Direct evidence concerning the 'major role' of fluoride dentifrices in the caries decline

A 6-year analytical cohort study

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The role of fluoride (F) dentifrices in caries decline was investigated by assessing the effect of variation in their use on caries scores among teenagers. The material comprised 211 subjects aged about 11 years at base line and 18 years at the last examination. Pairs of posterior bitewing radiographs were assessed by one examiner. Information concerning dental health behavior was collected by questionnaire and about treatment received from dental records. A reversal of the traditional DFS gender difference occurred during teenage years. Multivariate regression analyses showed an inverse relationship between variation in F dentifrice use and current decay (D_1S) at age 18 years ($P < 0.04$) and with caries incidence per year (D_1FS) during the whole observation period ($P < 0.02$). Total explained variance in 6-year ΔD_1FS scores was 29.8%, of which variation in toothbrushing behavior contributed 1.8 percentage points. While confirming the multifactorial nature of dental caries, these results also provided quantitative evidence for the role of variation in F dentifrice use in caries incidence and decline. □ *Dental caries; dentifrices; epidemiology; fluoride; trends*

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When it was realized that the decrease in caries prevalence had occurred both in populations with and without community or school-based caries preventive programs, it was postulated that widespread use of fluoride (F) dentifrices must have played a major role (1–3).

Randomized controlled clinical trials lasting up to 7 years have shown that use of F dentifrices on average reduces caries incidence among children and adolescents by 20% to 30% (3–5). That persons who brush their teeth frequently have less caries than those who brush less often has also been attributed to differences in exposure to F dentifrices (6–8). Further support for the role of F dentifrices in caries decline has been provided by Chesters et al. (9) and Chestnutt et al. (10), who reported that the caries increment was significantly influenced both by the frequency of toothbrushing and by the manner in which the mouth was rinsed with water after brushing. While these studies show that the use of F dentifrices probably has contributed to the observed caries decrease, they do not account for reductions of up to 85% (11, 12). They do not explain why the decline coincided with the release for sale of F dentifrices in Norway (2) but after a delay of many years in Denmark (13) and Iceland (14). Nor do they tell why the decrease in caries prevalence has continued in successive cohorts of children and adolescents with lifelong use of F dentifrices (13, 15) and why the DMF gender difference persists even though girls brush their teeth with F dentifrices more frequently than boys (12, 16). It is also difficult to explain why caries increased among Scottish 5-year-old children after two communities discontinued water fluoridation in spite of general availability of F dentifrices (17, 18) or how an increase in the market share of F dentifrices from 6% to 15% could account for a 25% to 85% reduction in caries experience among children in a Japanese town between 1975 and 1985 (19).

Considering that the caries-preventive efficacy of F dentifrices is established beyond doubt and their use is widespread in industrialized countries, it would be unethical to withhold F dentifrices from existing users to provide direct evidence for their 'major role' in the caries decrease. On the other hand, if F dentifrices are as potent a caries-preventive agent as claimed (1–3), then existing variation in the frequency of use (6–8, 20) and in rinsing practices after toothbrushing (9, 10, 21) might be used to provide some direct evidence for its likely contribution to caries decrease. Consequently, the purpose of this investigation was to study the effect of variation in F dentifrice use on caries prevalence and incidence on the basis of gender in the age range 10 to 18 years.

Materials and methods

Materials

The guardians of 495 children 10 to 12 years of age (born 1973–75) living at Voss (<0.05 mg F/l in the

Table 1. Distribution of subjects by gender, age (base line), reported oral hygiene practices, exposure to fluorides, intake of snacks, satisfaction/dissatisfaction with dental appearance, and belief in retention of natural teeth for life

