoride in their community water supplies. Four reports of findings from those surveys have been published (14-17).

The continued availability in 1990 and relative sociodemographic stability of the same Illinois communities provided a unique opportunity to conduct a comparable follow-up survey; however, the communities surveyed in Iowa in 1982 no longer were accessible. Because water fluoride concentrations in the Iowa communities had been adjusted upward since 1982, it was necessary to identify alternative communities having negligible water fluoride levels. Two rural communities in Nebraska met the criteria for the comparison and their school officials agreed to participate in the survey. Like the Illinois communities, the two Nebraska communities were small, rural Midwestern towns. Each had a per capita income of approximately $15,000, an agricultural economy, the same number of local dental practitioners, and similar percentages of high school graduates entering college.

A recently published paper presented findings for dental caries and dental fluorosis in the Illinois communities surveyed (18). The report compared findings in 1990 with those obtained during two earlier surveys in 1980 and 1985. The purpose of the present study was to assess the prevalence of dental caries and dental fluorosis in the nonfluoridated communities (water fluoride levels <0.3 ppm) of Broken Bow and Holdrege, Nebraska, and in the naturally fluoridated community (1 ppm) of Kewanee, Illinois. We anticipated that the survey would provide information

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regarding the relative effect of water fluoridation on dental caries and dental fluorosis in communities having either low or optimal levels of fluoride in drinking water. This paper reports findings for dental caries and dental fluorosis from the 1990 NIDR examination of schoolchildren in the two Nebraska communities, as compared with Kewanee, Illinois.

Methods

Written parental permission to participate in the study was obtained for all subjects. Procedures followed were in accord with the ethical standards of the NIDR committee on human experimentation. The study design and methodology for this 1990 follow-up investigation in Illinois and Nebraska have been described in the aforementioned publications (14-18); however, for the reader's convenience a brief review follows.

This study utilized a convenience sample of age-specific children and youth invited to participate in the examination. The number of students from Kewanee participating in the 1990 examination (260) included 93 students in the older age group who were examined in 1985. These students comprised 59.6 percent (93/156) of the 8- to 10-year-olds examined in 1985. The other children in the study—younger aged children in Broken Bow, Holdrege, and Kewanee and older youngsters residing in the two Nebraska communities — comprised fewer than 50 percent of students available at each age or grade level. Lack of parental consent accounted for the majority of students precluded from participating in the study; a smaller number of students were eliminated from the investigation because they had not lived in their respective communities on a continuous basis since birth. Information describing demographic and other characteristics of nonrespondents was not available.

Clinical Examinations. Findings are reported for children 8–10 years of age and adolescents 13–16 years of age who received both a dental caries examination and a dental fluorosis examination (n=495). All participants aged 8–10 and 13–16 years met this requirement. Examinations took place in schools attended by the study participants. Because of scheduling considerations, examinations of children residing in Broken Bow and Holdrege were conducted in April 1990, whereas examinations of children in Kewanee took place in October 1990. Portable dental chairs, artificial lights, number 23 explorers, and plane surface mouth mirrors were used. Radiographs were not taken.

Dental fluorosis was assessed according to the Tooth Surface Index of Fluorosis (TSIF) (14). The TSIF was applied by the same two NIDR dentists who had made these assessments during the earlier surveys in 1980 and 1985. Each dentist examined approximately half of the children. Replicate examinations to assess interexaminer reliability were conducted for 70 children (about 12% of the study population from each of four fluoride-level categories comprising the Illinois communities). Assessment of examiner reliability was conducted in the Illinois study population because of the anticipated higher prevalence of dental fluorosis, as compared with the study population in Nebraska. Scores for all tooth sites showed observed agreements of 79.4 percent and 87.5 percent, respectively, depending on whether agreement was determined by using the entire TSIF scale or on the less rigorous criterion of fluorosis versus no fluorosis. The corresponding kappa values were 0.54 and 0.69, representing moderate and substantial agreement, respectively (19). The majority of the disagreements occurred at the low end of the TSIF scale and, as with many health indices, the distinction between no dental fluorosis and the mildest form was the most difficult. Based on the aforementioned level of agreement observed during duplicate examinations, the investigators combined the fluorosis findings from the two examiners for the purpose of data analysis.

The caries experience of each child was determined by an NIDR dentist, utilizing the decayed, missing, and filled surface index (DMFS index). This examiner had applied the index on numerous occasions in the past during other surveys and clinical trials. The criteria used for diagnosing dental caries were those developed at the ADA's Conference on Clinical Testing of Cariostatic Agents in 1968 (20). This examiner also determined the presence of dental sealants.

