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Patterns of dental caries following the cessation of water fluoridation

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Abstract – *Objectives:* To compare prevalence and incidence of caries between fluoridation-ended and still-fluoridated communities in British Columbia, Canada, from a baseline survey and after three years. *Methods:* At the baseline (1993/4 academic year) and follow-up (1996/7) surveys, children were examined at their schools. Data were collected on snacking, oral hygiene, exposure to fluoride technologies, and socio-economic level. These variables were used together with D1D2MFS indices in multiple regression models. *Results:* The prevalence of caries (assessed in 5927 children, grades 2, 3, 8, 9) decreased over time in the fluoridation-ended community while remaining unchanged in the fluoridated community. While numbers of filled surfaces did not vary between surveys, sealed surfaces increased at both study sites. Caries incidence (assessed in 2994 life-long residents, grades 5, 6, 11, 12) expressed in terms of D1D2MFS was not different between the still-fluoridating and fluoridation-ended communities. There were, however, differences in caries experienced when D1D2MFS components and surfaces at risk were investigated in detail. Regression models did not identify specific variables markedly affecting changes in the incidence of dental decay. *Conclusions:* Our results suggest a complicated pattern of disease following cessation of fluoridation. Multiple sources of fluoride besides water fluoridation have made it more difficult to detect changes in the epidemiological profile of a population with generally low caries experience, and living in an affluent setting with widely accessible dental services. There are, however, subtle differences in caries and caries treatment experience between children living in fluoridated and fluoridation-ended areas.

Key words: caries; epidemiology; fluoridation; incidence; prevalence

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In the last 30 years, oral health in North America has improved dramatically (1, 2), although there are still significant oral health needs in some subgroups (3, 4). Much of the improvement in dental caries is attributed to the widespread use of fluorides (5, 6). Despite this generally held opinion, the literature fails to provide good current estimates for the effectiveness of water fluoridation, either alone or when used in conjunction with the many other available fluoride technologies (7–9). During the 1980s and 1990s, considerable attention has been paid to the safety and effectiveness of fluorides (5–11). This renewed scientific concern is being driven by the fragmented but constantly-present opposition to water fluoridation (12, 13), the changing trends of caries (2, 3, 14, 15), the complex exposures and ingestion patterns of fluoride (16–18), the need to balance fluorosis risk through adjusting the total amount of fluoride ingested from numerous sources (12, 19–23), the (still poorly-understood) effects of fluoride on bone (11), and the paucity of current data on fluorides (6, 8, 19, 24). Accordingly, there is still a need to estimate the caries-preventive benefits from fluoridated water (25). Considerably less attention has been devoted to the issue of cessation of fluoridation.

While historically the evidence for the effectiveness of water fluoridation was substantial, it is increasingly difficult to conduct controlled research on this topic due to ethical and logistical considerations. An opportunity is offered when the exposure is removed (26). There are relatively few studies reporting changes in decay in primary teeth after the fluoridation of water supplies is stopped (27–30) but, similar to the results in permanent teeth, the removal of fluoride was historically associated with increases in caries. A recent study reporting only permanent tooth data (31) found that, after fluoridation ceased in 1990, caries levels continued to decrease. This result, unexpected in relation to earlier findings (28), might be ascribed to diverse fluoride technologies that possibly mask the effect of water fluoridation being discontinued. Therefore, a re-examination of the current relevance of the association between fluoride in water and caries seems warranted, since this link was established mostly using pre-1975 data (32, 33). Consequently, the relationship between levels of dental caries and varying fluoride exposures may have changed. The opportunity to re-examine such relationship after cessation of water fluoridation occurred in British Columbia (BC), Canada. Results of referenda in 1992 in Comox/Courtenay and Campbell River led to the discontinuation of water fluoridation after being fluoridated for approximately 25 years. Kamloops voted to continue to fluoridate, and thus served as a positive control.

The present report outlines the results for caries D1D2MFS prevalence for participants living in the fluoridation-ended and the fluoridated sites between baseline and after 3 years, as well as a comparison of the incidence accrued during the 3 years from 1993/4 to 1996/7.