		Females			Males		
Variables	Categories	*n*	%	*P*	*n*	%	Both, %
Age (years)	10–	29	29		43	39	34
	11–	56	55	NS	51	46	51
	12+	16	16		16	15	15
Toothbrushing	≤Once/day	17	17		57	53	35
	≥Twice/day	84	83	<0.001	51	47	65
Interdental	Yes	38	39		22	20	29
	No	62	61	<0.008	86	80	71
Rinsing (water) after brushing	≤Once	50	50		53	49	51
	≥Twice	50	50	NS	55	51	49
Fluoride toothpaste	Yes	99	99		107	99	99
	No	1	1	NS	1	1	1
Fluoride tablets	Yes	69	70		71	66	68
	No	30	30	NS	37	34	32
Fluoride rinses	Yes	45	45		34	31	38
	No	55	55	NS	74	69	62
Fluoride topical	6–8	14	14		20	18	16
	9–11	78	78	NS	73	67	72
	12–14	8	8		16	15	12
Sweets	≤Once/day	82	82		87	81	82
	2–3	12	12	NS	14	13	13
	4+	6	6		6	6	6
Sugar/sugar-free	Always/mostly sugar	6	6		22	21	13
	Half-and-half	34	34	<0.025	34	32	33
	Always/mostly sugar-free	61	60		51	48	54
Snacks	Yes	25	25		26	24	25
	No	76	75	NS	81	76	75
Appearance	Satisfied	70	69		60	56	62
	Neither . . .	24	24	NS	42	39	32
	Dissatisfied	7	7		5	5	6
Teeth for life	Certain/fairly certain	80	79		78	73	76
	Uncertain	20	20	NS	27	25	23
	Definitely not	1	1		2	2	1

NS = not significant.

drinking water) gave written informed consent for their dependents to participate in an F varnish study (22). One hundred and six subjects were excluded during the 3-year trial because they wore a fixed orthodontic appliance, which made caries diagnosis difficult. Another 177 subjects moved from the area or failed to attend for examinations either during the trial (1985/85–1988/89) or during the follow-up period, which ended in February 1993. Of the remaining 212 subjects, 1 was excluded because of missing information about treatment received and oral health behavior. This left 211 subjects (101 girls), whose distribution in accordance with age at base line and gender is given in Table 1. Their mean age at base line was 11.3 (±0.6) years, and at the last examination 17.6 (±0.8) years. The girls were on average 1 month older than the boys ($p > 0.20$).

Missing information on independent variables (Table 1) explains the reduced number of subjects available for multivariate analyses (Tables 5–7).

Methods

Dental care. All participants received annual clinical and radiographic examinations and necessary dental treatment from the Public Dental Services during the 3-year trial. During this period they received dental prophylaxis followed by topical application of F varnish every 6 months. Both the length of recall intervals and the frequency of topical application of F varnish were adapted to the needs of the individual during the 3-year follow-up period. By the end of the observation period, the mean number of F varnish applications was 9.9 (95% confidence limits (CL), 9.7; 10.1).

Information about professional topical application of F (mostly Duraphat®), the number of surfaces filled during each course of treatment, and whether a change of dentist occurred during the follow-up period was obtained from patient records.

Caries assessment. Caries data are based on the radiographs from the first (base line) and the fourth examination of the clinical trial (22) and the final follow-up examination in 1992/93. One pair of posterior bitewing radiographs was exposed, using Kodak DF57 or DF53 ultra-speed films and a Kwik-bite filmholder. Exposure time and processing were in accordance with the manufacturer's recommendations. The radiographs were assessed under standardized conditions in a darkened room, using a radiographic viewer with a ×2 magnification. One trained examiner used the scoring criteria shown in Table 2 (23). The examination comprised 24 approximal surfaces of molars and premolars. In addition, radiographic occlusal fillings and gross caries were recorded for the same teeth (16 surfaces), as it was anticipated that occlusal caries would contribute a sizable proportion of the total caries score.

Caries diagnostic reproducibility was determined by independent reassessment of about 10% of the bitewing radiographs. Reproducibility was acceptable, with a Cohen's kappa greater than 0.81 (24). No statistically significant systematic error was detected by means of Student's t test for paired observations ($P > 0.10$).

Three to 4 years elapsed between the assessment of the radiographs from the trial and those taken during the follow-up period. To check whether the examiner had changed his interpretation and application of the diagnostic criteria, 72 sets of bitewing radiographs from the trial were re-examined in 1993 without access to previous records. Student's t test for paired observations showed no significant shift in caries diagnostic level over time ($P > 0.10$).