Fluoride History. Each participant's history of fluoride exposure was obtained from parents in a written questionnaire attached to the parent consent form. Information regarding the source of drinking water, type of toothpaste used currently and before the age of 6, use of dietary fluoride supplements, and receipt of professionally applied fluoride treatments was requested. A number of children in the Nebraska communities (n=76) received their drinking water from private wells. To confirm that the drinking water contained negligible concentrations of fluoride, specimens were obtained from a random sample (62%) of wells in Broken Bow and Holdrege, and tested using a fluoride-sensitive electrode (Orion Research, Inc.).

Data Analysis. Differences in mean DMFS scores of participants by community were tested for statistical significance using the least square means option under the SAS general linear models procedure (21). The chi-square test of homogeneity was used to compare differences in the prevalence of dental sealants among the communities and differences in responses to questions regarding the participants' fluoride histories (22). For dental fluorosis, the primary subject-based summary measure used in the statistical analyses consisted of the percentage of fluorosed surfaces per subject. Mean scores for this variable (MPFS) were computed for subjects in the three communities. Fixed effects ANOVA models were used to make comparisons among the subgroups. The LSMEANS procedure in SAS, which adjusts the group means for confounders present in the model, was used to compare adjusted means for statistical significance (21). For individual comparisons, an α=.02 value was used to control the overall experimentwise Type I error rate as a compromise between the more stringent Bonferroni α/k value and the unadjusted α=.05 value. This procedure adjusts for multiple comparisons, but retains the property of better power for conducting individual comparisons (23). All levels of significance reported are calculated P-values.

Because of the small number of high school participants in Holdrege, dental caries and dental fluorosis data have been combined for younger and older age groups in all three communities studied. Distributions of TSIF scores, however, are reported separately for children and adolescents. Both DMFS and MPFS scores have been adjusted for age differences among the study participants in the three communities. In addition, comparisons of DMFS and MPFS scores have been adjusted for differences among the three communities in reported use of dietary fluoride supplements; comparisons of DMFS scores also have been adjusted for differences in the presence of sealants and use of professionally applied, topical fluoride.

Results

The 1990 study population included 318 schoolchildren aged 8–10 years and 177 aged 13–16 years who had lived continuously in their respective communities since birth (Table 1). The mean ages of the younger and older groups of children were 9 years 2 months and 14 years 8 months, respectively. For logistic reasons, examinations in Kewanee and the other Illinois communities took place in the fall rather than the spring as they had in the two Nebraska communities. Nevertheless, at the time of the 1990 examination, children in Kewanee were on average only about one month older than their sampled counterparts in the Nebraska communities.

Children in Kewanee had always used the community water supply as their primary source of drinking water. Children in Broken Bow and Holdrege received their drinking water from public sources (< 0.3 ppm fluoride) or private wells. A randomly selected sample (n=47) of 76 private wells used by children residing in Nebraska revealed that fluoride concentrations were low (≤0.25 ppm F) and varied within a narrow range.

Dental Caries and Dental Sealants. Figure 1 shows the percentage of persons who were caries-free in the permanent dentition and the percentage of persons having one or more dental sealants by community. The percentage of children caries free in the permanent dentition varied from 25.2 percent and 39.8 percent, respectively, in the communities of Broken Bow and Holdrege, to 51.9 percent in Kewanee. Whereas the percentages of participants having any dental sealants in Broken Bow (7.5%) and Kewanee (6.5%) were low, over half of the participants in Holdrege (53.9%) had at least one sealant present (P<.001).

Table 2 provides a comparison of DMFS mean scores for participants aged 8–10 years and 13–16 years in Kewanee and the two Nebraska communities, Broken Bow and Holdrege. Multivariable-adjusted mean scores have been contrasted. The combined DMFS mean score for participants residing in the two Nebraska communities (3.3) was significantly higher than the DMFS mean score for Kewanee (1.8) participants. The associated 98 percent confidence interval for the difference as shown is [0.76, 2.30].

Further analysis (Table 2) revealed that the DMFS mean score for Broken Bow participants (3.6), as well as the DMFS mean score for Holdrege participants (2.9), were significantly higher than was the 1.8 DMFS mean score for Kewanee youngsters. The associated 98 percent confidence intervals for the differences in mean caries scores are [0.93, 2.79] and [0.21, 2.13], respectively. Mean caries scores in Broken Bow and Holdrege statistically were similar. The associated 98 percent confidence interval was [–0.45, 1.83].