Material and methods

Procedure

This multi-site study is both a repeated cross-sectional prevalence survey and a longitudinal investigation. The baseline survey was carried out during the 1993/4 academic year and the follow-up occurred in 1996/7. On average, children were re-examined 36 months after baseline. All children were examined at their schools using methods previously reported (34, 35). Informed consent was sought from parents and children at baseline and at the follow-up, as approved by the Ethical Review Board of the University of British Columbia.

For dental caries, the clinical examination utilized a modified D1D2MFS Index (36) for incipient and cavitated lesions. Briefly, an incipient lesion (D1) was scored when there was evidence of (i) incipient decay on a pit-and-fissured (PF) surface (white chalky enamel or softness) or (ii) a chalky white spot on a smooth surface that did not appear glossy after drying. A cavitated lesion was scored (D2) on both PF and smooth tooth surfaces. No cleaning of teeth was undertaken before examinations. The same four examiners participated at the same sites at both examinations. Examiners were trained and calibrated twice during each examination series. Inter- and intra-examiner duplicate examinations were performed on randomly selected participants. A pre-tested questionnaire was employed for collecting data on snacking, oral hygiene, exposure to diverse fluoride technologies, and socio-economic status.

Prevalence and incidence data

Attempts were made to contact all participants from the 1993/4 survey for the follow-up, hoping to examine all original participants who were in grades 2, 3, 8 and 9 in 1993/4, and who were in grades 5, 6, 11 and 12 in 1996/7. We also targeted all new children in grades 2, 3, 8 and 9 in 1996/7. The actual fluoridation of water had been terminated approximately 14 months prior to initiation of the baseline examinations, which took about 5 months to complete. Therefore, at baseline children were examined anywhere from 14 to 19 months after the fluoridation stopped.

Prevalence figures were thus obtained for children in grades 2, 3, 8 and 9 at baseline and at the follow-up survey, and incidence figures obtained for continuous participants in the study in grades 5, 6, 11 and 12 in the 1996/7 survey.

Only permanent teeth were included in this study. Because the proportion of tooth surfaces at risk appeared to change over the study interval (due mainly to increased sealant use (35)), caries attack rates were calculated as proportions per 100 surfaces at risk during the 36 months of the follow-up (37). Surfaces at risk were those surfaces which had erupted and which were not sealed at baseline. Since recurrent decay was found to be minuscule overall ($<0.1\%$) (35), whether a surface was filled or not was deemed not to affect caries attack rates. Prevalence and incidence variables were D1D2MFS, D1S, and D2S (all surfaces); D1D2MFS, D1S, and D2S per 100 tooth surfaces at risk (100AR); and D1D2MFS, D1S, and D2S per 100 pit-and-fissured tooth surfaces at risk (100PFAR). The separate inclusion of indices only for surfaces at risk aimed to reduce the effects of professional treatment on incidence data.

Data were analyzed as required using descriptive statistics, Cohen's kappa, one-way ANOVA and Student's *t*-test. Level of statistical significance was 0.05.

Regression analyses

Step-wise (backward elimination) multiple regression models were developed with the D1D2MFS indices and their components as dependent variables. These were used in three series of analyses. One included all subjects and prevalence data. The second series included all lifelong residents in the longitudinal cohort. The last one included incidence data for only those lifelong residents whose D1D2MFS was greater than zero at the baseline examination. This latter series was included in an attempt to explain the pattern of disease in study subjects with caries, and to reduce possible dilution of effects from subjects with no caries activity. Independent variables included residence in either fluoridated or fluoridation-ended study sites (SITE), AGE and gender (SEX). Generated Variables derived from questionnaire data included:

1. A composite measure of socio-economic level attained through separate appraisals of parental levels of schooling, and frequency of dental attendance (SES);
2. pre- and post-eruptive exposure to fluorides through the use of fluoride supplements (FSUPTOT);
3. post-eruptive exposure to fluorides through assessing the frequency of mouthrinsing and toothbrushing with home care products containing fluoride (REGIME);
4. a picture-based evaluation of the amount of toothpaste used in the first 4 years of life as a proxy measure for swallowing toothpaste, either considering a combination of toothbrushing frequency with amount of toothpaste reportedly used (SWALLOW1) or just the amount of toothpaste (SWALLOW2); and
5. an assessment of overall snacking practices (including beverages) (SNACKS).