Questionnaire. At the last examination the subjects completed a pretested and precoded questionnaire containing 18 questions. The items relevant to the present investigation are listed in Table 1. To check and improve the reliability of information about the type of dentifrice used, the subjects were first asked whether the dentifrice they used contained F. They were then asked to indicate on colored photographs, which, if any, of the 15 dentifrices most sold at Voss they used. Concordant answers were given in 92% of instances, and 15 subjects who replied 'don't know' to the former question chose an F-containing dentifrice in the pictorial set-up. The respondents were also asked the extent to which they rinsed their mouths with water after toothbrushing (9).

Data analyses. The data were coded, computerized, and proofread. The SPSS for Macintosh (version 6.1) was used for the analyses.

Chesters et al. (9) suggested that the associative effects of brushing frequency and methods of mouthrinsing on caries are probably additive. In keeping with this assumption, the frequency of toothbrushing yesterday (0 = did not brush; 1 = once; 2 = twice or more), use of F dentifrice (0 = no; yes = 1), and the number of mouthrinses with water after toothbrushing (1 = 2 or more; 2 = one; 3 = none) were combined into an additive index (scale, 1–6). Since 99% of the subjects reported F dentifrice use, an alternative index consisting of brushing and water mouthrinsing frequency was also constructed (scale, 1–5). The variables cariogenic snacks between meals (0 = yes; 1 = no), consumption of sweets yesterday (1 = more than 3 times; 2 = three times; 3 = twice; 4 = once; 5 = none), and choice of sugar-free chewing gum/pastilles (0 = always sugar; 1 = mostly sugar; 2 = half-and-half; 3 = mostly sugar-free; 4 = always sugar-free) were also combined to form a scale from 1 to 10. Low values indicated undesirable, high values desirable behavior.

Mean scores and their standard deviations were used to summarize continuous (age; duration of study) and numerical discrete variables (DFS; F applications) and the frequency distribution (percentage) of subjects for categoric variables (gender, behavior, satisfaction, and so forth) (Tables 1 and 3).

The bivariate associations between dependent and independent, and among independent variables were studied using Spearman's rank correlation coefficient. Independent variables that correlated with each dependent caries variable ($P < 0.20$) were then used in linear stepwise multiple regression analyses. With weak and statistically not significant correlations between explanatory/control variables, collinearity was no problem. The distributions of subjects in accordance with caries score (DS; DFS) showed positive skewness, and the standard deviations tended to be proportional to the mean. Log_{10} transformation was used to stabilize variance and to make distributions more normal (25).

Student's t test for independent samples and for paired observations was used as appropriate. The significance of multiple correlation coefficients was tested using the F test (25). Chi-square tests were used when comparing frequency distributions of boys and girls on the basis of behavioral characteristics. The level of significance was set at 5%.

Table 2. Scoring codes and criteria for diagnosis of approximal radiographic caries* (23)

Scoring code	Description
0	Caries-free surfaces (sound)
1	Caries in the enamel not penetrating more than halfway into enamel
2	Caries penetrating more than halfway into enamel but not involving the amelodentinal junction
3	Caries of enamel and dentin regardless of depth of penetration
4	Secondary caries regardless of depth
5	Filled surfaces without evidence of secondary caries
6	Extracted surfaces because of caries
7	Missing for other reasons
8	Surfaces missing from the film or overlapping and unreadable
9	Unerupted surfaces

* If in doubt about the existence or degree of caries in accordance with these criteria, then 'sound' or the lesser degree of caries was recorded.

Table 3. Mean and standard deviation (s) caries scores in accordance with gender and examination

Index	Females (n = 101)			Males (n = 110)		Both (n = 211)	
	Mean	s		Mean	s	Mean	s
First examination							
D_1FS	1.12	1.72	NS	1.02	1.53	1.07	1.62
Last examination							
D_1S	1.59	1.86	***	3.59	3.54	2.64	3.03
D_1FS	4.68	5.03	***	7.48	5.92	6.14	5.67
D_3FS	3.59	4.43	*	5.09	4.92	4.37	4.74
D_1FS (approx. + occl.)	9.98	8.31	***	14.19	8.83	12.18	8.82
Caries incidence/year†							
ΔD_1FS	0.56	0.62	***	1.02	0.82	0.80	0.77