An assessment of caries findings was conducted for mean caries scores (decayed surfaces or DS), mean

TABLE 1
Demographic Profile of Lifelong Residents of Communities Having Low or Optimal Levels of Fluoride in Drinking Water, 1990

Community	Water Fluoride Concentration	Continuous Residents: Sex	No. of Participants	8–10 Years Old	13–16 Years Old
Kewanee, IL	1 ppm	M	131	86	45
		F	129	81	48
Holdrege, NE	<0.3 ppm	M	58	54	4
		F	70	50	20
Broken Bow, NE	<0.3 ppm	M	48	22	26
		F	59	25	34
Total				318	177

FIGURE 1
Percent of Persons Caries Free and Percent of Persons Having Dental Sealants,

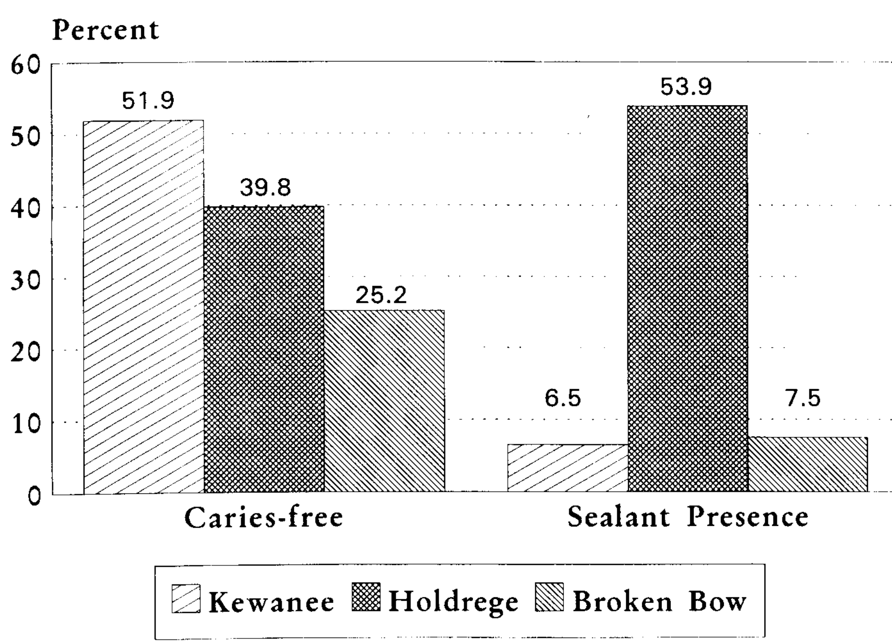

TABLE 2
Comparisons of Mean DMFS Scores for All Participants in Kewanee, Broken Bow, and Holdrege, 1990

		Age-adjusted Mean No.		Multivariable-adjusted Mean No.		% Increase from	98% Confidence Interval for Difference in§ Multivariable-adjusted Means		
Communities	*n*	DMFS	(SE)*	DMFS	(SE)†	KE‡	BB	HO	BB & HO
Kewanee	260	1.9	(.20)	1.8	(.22)	—	(0.93, 2.79)	(0.21, 2.13)	(0.76, 2.30)
Holdrege	128	2.6	(.29)	2.9	(.35)	61.1	(–0.45, 1.83)¶		
Broken Bow	107	3.7	(.31)	3.6	(.34)	100.0			
Broken Bow & Holdrege	235	3.1	(.22)	3.3	(.24)	83.3			

*Mean DMFS scores have been age-adjusted; numbers in parentheses are standard errors of mean.
†Mean DMFS scores have been adjusted for age, sealant presence, reported use of dietary fluoride supplements, and reported use of professionally applied topical fluoride (*n*=485).
‡Percent increase in multivariable-adjusted mean DMFS score; communities: KE=Kewanee (optimal water fluoridation); HO=Holdrege (<0.3 ppm F); BB=Broken Bow (<0.3 ppm F).
§The first three (1–α)100 confidence intervals presented are for the difference in multivariable-adjusted mean DMFS scores between KE and BB, KE and HO, and between KE and BB & HO, respectively.
¶(1–α)100 confidence interval for difference in multivariable-adjusted mean DMFS scores between HO and BB.

TABLE 3
Comparison of Mean DMFS Scores for All Participants by Tooth Surface Type and Community, 1990

	Community* (*n*)			*P*-values for Contrasts		
Mean DMFS Score	KE (260)	HO (128)	BB (107)	KE vs HO	KE vs BB	HO vs BB
Occlusal surfaces	1.2† (.11)‡	1.3 (.16)	2.2 (.18)	0.570	0.000§	0.000§
Buccolingual surfaces	0.6 (.08)	1.1 (.12)	1.2 (.13)	0.002§	0.000§	0.476
Approximal surfaces	0.1 (.05)	0.3 (.08)	0.3 (.09)	0.092	0.145	0.911

*Communities: KE=Kewanee (optimal water fluoridation); HO=Holdrege (<0.3 ppm F); BB=Broken Bow (<0.3 ppm F).
†Mean DMFS scores have been age-adjusted.
‡Numbers in parentheses are standard errors of the mean.
§Significant, $P<.02$.