Results

Basic results

Basic demographic information is presented in Table 1, depicting actual numbers of participants

Table 1. D1D2MFS, FS and sealed surfaces prevalence in participants from fluoridation-ended (F-E) and still-fluoridated (S-E) sites by grade – all residents

Study site/grades	Measure	1993/4 Survey	1996/7 Survey	*P*-value‡
F-E 2 & 3	Actual number	1468	1067	n/a*
	Mean age	8.3	8.2	NSSD†
	D1D2MFS	1.29±2.10	0.63±1.69	$P<0.01$
	FS	0.41	0.36	NSSD†
	Surfaces sealed	1.97±1.76	2.39±2.24	$P<0.0001$
S-E 2 & 3	Actual number	1239	1111	n/a*
	Mean age	8.3	8.3	NSSD†
	D1D2MFS	0.37±1.11	0.30±0.94	NSSD†
	FS	0.20	0.17	NSSD†
	Surfaces sealed	1.29±1.73	1.67±1.96	$P<0.0001$
F-E 8 & 9	Actual number	1716	1144	n/a*
	Mean age	14.3	14.3	NSSD†
	D1D2MFS	4.93±6.43	3.68±5.67	$P<0.01$
	FS	3.05	2.71	NSSD†
	Surfaces sealed	4.82±4.91	5.96±5.36	$P<0.0001$
S-E 8 & 9	Actual number	1504	608	n/a*
	Mean age	14.4	14.3	NSSD†
	D1D2MFS	2.27±3.88	2.41±4.58	NSSD†
	FS	1.91	1.98	NSSD†
	Surfaces sealed	4.21±4.94	5.41±5.34	$P<0.0001$

* Not applicable.
† Not statistically significantly different.
‡ Student's *t*-test.

Table 2. D1D2MFS, D1S, D2S and sealed surfaces prevalence for all participants from fluoridation-ended (F-E) and still-fluoridated (S-E) sites by grade – 1996/7 survey*

Study sites/grades	Surfaces sealed	All surfaces			100 Surfaces at risk			100 Pit-and-fissured surfaces at risk		
		D1D2MFS	D1S	D2S	D1D2MFS 100AR	D1S 100AR	D2S 100AR	D1D2MFS 100PFAR	D1S 100PFAR	D2S 100PFAR
F-E 2 & 3	2.39±2.24	0.63±1.69	0.22±0.82	0.04±0.45†	0.92±2.56	0.42±1.49	0.10±1.39	7.02±18.42	1.14±6.51	0.35±2.93
S-F 2 & 3	1.67±1.96	0.30±0.94	0.06±0.35	0.07±0.35†	0.46±1.47	0.12±0.73	0.15±0.80	4.07±12.88	0.59±4.56	0.96±4.95
F-E 8 & 9	5.96±5.36	3.68±5.67	0.87±2.38	0.08±0.44	2.13±3.20	0.68±1.81	0.06±0.32	13.59±18.59	0.72±2.92	0.22±1.24
S-F 8 & 9	5.41±5.34	2.41±4.58	0.25±1.14	0.18±0.70	1.37±2.57	0.19±0.89	0.13±0.53	9.60±14.53	0.42±1.94	0.66±2.65

* Differences in prevalence scores between the F-E and the S-F sites were statistically significant.
† Difference was not statistically significant (P=0.082).
P-value=0.082.

by study site; grade; and mean age of each group in the two surveys. Overall gender distribution was 51% females in the 1996/7 survey.

Combined intra-examiner reliability for D1D2MFS (98 cases) at follow-up was high (kappa=0.80), as was combined inter-examiner reliability (155 cases) (kappa=0.74). Reliability data for baseline were also high and have been reported elsewhere (38).

Prevalence results

D1D2MFS prevalence scores were significantly lower in 1996/7 than 1993/4 only for the fluoridation-ended site for participants attending grades 2, 3, 8 and 9 ($P<0.01$) (Table 1). Prevalence data on filled surfaces did not vary significantly between surveys. The number of sealed surfaces, however, increased significantly in both study sites between the surveys.