† Between the first and the last examination.
NS = not significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Results

Behavior

Whereas all except two subjects reported that they used an F-containing dentifrice, there was variation in the frequency of brushing and of rinsing with water after toothbrushing and in the use of dental floss/toothpicks (Table 1). Girls reported significantly higher frequency of toothbrushing and interdental cleaning than boys ($P < 0.01$). They were also more likely than boys to choose sugar-free chewing gum/pastilles ($P < 0.025$). Otherwise, there were no significant differences in dental health behavior (Table 1).

Caries prevalence

Table 3 shows mean ($\pm s$) caries scores in accordance with gender and examination. The D_1S score (last examination), which was significantly higher among boys than among girls ($P < 0.001$), was significantly associated with the frequency of toothbrushing ($P < 0.01$) and the two toothbrushing indices ($P < 0.05$) but not with the frequency of rinsing with water after brushing in bivariate analyses (Table 4). The effect of frequency of toothbrushing (Table 5) and the toothbrushing indices (results not presented) remained statistically significant after controlling for confounding by multiple regression analysis.

The mean D_1FS and D_3FS (dentin caries) at the last examination were significantly higher among boys than among girls ($P < 0.05$). The D_1FS scores were 1.3 to 1.5 times higher than their D_3FS counterparts (Table 3). Bivariate analyses showed a significant association of frequency of toothbrushing with D_1FS and with D_1FS (40 surfaces) (Table 4), but neither individual variables nor indices of toothbrushing behavior (Table 6) entered any of the multiple regression equations for the dependent variables D_1FS, D_3FS, and D_1FS (40 surfaces). Adjusted R^2 (explained variance) varied between 14.2% and 24.5% (Table 6).

Fig. 1 shows that, although there was a small difference in the expected direction (girls > boys) at age 11 years ($P > 0.20$), girls had significantly lower D_1FS scores (24 surfaces) at ages 14 ($P < 0.03$) and 18 years ($P < 0.001$). The same applied to scores based on 40 surfaces when surfaces extracted because of caries were included (2 subjects had lost 1 tooth each). It should be noted, however, that the F toothbrushing index did not enter the regression equations with D_1S,

Table 4. Spearman's rank correlation coefficient (r_s) between frequency of toothbrushing (Brush); the number of postbrushing water rinses (PBWR); the fluoride toothbrushing index (FTBI), the frequency of brushing and postbrushing water rinsing index (BRWRI), and the caries prevalence or incidence scores (n = 208–209)

Caries index	Rank correlation (r_s)			
	Brush	PBWR	FTBI	BRWRI
D_1S	−0.21**	−0.06	−0.17*	−0.17*
D_1FS	−0.19**	−0.03	−0.12	−0.13
D_3FS	−0.13	0.00	−0.07	−0.07
D_1FS (40 surfaces)	−0.21**	−0.02	−0.13	0.13
ΔD_1FS	−0.19**	−0.05	−0.14*	−0.14*

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$ (t test).

Table 5. Result of stepwise multiple regression analysis with the $\log_{10}$-transformed number of decayed surfaces (D_1S) at the last examination as the dependent variable (n = 195)

Independent variables	β	Standard error (β)	Probability
Gender	0.146	0.049	0.004
Brushing	−0.101	0.048	0.037
F tablets	−0.109	0.048	0.025
F topical (prof.; follow-up)	0.042	0.018	0.021
Soft drinks (NOK)	0.002	0.001	0.044
Constant	0.218	–	–
Adjusted R^2	0.156	–	0.000

Variables not in the equation: age, snacks between meals, sugar behavior index, and satisfaction with teeth.