TABLE 4
Percent Distribution of TSIF Scores for Participants by Age Group and Community, 1990

	No. of	No. of	% Distribution of TSIF Scores					% Surfaces*
Community (Water Fluoride Level)	Children	Surfaces	0	1	2	3	4–7	Fluorosed
Participants 8–10 years of age (age group 1)								
Kewanee (optimal water F)	167	4,867	81.4	14.4	2.8	1.3	0.0†	18.5
Holdrege (<0.3 ppm F)	104	2,956	81.7	12.6	3.4	2.3	0.1	18.4
Broken Bow (<0.3 ppm F)	47	1,424	82.3	15.2	2.2	0.3	0.0	17.7
Participants 13–16 years of age (age group 2)								
Kewanee	93	6,203	85.0	13.1	1.6	0.3	0.1	15.1
Holdrege	24	1,447	97.9	1.9	0.2	0.0	0.0	2.1
Broken Bow	60	3,748	90.9	8.1	0.7	0.4	0.0	9.2

*Percent surfaces fluorosed across all subjects.
†Two surfaces were affected.

TABLE 5
Mean Percent of Fluorosed Tooth Surfaces per Person for All Participants by Community, 1990

Community (Water Fluoride Level)	No. Participants	Age-adjusted Mean % of Fluorosed Tooth Surfaces	Bivariable-adjusted Mean % of Fluorosed Tooth Surfaces	98% Confidence Interval* for Difference in Bivariable-adjusted Means	
				Broken Bow	Holdrege
Kewanee (optimal water F)	260	16.7	17.6	(–.011, .101)	(–.003, .109)
Holdrege (<0.3 ppm F)	128	13.6	12.3	(–.057, .073)	—
Broken Bow (<0.3 ppm F)	107	13.8	13.1	—	—

*$(1-\alpha)100$ confidence interval for difference in mean MPFS scores between communities, adjusted for age and reported use of dietary fluoride supplements (n=493).

TABLE 6
Summary of Parental Response for Each Participant's History of Fluoride Exposure, Illinois and Nebraska Communities, 1990

Question	Response (%)			*P*-value for % Diff. Between BB and HO*
	Kewanee	Holdrege	Broken Bow	
What kind of toothpaste did your child use before age 6?				
Fluoride toothpaste	86.9	92.9	84.1	0.095
Nonfluoride toothpaste/no toothpaste	5.4	3.9	7.5	
Don't know	7.7	3.2	8.4	
What kind of toothpaste does your child currently use?				
Fluoride toothpaste	97.7	98.4	94.3	0.090
Nonfluoride toothpaste/no toothpaste	2.3	1.6	5.7	
Has your child ever received Rx fluoride drops and/or tablets?				
Yes	3.9	53.2	36.5	0.011†
No	96.1	46.8	63.5	
Has your child ever received fluoride treatments, such as liquids or gels, at the dentist's office?				
Yes	29.3	77.0	62.4	0.016†
No	70.7	23.0	37.6	

*BB=Broken Bow, HO=Holdrege.
†Chi-square analysis, significant, $P<.02$.

number of missing tooth surfaces (MS), and mean filled scores (filled surfaces or FS) for participants by community of residence. The mean DS, MS, and FS scores were adjusted for differences in age among the three communities. In all three communities the mean numbers of missing tooth surfaces (MS) were small and similar (≤0.1 surfaces). The mean DS score in Broken Bow (1.6) was significantly higher than the mean DS score observed in either Holdrege (1.0; P=.004) or Kewanee (0.8; P=.000). Mean DS scores in Holdrege and Kewanee were similar (P=.284). The mean FS scores in Holdrege (1.6) and either Broken Bow (2.1) or Kewanee (1.0) were similar ($P\geq.037$); however, the mean FS score in Broken Bow was significantly higher than the mean score observed in Kewanee (P=.000).

An additional assessment of caries findings was conducted for mean DMFS scores by tooth surface type and community (Table 3). The mean caries score on occlusal surfaces of participants residing in Broken Bow (2.2 DMFS) was significantly higher than the mean score for participants from either Holdrege (1.3 DMFS) or Kewanee (1.2 DMFS; for both comparisons, $P<.001$). The mean caries score on buccolingual surfaces of Kewanee youngsters (0.6 DMFS) was significantly lower than the mean score of participants residing in either Holdrege (1.1 DMFS; P=.002) or Broken Bow (1.2 DMFS; $P<.001$). Mean caries scores on approximal surfaces of participants from all three communities were small (less than one-third DMFS) and similar.