D1S, D2S and D1D2MFS prevalence results for the 1996/7 survey are emphasized further in Table 2. Comparisons of the scores between fluoridated and fluoridation-ended sites indicated that most scores were statistically significantly different, except for D2S in grades 2 and 3. D1S and D1D2MFS scores were consistently higher at the fluoridation-ended sites while D2S scores were consistently higher at the fluoridated site.

Incidence results

Follow-up rate at 3 years was 64.2%. Under a framework whereby only 79.8% of baseline participants were lifelong residents, we were able to gather information usable at follow-up for 51.2% of the entire baseline population (57.5% still-fluoridated site, 45.1% fluoridation-ended site). Almost 90% of all eligible children in the study sites were examined at baseline (35), and showed similar SES and demographic features.

Incidence rates for components of the D1D2MFS indices are shown in Tables 3 to 5 only for participants who were lifelong residents of the study sites (39). Tables 4 and 5 include only those tooth surfaces that had erupted, and were not sealed, at baseline.

Data for all tooth surfaces, 100AR, and 100PFAR suggested that, in general, the untreated decay components of caries incidence were lower in the fluoridation-ended sites for both incipient and cavitated decay. While trends from both sites suggested that changes over time were generally small, the fluoridation-ended site always had small negative changes while the fluoridated site remained static

Table 3. D1D2MFS incidence for lifelong residents from fluoridation-ended (F-E) and still-fluoridated (S-E) sites by age group – all surfaces

	Caries incidence after three years					
Study site/grades	*n*	D1	D2	FS	D1D2MFS	D1D2MFS Percent difference
F-E 5 & 6	775	−0.21*	−0.05*	0.89*	0.63±2.37	
S-F 5 & 6	701	0.02*	0.06*	0.42*	0.50±1.59	20.6%
F-E 11 & 12	640	−0.33*	−0.06*	2.68*	2.29±5.60	
S-F 11 & 12	878	0.07*	0.06*	1.69*	1.82±4.21	20.5%

* Differences in incidence scores between F-E and S-F communities that were statistically significant.

Table 4. D1D2MFS incidence for lifelong residents from fluoridation-ended (F-E) and still-fluoridated (S-E) sites by age group – 100 tooth surfaces at risk*

	Caries incidence after three years – 100AR					
Study site/grades	*n*	D1	D2	FS	D1D2MFS	D1D2MFS Percent difference
F-E 5 & 6	775	−0.01	−0.04†	1.11†	1.06†±2.91	
S-F 5 & 6	701	0.05	0.07†	0.53†	0.65†±1.93	38.6%
F-E 11 & 12	640	−0.24†	−0.04†	2.01†	1.73±4.10	
S-F 11 & 12	878	0.05†	0.05†	1.28†	1.38±3.10	20.2%

* 100 tooth surfaces at risk indicate the caries attack rate over the 36 months of follow-up for all tooth surfaces combined.
† Differences in incidence scores between F-E and S-F communities that are statistically significant.

Table 5. D1D2MFS incidence for lifelong residents from fluoridation-ended (F-E) and still-fluoridated (S-E) sites by age group – 100 Pit-and-Fissured tooth surfaces at risk*

	Caries incidence after 3 years – 100PFAR					
Study site/grades	*n*	D1	D2	FS	D1D2MFS	D1D2MFS Percent difference
F-E 5 & 6	775	−1.14†	−0.59†	8.19†	6.46†±19.34	
S-F 5 & 6	701	0.07†	0.34†	3.50†	3.91†±12.68	39.4%
F-E 11 & 12	640	−0.51	−0.43†	9.34†	8.40†±13.79	
S-F 11 & 12	878	−0.23	0.14†	6.44†	6.35†±11.74	24.4%

* 100 Pit-and-Fissured tooth surfaces at risk indicate the caries attack rate over the 36 months of follow-up only for pit-and-fissured tooth surfaces.
† Differences in incidence scores between F-E and S-F communities that are statistically significant, $P<0.01$.

or had little increment. These phenomena were offset by more surfaces being filled in children living in the fluoridation-ended site (for all tooth surfaces, 100AR, and 100PFAR). In other words, most of the decay incidence overall was detected in the Filled component, while the Decayed component was usually small.