Table 6. Results of stepwise multiple regression analyses with log_{10}-transformed dependent variables: D_1FS, D_3FS (24 surfaces), and D_1FS including posterior occlusal surfaces (40 surfaces) (n = 196)

Independent variables	D_1FS		D_3FS		D_1FS (40)	
	β	P	β	P	β	P
Gender	0.191	0.001	–	–	0.168	0.002
F tablets	−0.221	0.000	−0.230	0.000	−0.230	0.000
F topical	0.071	0.000	0.065	0.001	0.070	0.000
Soft drinks (NOK)	0.003	0.021	0.003	0.029	0.003	0.019
Satisfaction	−0.089	0.009	−0.097	0.007	−0.100	0.002
Constant	−0.007	–	0.234	–	0.380	–
Adjusted R^2	0.233	0.000	0.163	0.000	0.246	0.000

Not in the equation: age, frequency of toothbrushing, snacks, sugar behavior index, and for D_3FS also gender.

D_1FS, D_3FS, and D_1FS (40 surfaces) as dependent variables in separate analyses for boys and girls (results not presented).

Caries incidence

The mean caries increment (ΔD_1FS) from the first to the last examination was 5.09 ($\pm$4.88) or 0.80 ($\pm$0.77) per year (Table 3). The corresponding estimates for the follow-up period were 3.26 ($\pm$3.73) or 1.05 ($\pm$1.22) per year, and there was a significant gender difference in incidence regardless of period ($P < 0.002$) (Table 3 and Fig. 1).

Since information about individual self-care was collected at the end of the study, separate multivariate analyses were carried out for caries increments during the follow-up and during the whole observation period. Table 7 shows that toothbrushing behavior (brushing/rinsing index) only entered the equation for ΔD_1FS/year throughout the study period. The first independent variable to enter all these four equations was caries experience at the beginning of respective time intervals; it was the only variable in the equation when ΔD_3FS/year during the follow-up period was the dependent variable. Explained variance was from 17.6% to 32.4% (Table 7).

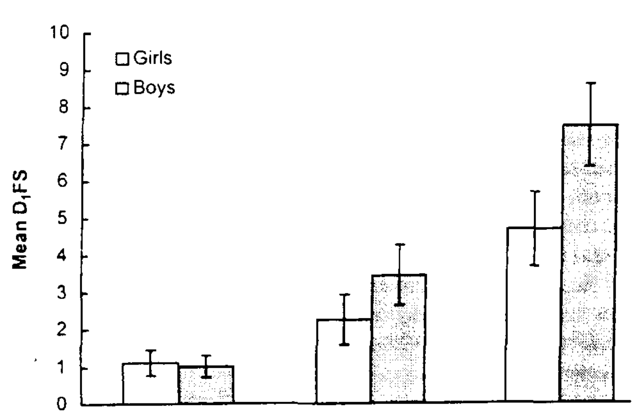

Fig. 1. Mean D_1FS and 95% confidence interval for boys (n = 110) and girls (n = 101) in accordance with age and gender (24 posterior approximal surfaces).

None of the variables measuring toothbrushing behavior entered the regression equations when caries increment was the dependent variable in separate multivariate analysis for boys and girls ($0.071 < R^2 < 0.367$) (results not presented).

The seemingly illogical positive association between the frequency of professional topical application of F varnishes and caries scores (Tables 5–7) is contrary to expectations but is probably attributable to efforts to limit their use to high-risk individuals.

Discussion

The finding that girls reported more favorable dental health behavior than boys (Table 1) agrees with the results of previous studies in Norway and other countries (20, 26) and confirms that the gender difference in frequency of toothbrushing may be used to provide direct evidence for or against 'a major role' of F dentifrices in caries decline (12). That the traditional age-specific mean D_1FS gender difference (girls > boys) was reversed between ages 11 and 18 in this study (Fig. 1) was to be expected in view of reported behavior (Table 1), some survey findings (6–8), and because girls have experienced greater percentage caries reductions than boys after unsupervised use of F dentifrices in clinical trials (27–29). While the observed reversal of the D_1FS gender difference was to be expected, it is at variance with the 1988–91 national U.S. survey of children and adolescents (16) and with most prevalence studies in the past (12). Thus, a meta-analysis based on cross-sectional surveys of adolescents before and after the introduction of F dentifrices found no significant change in the percentage mean gender difference (12). Methodologic differences among studies