Dental Fluorosis. Table 4 shows the percent distribution of TSIF scores on permanent tooth surfaces across all subjects for children aged 8–10 years (age group 1) and 14–16 years (age group 2). The TSIF data have not been age-adjusted because the variation of dental fluorosis scores in each community within age grouping was insignificant (P=.812 and P=.352, respectively, for the younger and older age groups). Because the percentages of TSIF scores 4 through 7 are relatively small or zero, these scores have been combined. Scores in categories 1–3 represent various degrees of whitish discoloration, whereas scores of 4–7 reflect the more generally undesirable sequelae of staining, pitting, or both (15). For children from all three communities in age group 1, slightly more than 80 percent of the TSIF surface calls indicated no dental fluorosis present. Of those affected surfaces, a majority showed whitish discoloration involving less than one-third of the tooth surface (a score of 1). Only four tooth surfaces received scores higher than 3 and none exceeded a score of 5.

For adolescents in age group 2 (Table 4), in both Broken Bow and Holdrege more than 90 percent of the TSIF surface scores recorded indicated the absence of dental fluorosis; in optimally fluoridated Kewanee, 85 percent of TSIF scores were zero. As was observed for the 8–10-year-olds, most of the affected surfaces found showed whitish discoloration involving less than one-third of the tooth surface (a score of 1). Again, only a few tooth surfaces (n=3) received scores greater than 3 and none were higher than a score of 5.

Table 5 presents the mean percentage of fluorosed surfaces per subject, or MPFS score. For all participants 8–10 and 13–16 years of age, mean MPFS scores, adjusted for differences in age and reported use of dietary fluoride supplements, in Kewanee (17.6%), Holdrege (12.3%), and Broken Bow (13.1%) were similar (98% CI).

History of Fluoride Exposure. Parental responses to questions concerning their children's history of fluoride exposure through the use of fluoride-containing toothpaste, fluoride tablets/drops, or professionally applied fluoride liquids or gels are summarized in Table 6. In each of the three communities surveyed, the percentage of participants reported to have used fluoride-containing toothpaste before the age of 6 was high (for all communities, use ≥84%). No difference could be detected in the reported use of fluoride-containing toothpaste before age 6 among Broken Bow and Holdrege participants (P=.095). Also, a large majority of participants from all three communities were reported to have used fluoride-containing dentifrice within the "current" time frame of the study (use ≥94%). Again, no differences were observed in the reported current use of fluoride-containing toothpaste among participants residing in Broken Bow and Holdrege (P=.090). A significantly smaller percentage of participants residing in Broken Bow than in Holdrege were reported to have ever received fluoride tablets/drops or professionally applied fluoride treatments (for each procedure, P=.011 and .016, respectively).

Discussion

The intent of this study was to examine the relative effect of water fluoridation on dental caries and dental fluorosis among communities having either low or optimal levels of fluoride in drinking water. The two Nebraska communities, Broken Bow and Holdrege, were selected for inclusion in this study based upon the assumption that they shared a number of similar characteristics, including the level of fluoride exposure of residents. Each community was known to have a negligible concentration of fluoride in the public water supply (<0.3 ppm F), and both were small, rural midwestern towns with similar economic bases and sociodemographic population characteristics. No reasons were evident to expect any differences in the communities that would influence differentially the prevalences of dental caries and dental fluorosis. The results of this investigation, however, demonstrate that study participants from the two Nebraska communities were quite different with respect to oral health-related factors other than the concentration of fluoride in the drinking water.

Although the relative effectiveness of water fluoridation continues to be questioned (24,25), findings from the present study suggest that it still is beneficial. Multivariable-adjusted mean caries scores for Broken Bow and Holdrege participants (exposed to low water fluoride levels) were substantially higher (100% and 61%, respectively) than the overall mean caries score for Kewanee participants (exposed to an optimal water fluoride level). The difference in mean caries scores between Kewanee and Broken Bow likely reflects the benefit of water fluoridation as compared with the use of dietary fluoride supplements and professionally applied fluoride treatment because the prevalence of dental sealants in the two communities was similar. The difference in mean caries scores between Broken Bow and Holdrege likely is due primarily to dental sealants for the following reasons. The two communities had similar concentrations of fluoride in the drinking water. The one surface difference (statistically significant, P=.015) in age-adjusted mean caries scores observed between the two communities remained after adjusting for age, use of dietary fluoride supplements, and receipt of professionally applied fluoride treatments (P=.020). Dental caries scores in occlusal surfaces of Broken Bow participants were about one surface higher than were caries scores in occlusal surfaces of Holdrege participants. In addition, the observed caries-preventive benefit from exposure to drinking water containing an optimal concentration of fluoride was greater (2.0-fold and 1.6-fold differences in mean DMFS scores between Kewanee and Broken Bow, and Kewanee and Holdrege, respectively), as compared with individualized, disease-preventive strategies (1.2-fold difference in mean DMFS scores between Holdrege and Broken Bow).