The summing of D1S and D2S changes with the overall increase in FS led to no significant differences between sites when D1D2MFS for all surfaces was compared (Table 3). This contrast was modified when 100AR were used to assess caries incidence (only the group in grades 5 and 6 was different – Table 4), as well as in the case of 100PFAR (groups in grades 5, 6, 11 and 12 were different – Table 5): D1D2MFS patterns suggested that the fluoridation-ended site had higher D1D2MFS incidence figures than the fluoridated site. It is noteworthy that these trends were particularly apparent when the protective effect of sealants was controlled for through the separate appraisal of only surfaces at risk (Tables 4 and 5).

Regression analysis results

Prevalence model/all subjects

Twelve exploratory multiple stepwise models re-

Table 6. Multiple stepwise regression analyses, regressing prevalence D1D2MFS and its components on socio-demographic and generated variables – all residents

Dependent variable	(Constant)	Age	Sex	SES	Site	Snacks	Swal1	Swal2	Regime	FSUPTOT	R^2
D1D2MFS All surfaces	−0.199§	0.184‡	–	−0.083‡	−0.353‡	0.05*	–	–	–	–	0.058
D1S All surfaces	0.535‡	0.038‡	–	−0.035‡	−0.259‡	–	−0.012‡	0.017‡	–	–	0.052
D2S All surfaces	0.071*	–	–	−0.015‡	0.048‡	–	–	–	–	–	0.009
D1D2MFS Pit-and-fissured surfaces	−0.200§	0.127‡	–	−0.055‡	−0.128†	–	–	–	–	–	0.044
D1S Pit-and-fissured surfaces	0.178‡	0.008†	−0.304†	−0.013‡	−0.054‡	–	–	–	–	–	0.019
D2S Pit-and-fissured surfaces	0.019§	–	–	−0.010‡	0.055‡	–	–	–	–	–	0.012
D1D2MFS100AR	1.079‡	0.089‡	–	−0.089‡	−0.431‡	–	–	–	–	–	0.032
D1S100AR	0.821‡	0.021*	–	−0.041‡	−0.289‡	–	−0.013†	0.017†	–	–	0.042
D2S100AR	0.061§	–	–	−0.016‡	0.068‡	–	–	–	–	–	0.010
D1D2MFS100PFAR	3.585§	0.699‡	–	−0.566‡	−2.885‡	–	–	–	1.864*	–	0.022
D1S100PFAR	3.053‡	–	–	−0.173‡	−0.800‡	–	–	–	–	–	0.010
D2S100PFAR	−0.067§	–	–	−0.093†	0.708‡	–	–	–	–	0.045*	0.013

* $P<0.05$.
† $P<0.01$.
‡ $P<0.001$.
§ Non-significant.

Table 7. Multiple stepwise regression analyses, regressing incidence D1D2MFS and its components on socio-demographic and generated variables – all lifelong residents

Dependent variable	(Constant)	Age	SES	Site	Snacks	Swal1	Swal2	Regime	FSUPTOT	R^2
D1D2MFS All surfaces	−2.136†	0.413‡	−0.143†	–	–	–	–	–	−0.087*	0.092
D1S All surfaces	0.290§	–	–	−0.268*	–	–	–	–	–	0.012
D2S All surfaces	−0.433‡	0.047‡	–	–	–	–	–	–	−0.014*	0.035
D1D2MFS Pit-and-fissured surfaces	−0.708§	0.173‡	−0.074*	–	–	–	–	–	–	0.057
D1S Pit-and-fissured surfaces	0.050§	–	–	−0.144*	–	–	0.010*	–	–	0.027
D2S Pit-and-fissured surfaces	–	–	–	–	–	–	–	–	–	–
D1D2MFS100AR	−1.250§	0.197†	−0.124*	0.624†	–	–	–	–	–	0.045
D1S100AR	−0.273§	–	–	–	–	−0.014*	–	–	–	0.011
D2S100AR	−0.278†	0.028†	–	–	–	–	–	–	–	0.017
D1D2MFS100PFAR	−2.424§	–	–	4.675†	–	–	–	–	–	0.019
D1S100PFAR	−1.613†	–	–	–	–	–	0.173†	–	–	0.023
D2S100PFAR	–	–	–	–	–	–	–	–	–	–

* $P<0.05$.
† $P<0.01$.
‡ $P<0.001$.
§ Non-significant.

gressed the various D1D2MFS indices and their components on the socio-demographic variables and Generated Variables (Table 6). Besides SITE and SES and to a lesser extent AGE, few other independent variables were significant in the models. The extent of the variation explained was usually small. Lower SES and higher AGE were associated with higher caries activity. The effect of SITE depended on which caries index was examined: in the still-fluoridated site, higher scores were found for non-cavitated lesions (D1) and the complete D1D2MFS indices. By contrast, in the fluoridation-ended site, higher scores were present for cavitated lesions (D2) (Table 6).