Table 7. Results (β) of stepwise multiple regression analyses with $\log_{10}$-transformed dependent caries incidence variables from the follow-up: ΔD_1FS/year; ΔD_3FS/year, and ΔD_1FS (40)/year, and from the whole study period: $\Delta D_1FS/year^{(W)}$, and independent caries experience variables: D_1FS at the start of follow-up and at base line*

Independent variables	ΔD_1FS/year (n = 194)		ΔD_3FS/year (n = 194)		ΔD_1FS (40)/year (n = 195)		$\Delta D_1FS/year^{(W)}$ (n = 195)	
	β	P	β	P	β	P	β	P
Gender	0.046	0.004	–	–	0.102	0.000	0.067	0.000
Age	−0.003	0.001	–	–	–	–	–	–
D_1FS experience	0.089	0.000	0.199	0.000	0.126	0.000	0.157	0.000
F topical	–	–	–	–	0.030	0.002	0.019	0.000
F brush/rinse	–	–	–	–	–	–	−0.020	0.017
Constant	1.134	–	0.353	–	0.211	–	0.170	–
Adjusted R^2	0.172	0.000	0.297	0.000	0.224	0.000	0.298	0.000

Not in the equation: F tablets, expenditure of soft drinks, snacks, sugar behavior index, satisfaction with own teeth, and variables marked in the table.

* $^{(W)}$ = Whole observation period.

may account for these discrepancies. While this was a prospective cohort study, the other studies were cross-sectional; this study relied on caries data recorded on posterior bitewing radiographs (partial recording), and the others on full-mouth mirror and probe examinations. Other reasons for conflicting results may be confounding, selection bias, and recording error.

In an analysis of co-variance, Chesters et al. (9) found a significant effect on caries prevalence of rinse method and brushing frequency, findings that are supported by studies of oral retention of fluoride after toothbrushing and postbrushing mouthrinsing with water (9, 21). Controlling for confounding by stepwise multiple regression analysis, the present study gave less conclusive results (Tables 5–7). The variables reflecting exposure to F in dentifrices entered only 4 of the 24 equations and never in the first step. They contributed 5% to 10% of total explained variance (adjusted R^2 < 30%) for all subjects and increased it by less than 2 percentage points on entering the equation. In the two instances in which toothbrushing variables entered the regression equations for boys (dependent variables, D_1FS and D_1FS (40 surfaces) at the last examination), they accounted for 34% to 37% of total explained variance, which was 11% and 15%, respectively. Explained variance in caries prevalence scores less than or of the same order of magnitude as the estimates reported for 18-year-olds in this study (Tables 5 and 6) is a common finding (30–32).

Variance in caries incidence due to toothbrushing behavior was 6% of total explained variance (adjusted R^2 = 0.298) in ΔD_1FS for the whole observation period. It entered the analysis in the final step (fourth) and increased explained variance by 1.8 percentage points (Table 7). Using logistic regression analysis, Disney et al. (33) also found a significant effect on caries incidence of oral hygiene, expressed as mean plaque score.

When interpreting these relatively modest contributions to explained variance in caries scores, it should be remembered that it is explained variance due to variation in F toothbrushing practices, rather than the effect of F-containing dentifrices, as only two subjects used a toothpaste without fluoride (Table 1). The same applies when assessing regression coefficients (b), whose absolute values are reduced by the $\log_{10}$ transformations. Furthermore, it is conceivable that the effect of F toothbrushing practices on caries scores has been underestimated because the frequency of toothbrushing may have been overreported (34).

Using a point estimate of toothbrushing behavior (last examination) may also have weakened the association between caries scores and F dentifrice exposure because of changes of brushing frequency over time. Thus, more than two-thirds of the participants in a longitudinal Finnish study reported one or more changes in toothbrushing frequency between 12 and 18 years of age (34). That a socioeconomic status variable was unavailable may have caused overestimation of the effect of F toothbrushing behavior (25). The use of initial caries experience as an independent variable in the analyses of caries incidence may to some unknown extent have compensated for this omission because of the repeatedly demonstrated significant association between social class and DMF scores (35).

In the four regression equations with caries incidence as dependent variable, initial caries experience entered the analyses in step one, or as the only variable, and accounted for more than 41% of total explained variance. This finding is in agreement with published results (33, 36).