These findings suggest that replacement of other fluoride therapies by community water fluoridation probably will have a greater public health impact than the alternative of adding dental sealant placement to existing programs providing dietary fluoride supplements and professionally applied fluoride treatments. The best option, however, would be to combine community water fluoridation with a dental sealant program. The findings from this study, however, might underestimate the beneficial effects of water fluoridation in caries prevention because of the possible extension of the benefits of optimally fluoridated drinking water to residents of the fluoride-deficient communities through consumption of foods and beverages processed elsewhere with fluoridated water (26).

A small number of participants were excluded from the analyses of differences in multivariable-adjusted mean caries scores (n=10) and in bivariable-adjusted mean MPFS scores (n=2) because complete data were unavailable for sealant presence, use of dietary fluoride supplements, or use of professionally applied, topical fluoride applications. Their absence from the data base, however, did not adversely effect caries and fluorosis findings since age-adjusted DMFS and MPFS mean scores remained the same whether or not the 10 youngsters were included in the caries analyses.

MPFS scores reported in this study were combined for younger and older participants because the number of high school participants from Holdrege was small (*n*=24). It would have been preferable to have had a large enough sample of older youngsters from the Holdrege community to have conducted a more complete analysis by age subgrouping.

A number of scientific reports have shown that the relationship between dental caries and water fluoride concentration is not as clear today as it has been in the past (11,24,26-28). Residents of communities that once were designated as "nonfluoridated" because of the lack of optimal levels of fluoride in drinking water often now receive significant amounts of fluoride from other sources, such as fluoride-containing toothpaste, dietary fluoride supplements, and foods and beverages processed in fluoridated communities (11,24,26-32). Although in the present investigation significant differences were reported in the use of dietary fluoride supplements and receipt of professionally applied fluoride treatments by Broken Bow and Holdrege study participants, the one surface difference (*P*=.015) in age-adjusted mean caries scores observed between Broken Bow (3.7 DMFS) and Holdrege (2.6 DMFS) remained after adjusting for age and use of the aforementioned fluoride therapies (*P*=.020). There are two important limitations to this analysis. First, data regarding use of these fluoride therapies relied on parents' recall of past events that may not have been totally accurate. Second, the dosage schedule followed by each child for dietary fluoride supplementation and the level of compliance are unknown. In future surveys of dental caries and dental fluorosis, information regarding sources of fluoride exposure should be validated.

As dental caries in permanent teeth has become predominately a disease of the pits and fissures in both fluoridated and nonfluoridated communities (33), dental sealants can provide additional protection for pit and fissure surfaces beyond that afforded by fluoride therapy alone (34,35). Fluorides provide their greatest relative protection to smooth tooth surfaces; however, because pit and fissure lesions are the most prevalent caries type, the greatest absolute benefit of fluoride therapy accrues to the pit and fissure surfaces (36). Findings from the present survey suggest that dental sealants likely contributed substantially to the reduced caries levels observed in occlusal surfaces of participants from Holdrege in comparison with their peers from Broken Bow. The mean caries score in occlusal surfaces of participants residing in Holdrege was significantly lower than the mean score in occlusal surfaces observed for participants from Broken Bow (Table 3). In addition, the one surface difference in overall mean DMFS scores (age-adjusted) observed between Broken Bow and Holdrege did not remain after adjusting for age and sealant presence (*P*=.19). A comparison of mean number of decayed surfaces (DS), mean number of missing tooth surfaces (MS), and mean number of filled surfaces (FS) by community indicates that there were no apparent differences in levels of restorative care (mean FS scores) provided to participants from Holdrege or Broken Bow (or Kewanee); rather, the observed difference in caries experience between Broken Bow and Holdrege (or Kewanee) was reflected in the larger number of untreated carious lesions in Broken Bow participants.

In comparison with studies undertaken in past decades, the difference in fluorosis prevalence between fluoridated and nonfluoridated communities has narrowed considerably (25). Findings from the present survey appear to support this premise. The mean percentage of fluorosed tooth surfaces per person for all participants in the three communities was similar, about 15 percent. Also, in each of the three communities, more than 80 percent of tooth surfaces were fluorosis-free in both age groups; of the relatively small percentage of tooth surfaces affected with dental fluorosis, most showed minimal levels of whitish discoloration (Tables 4 and 5).

Since the 1980s, there has been a growing concern that the ingestion of fluoride from multiple sources in both fluoridated and nonfluoridated communities has increased significantly, and that this may have caused a concomitant increase in the prevalence of dental fluorosis (10,12,37). In nonfluoridated and optimally fluoridated areas, reports of higher prevalences of dental fluorosis through the 1980s have been confined mainly to the milder levels (categories) of the condition (13). Many investigators have concluded that the use of fluoride supplements during the first six years of life increases the risk of dental fluorosis (32). Yet, their overall contribution to the increase in the prevalence of dental fluorosis may be less than that attributed to water fluoridation and fluoride-containing toothpaste because their use usually is more limited and shorter in duration (32).