Incidence model/all subjects

The most significant variable was AGE. The proportion of variation explained by this variable, however, was small. Other significant variables were whether the study SITE was fluoridated or not, and SES. Most independent variables were, however, not significant. Significant models can be summarized by saying that age, socio-economic status and, to a lesser extent, past use of fluoride supplements were

Table 8. Multiple stepwise regression analyses, regressing incidence D1D2MFS and its components on socio-demographic and generated variables – only for lifelong residents who were not D1D2MFS=0 at baseline

Dependent variable	(Constant)	Age	SES	Site	Snacks	Swal1	Swal2	Regime	FSUPTOT	R^2
D1D2MFS All surfaces	−2.992§	0.632‡	−0.366*	–	–	–	–	–	–	0.156
D1S All surfaces	–	–	–	–	–	–	–	–	–	–
D2S All surfaces	−1.039‡	0.102‡	–	–	–	–	–	–	0.038*	0.099
D1D2MFS Pit-and-fissured surfaces	−1.902*	0.281‡	–	–	–	–	–	–	–	0.821
D1S Pit-and-fissured surfaces	−0.572‡	–	–	–	–	–	0.032*	–	–	0.043
D2S Pit-and-fissured surfaces	–	–	–	–	–	–	–	–	–	–
D1D2MFS100AR	–	–	–	–	–	–	–	–	–	–
D1S100AR	–	–	–	–	–	–	–	–	–	–
D2S100AR	−0.723‡	0.064†	–	–	–	–	–	–	–	0.058
D1D2MFS100PFAR	–	–	–	–	–	–	–	–	–	–
D1S100PFAR	−5.232‡	–	–	–	–	–	0.485†	–	–	0.069
D2S100PFAR	–	–	–	–	–	–	–	–	–	–

* $P<0.05$.
† $P<0.01$.
‡ $P<0.001$.
§ Non-significant.

associated with the overall D1D2MFS increment (Table 7). D1D2MFS100PFAR was also related to socio-economic status. Increments for early carious lesions overall and on pit-and-fissured surfaces were indeed associated with the fluoridation status of the communities under study, but this relationship was not significant when cavitated lesion increments were analyzed. Age and past use of fluoride supplements were associated with this more advanced stage of decay overall, but not on pit-and-fissured surfaces. As with the prevalence results, lower SES and higher AGE were associated with higher caries activity. The effect of SITE for incidence results was not as clear cut as in the case of prevalence results. SITE was only a significant predictor in four of the 12 models – two of the models indicated that the still-fluoridated site had lower caries experience, while the other two had higher experience; however, the latter models were limited to at-risk surfaces (Table 7).

Incidence model/subjects who at baseline had D1D2MFS>0

Most independent variables were not significant (Table 8). Age appeared in four models; higher AGE was associated with higher caries activity. SES only appeared in the models once, again in relation to D1D2MFS, and SITE was never significant.

Discussion

This study investigated the impact of stopping water fluoridation using concurrent positive controls and a longitudinal design. This study was unique in that it used a modified D1D2MFS index that permitted detailed investigation of the relative changes in smooth and PF surfaces over time. Furthermore, caries attack rates were calculated which adjusted for the number of surfaces at risk and presented a more accurate measurement of disease activity than traditional DMFT or DMFS indices. Despite these strengths, a possible disadvantage was the likelihood that the questionnaire information may be suspect on account of recall bias. Another shortcoming was the hiatus between actual cessation of water fluoridation and the beginning of data collection. The fact that examiners were different for each study site and were not blinded to its fluoridation status detracts from an ideal design. Moreover, the very low levels of decay found at baseline and at follow-up suggest that, while valuable, findings from the present age cohorts may not be depicting the situation in the segments of the population more severely affected by caries activity. It is not a rhetorical question to ask ourselves if continued epidemiologic attention to the younger age groups in this day and age is wasting an opportunity to re-focus such attention to other groups, perhaps at increased caries risk, such as middle-aged adults and dentate elderly people.