Stephen et al. (38) have suggested that study results assessing the association between the use of dietary fluoride supplements and dental fluorosis may be influenced by participants' ingestion of other sources of fluoride. A few studies have been reported in which the investigators found no relation between the use of dietary fluoride supplements and dental fluorosis (29,38,39). For the latter studies, however, the lack of a significant association between dietary fluoride supplement use and dental fluorosis could have resulted from such influences as poor patient compliance with the recommended dietary fluoride regimen or commencement of supplement utilization after the critical period of tooth formation. Results of the present study suggest that, although the more prevalent use of dietary fluoride supplements in Holdrege may have contributed to reduced caries levels among its residents, this source of fluoride was not associated with a significant increase in the prevalence of dental fluorosis over that detected in residents of the other community having a low water fluoride level and a significantly lower use of dietary fluoride supplements (dental caries scores, Table 2; MPFS scores, Table 5; fluoride history, Table 6).

Survey findings for dental fluorosis in Kewanee (optimal concentration of fluoride in drinking water) and Broken Bow and Holdrege (low levels of fluoride in drinking water) suggest that dental fluorosis may not be a public health problem in these communities. Greater than 80 percent of tooth surfaces were diagnosed as fluorosis free in older as well as younger participants; of those surfaces affected, the majority showed whitish discoloration involving less than one-third of the tooth surface (Table 4). The ultimate determination, however, of the aesthetic impact of observed dental fluorosis rests with the residents of the communities. Reports of studies that assessed dental caries and dental fluorosis in populations within Nova Scotia, Canada (28), and Antigua, West Indies (40), showed that examined children (having distributions of fluorosed tooth surfaces similar to those of the present study) did not perceive any esthetic problem with dental fluorosis. Recent reports of increased dental fluorosis, particularly in nonfluoridated areas, however, underscore the need to conduct studies designed to gain knowledge regarding public perceptions and degree of concern related to dental fluorosis (13,41).