The current context in which these results are presented differs greatly from the North American context of widespread dental decay 50 years ago, in which the benefit of water fluoridation could be unequivocally appreciated. The fact that caries experience has changed over time has led to new perceptions with regard to the trade-off between risk of decay and use of fluorides. There is no doubt that diminishing benefits in dental decay prevention associated with fluoridation measures warrant a re-examination of the issue, in particular in the epidemiological context of developed countries with widespread use of fluoride in many forms. Such re-examination of the evidence should take into account the public health nature of the measure. Since the ranges of treatment and preventive needs are wide, some segments of the population derive small direct benefits from having controlled exposure to fluorides while others benefit greatly from it. Dental caries is not only unequally distributed but also can be a serious problem in the younger age groups (2, 3) in North America. While great variation exists in this regard from one country to another, and within the same country, the groups that would benefit the most from the preventive effect of fluorides are usually the least able to access rehabilitative care to deal with established disease.

A direct comparison of our results with other publications is not straightforward. Some reports on the cessation of water fluoridation in settings still affected by relatively high caries activity have indicated that, after stopping fluoridation, caries experience increases (27, 29, 30). While such a phenomenon appears to be more common in primary teeth, this feature may be ascribable to the indices used in studies, or their cross-sectional designs, rather than clear-cut age differences. In some cases, cessation of water fluoridation has taken place within changing environments characterized by diminishing caries experience (26, 29, 31). The impact of stopping fluoridation is more difficult to assess accurately under those circumstances, in particular if the study design encompassed several cross-sectional samples. The decrease in caries levels reported by Künzel & Fischer (31) could be attributed to a partial offset of the effect of stopping fluoridation by introducing fluoridated domestic salt, and increased availability of fluoridated toothpastes. It is difficult to appraise the impact of these measures when more cariogenic snacks became simultaneously available and changes in the dental care system occurred. Lacking a positive control town, Kalsbeek et al. (26) found that, during a 10-year follow-up, decay levels first increased and then decreased in both a fluoridation-ended town and a never-fluoridated control town. More recently, Seppä et al. (40) found no increase in caries experience after fluoridation stopped between two cross-sectional samples of 6-, 9-, 12- and 15-year-olds who have had access to comprehensive dental services. A contrast of the roles of lay and professional preventive activities with the Finnish study is unfeasible.

How do we place the results of the present study in the larger context of the cessation of water fluoridation? British Columbia enjoys a high standard of living, with approximately 70% of the population having dental insurance (41). In adult dental office attendees, less than 5% of DMFT was DT; and 55% of people 16–45 years old were considered regular patients (41). While the last epidemiological survey in children undertaken in this affluent province of Canada took place in 1980, a comparison of those findings with another epidemiological survey in 1968–74 showed DMFT reductions of about a third of DMFT levels between the two surveys for 9-, 13- and 15-year-olds (42). Not only has the percentage of decayed teeth declined by well over 50, but also the percentage of filled teeth decreased markedly. In our investigation, although the FS prevalence figures remained similar between the baseline survey and the follow-up (Table 1), the D1D2MFS prevalence figures were substantially reduced only in the fluoridation-ended site. In general, caries experience was small (Table 2). The incidence of both non-cavitated and cavitated decay had negative increments in the fluoridation-ended site while positive incidence rates occurred consistently in the fluoridated site (with one exception, D1S in 100PFSAR) (Tables 3–5). Traditionally, after fluoridation ceases, caries experience would have been expected to increase. In the absence of professional intervention, more untreated decay would have been expected to be detectable. We postulate that, together with increasing utilization of sealants in both study sites during the follow-up interval, earlier and/or more common restorative intervention in the fluoridation-ended areas may have supported a negative trend for the D1S and D2S rates. According to this explanation, clinicians working in a fluoridated area may have different thresholds for intervention compared to clinicians whose patients no longer enjoy the benefit of fluoridated water. Under this hypothetical scenario, the clinicians in fluoridated areas would be more "comfortable" leaving certain lesions undisturbed between recalls, in contrast with the substantially higher incidence of FS in fluoridation-ended areas. Under this scenario, a surface would be filled as soon as an incipient lesion was suspected of progressing (Tables 3 to 5). Hence, the increase in the filled components accounted for a substantial proportion of the change in D1D2MFS figures. This scenario is only tenable if a more aggressive treatment philosophy evolved in the fluoridation-ended site. We lack direct evidence to that effect.

Regression analyses hinted at the general direction that variables seem to influence caries experience. Caries modeling, however, often shows that independent variables are not strong predictors of outcome. It was our expectation that whether the site of residence was fluoridated or not would explain a larger proportion of the changes to the indices (as has been found in other settings, such as the United Kingdom [27, 29, 30, 43]). This was not the case. Even socio-economic status failed to explain a substantial proportion of these changes, a link more commonly found (44). Some reports have indicated that a re-examination of the relationship between SES and caries is difficult to follow over long periods of time due to SES changes in the populations under study (29, 45). Results were as expected concerning subject age, since increasing age would lead to an increasing opportunity for a tooth to decay. Our results highlight a complicated and somewhat new picture derived from the cessation of fluoridation. Apparently, the changes in the patterns of dental caries observed in the earlier days of fluoridation as a single source of fluoride no longer apply. With multiple sources of fluoride present in modern life, it is becoming more difficult to detect changes in the epidemiological profile in a low-risk population such as ours. When assessment of the specific roles of dental and non-dental variables in shaping the epidemiological changes was attempted, we found that the predictive power of independent variables was limited. This is only to be expected if we take into account that not only was caries experience low generally, but also the variation within the independent variables failed to provide clear-cut differences between segments of the population. In the BC setting of relatively homogeneous exposure to fluorides, widespread use of fluoride toothpastes and good adherence to oral hygiene regimens, and good access to oral health care generally, the independent variables may fail to highlight substantial differences in caries experience simply because they do not exist. A contrast could be more apparent if markedly dissimilar situations prevailed to differentiate segments of the population under study, such as in the scenarios in pre-WWII North America; current situations in industrializing countries (46–48); or sub-groups within developed societies disproportionately affected by oral diseases, either young (30, 43) or mature (49).

It would appear that the intervention of the dental profession, and perhaps improved customs of oral health care at home, played an important role in shaping the epidemiological profile of this population during the follow-up interval. The use of sealants in both sites was very high (at baseline, 60% of subjects had one or more sealants present, with a mean 3.2 sealants per subject) (35) and certainly much higher than other published relevant studies. Most subjects in these communities were covered by third party dental plans, and as such are likely to be regular visitors to dental offices. While our primary focus was not to determine the effects of professional intervention on caries experience, data point to this factor as being important. A marked contrast between the present results and Finnish data (40) was that while no increase in caries took place after fluoridation had ceased, the use of sealants decreased sharply in Kuopio, Finland between the cross-sectional surveys (1992 and 1995).

Our findings suggest there are subtle differences in dental caries, and caries treatment experience, between people living in fluoridated areas and in areas in which fluoridation had ceased. We found that D1D2MFS incidence was not significantly different between communities, with large numbers of sealants placed overall, and more surfaces filled in the fluoridation-ended sites. The question after a 3-year longitudinal follow-up remains whether those changes have an impact on caries experience and its rate of progression when all other sources of fluoride, as well as preventive/rehabilitative dental care measures, are taken into account. The preventive impact of water fluoridation is of necessity different in a place with comprehensive, widely accessible dental services, and which also enjoys the benefits of various sources of fluoride that contribute to substantial overall exposure for most children. This is in agreement with the recent findings by Seppä et al. (40). In the larger scheme of things, it appears that the role of water fluoridation in supporting good oral health must be weighed against other measures that may achieve similar success but at a higher cost, such as the widespread utilization of sealants. Moreover, it is unwise to resort to restorative interventions to meet the challenge of dental decay when a primary prevention measure such as water fluoridation preserves the integrity of dental tissues overall, is less expensive, and is more effective.

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