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References

1. Glass RL, ed. The first international conference on the declining prevalence of dental caries. Dent Res 1982;61(Spec Iss): 1301-83.
2. Leverett DH. Fluorides and the changing prevalence of dental caries. Science 1982; 217:26-30.
3. Stamm JW. Is there a need for dental sealants? Epidemiological indications in the 1980s. J Dent Educ 1984;48(Suppl):9-17.
4. Brunelle JA. Oral health of United States children. The national survey of dental caries in US schoolchildren: 1986-87. National and regional findings. NIH pub no 89-2247. Washington, DC: US Department of Health and Human Services, 1989.
5. Brunelle JA, Carlos JP. Recent trends in dental caries in US children and the effect of water fluoridation. J Dent Res 1990; 69(Spec Iss):723-7.
6. Naylor MN, ed. Second international conference on changing caries prevalence. Int Dent J 1994;44:363-458.
7. Graves RC, Stamm JW. Oral health status in the United States: prevalence of dental caries. J Dent Educ 1985;49:341-51.
8. Newbrun E. Effectiveness of water fluoridation. J Public Health Dent 1989; 49:279-89.
9. Horowitz HS. Appropriate uses of fluoride: considerations for the '90s. Introductory paper. J Public Health Dent 1991;51: 20-2.
10. Szpunar SM, Burt BA. Trends in the prevalence of dental fluorosis in the United States: a review. J Public Health Dent 1987;47:71-9.
11. Kumar JV, Green EL, Wallace W, Carnahan T. Trends in dental fluorosis and dental caries prevalences in Newburgh and Kingston, NY. A J Public Health 1989;79:565-9.
12. Burt BA. The changing patterns of systemic fluoride intake. J Dent Res 1992;71: 1228-37.
13. Department of Health and Human Services, US Public Health Service. Review of fluoride benefits and risks. Report of the Ad Hoc Subcommittee on Fluoride of the Committee to Coordinate Environmental Health and Related Programs. Washington, DC: US Public Health Service, 1991.
14. Horowitz HS, Driscoll WS, Meyers RJ, Heifetz SB, Kingman A. A new method for assessing the prevalence of dental fluorosis — the Tooth Surface Index of Fluorosis. J Am Dent Assoc 1984;109:37-41.
15. Driscoll WS, Heifetz SB, Horowitz HS, Kingman A, Meyers RJ, Zimmerman ER. Prevalence of dental caries and dental fluorosis in areas with optimal and above-optimal water fluoride concentrations. J Am Dent Assoc 1983;107:42-7.
16. Driscoll WS, Horowitz HS, Meyers RJ, Heifetz SB, Kingman A, Zimmerman ER. Prevalence of dental caries and dental fluorosis in areas with negligible, optimal, and above-optimal fluoride concentrations in drinking water. J Am Dent Assoc 1986;113:29-33.
17. Heifetz SB, Driscoll WS, Horowitz HS, Kingman A. Prevalence of dental caries and dental fluorosis in areas with optimal and above-optimal water-fluoride concentrations: a 5-year follow-up survey. J Am Dent Assoc 1988:116:490-5.
18. Selwitz RH, Nowjack-Raymer R, Kingman A, Driscoll WS. Prevalence of dental caries and dental fluorosis in areas with optimal and above-optimal water fluoride concentrations: a 10-year follow-up survey. J Public Health Dent 1995;55:85-93.
19. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159-74.
20. Radike AW. Criteria for diagnosis of dental caries. In: Proceedings of the conference on the clinical testing of cariostatic agents. Chicago: American Dental Association 1972;72:87-8.
21. SAS Institute Inc. SAS/STAT user's guide. Version 6. 4th ed. Vol 2. Cary, NC: SAS Institute, 1990:891-6.
22. SAS Institute Inc. SAS procedures guide. Version 6. 3rd ed. Cary, NC: SAS Institute, 1990:325-36.
23. Kleinbaum DG, Kupper LL, Muller KE. Applied regression analysis and other multivariable methods. 2nd ed. Boston: PWS-Kent Publishing Company, 1988: 30-2.
24. Newbrun E. Effectiveness of water fluoridation. J Public Health Dent 1989; 49:279-89.
25. Lewis DW, Banting DW. Water fluoridation: current effectiveness and dental fluorosis. Community Dent Oral Epidemiol 1994;22:153-8.
26. Ripa LW. A half-century of community water fluoridation in the United States: review and commentary. J Public Health Dent 1993;53:17-44.
27. Ismail AI, Brodeur J-M, Kavanagh M, Boisclair G, Tessier C, Picotte L. Prevalence of dental caries and dental fluorosis in students, 11-17 years of age, in fluoridated and nonfluoridated cities in Quebec. Caries Res 1990;24:290-7.
28. Ismail AI, Shoveller J, Langile D, MacInnis WA, McNally M. Should the drinking water of Truro, Nova Scotia, be fluoridated? Water fluoridation in the 1990s. Community Dent Oral Epidemiol 1993; 21:118-25.
29. Bagramian RA, Narendran S, Ward M. Relationship of dental caries and fluorosis to fluoride supplement history in a nonfluoridated sample of schoolchildren. Adv Dent Res 1989;3:161-7.
30. Pendrys DG, Stamm JW. Relationship of total fluoride intake to beneficial effects and enamel fluorosis. J Dent Res 1990;69: 529-38.
31. Clark DC. Trends in prevalence of dental fluorosis in North America. Community Dent Oral Epidemiol 1994;22:148-52.
32. Ismail AI. Fluoride supplements: current effectiveness, side effects, and recommendations. Community Dent Oral Epidemiol 1994;22:164-72.
33. Garcia AI. Caries incidence and costs of prevention programs. J Public Health Dent 1989;49:259-71.
34. Weintraub JA. The effectiveness of pit and fissure sealants. J Public Health Dent 1989;49:317-30.
35. Mandel ID. Dental caries: another extinct disease? In: Bowen WH, Tabak LA, eds. Cariology for the nineties. Rochester, NY: University of Rochester Press, 1993: 1-10.
36. Ripa LW. A critique of topical fluoride methods (dentifrices, mouthrinses, operator-, and self-applied gels) in an era of decreased caries and increased fluorosis prevalence. J Public Health Dent 1991; 51:23-41.
37. Leverett D. Prevalence of dental fluorosis in fluoridated and nonfluoridated communities — a preliminary investigation. J Public Health Dent 1986;46:184-7.
38. Stephen KW, McCall DR, Gilmour WH. Incisor enamel mottling prevalence in child cohorts which had or had not taken fluoride supplements from 0–12 years of age. Proc Finn Dent Soc 1991;87:595-605.
39. Szpunar SM, Burt BA. Dental caries, fluorosis, and fluoride exposure in Michigan schoolchildren. J Dent Res 1988;67:802-6.
40. Vignarajah S. Dental caries experience and enamel opacities in children residing in urban and rural areas of Antigua with different levels of natural fluoride in drinking water. Community Dent Health 1993;10:159-66.
41. Report for working group II: strategies for improving the assessment of dental fluorosis. In: Selwitz RH, ed. Proceedings of the workshop on methods for assessing fluoride accumulation and effects in the body. Adv Dent Res 1994;8:116-17.