Selection bias and loss of subjects may have affected the caries scores and reported behavior. This is because the participants volunteered for a clinical trial (22). Subjects who were lost to follow-up had a base-line D_1FS score per person of 2.06 ($\pm$2.73), compared with 1.07 ($\pm$1.62) for those who were examined at the last examination (P < 0.001), indicating more favorable dental health behavior among participants than among non-participants. Generalization of observed caries scores and rates of dental health behavior to the population of teenagers in Voss is therefore inadmissible. This is, however, not a problem in a study of the effect of variation of F dentifrice behavior on the trend in the DFS gender difference with increasing age and the contribution of this variation to total explained variance in caries scores. For these purposes it is more important that the same individuals were followed throughout the observation period and that the percentage of boys and girls in the study group (female, 48%) was close to that of the population; that is, any selection is likely to have affected the results of boys and girls equally.

Checks of examiner diagnostic reproducibility gave acceptable results. Neither systematic error of recording nor a shift in caries diagnostic level over time was found. In addition, the examiner was unaware of the gender of the subjects while interpreting their radiographs. Consequently, it is precluded that the observed change in direction of the DFS gender difference (Fig. 1) and other findings are attributable to examiner error or bias.

The statistically significant reversal of the traditional gender difference in caries score (Fig. 1) and the differences in F dentifrice behavior (Table 1) in this 6-year cohort study lends support to the hypothesis that regular use of F dentifrices may be an important determinant of the caries decrease in Western industrialized countries. The multivariate analyses (Tables 5–7) provided less compelling evidence, both in terms of explained variance and the step at which the variables pertaining to F dentifrice behavior entered the stepwise regression analyses. They confirmed the significant role of some other determinants of caries prevalence and incidence (Tables 5–7) (8, 12, 19, 30–33, 35–36) and the need to consider these when exploring reasons for the caries decline (1, 12, 37). Because of the importance of this issue when choosing a caries-preventive strategy, there is a need for further studies to refute or confirm these results, preferably in a setting in which the proportion of the population using F dentifrices is lower than among the participants of this study.

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References

1. Glass RL. Fluoride dentifrices: the basis for the decline in caries prevalence. JR Soc Med 1986;79 Suppl 14:15–17.
2. Rölla G, Øgaard B. Reduction in caries incidence in Norway from 1970 to 1984 and some considerations concerning the reasons for this phenomenon. In: Frank RM, O'Hickey S, editors. Strategy for dental caries prevention in European countries according to their laws and regulations. Oxford: IRL Press; 1987. p. 223–9.
3. Stookey GK, DePaola PF, Featherstone JDB, Fejerskov O, Möller IJ, Rotberg S, et al. A critical review of the relative anticaries efficacy of sodium fluoride and sodium monofluorophosphate dentifrices. Caries Res 1993;27:337–60.
4. von der Fehr FR, Möller IJ. Caries-preventive fluoride dentifrices. Caries Res 1978;12 Suppl 1:31–7.
5. World Health Organization. Fluoride and oral health. Geneva: World Health Organization; 1994. WHO Technical Report Series No. 846: 26–9.
6. Leske GS, Ripa LW, Barenie JT. Comparisons of caries prevalence of children with different daily toothbrushing frequencies. Community Dent Oral Epidemiol 1976;4:102–5.
7. Ainamo J, Parviainen K. Influence of increased toothbrushing frequency on dental health in low, optimal, and high fluoride areas in Finland. Community Dent Oral Epidemiol 1989;17: 296–9.
8. Bjertness E. The importance of oral hygiene on variation in dental caries in adults. Acta Odontol Scand 1991;49:97–102.
9. Chesters RK, Huntington E, Burchell CK, Stephen KW. Effect of oral care habits on caries in adolescents. Caries Res 1992;26:299–304.
10. Chestnutt IG, Jones PR, Jacobson APM, Schäfer F, Stephen KW. Prevalence of clinically apparent recurrent caries in Scottish adolescents, and the influence of oral hygiene practices. Caries Res 1995;29:266–71.
11. Horowitz HS. Critique of Kingman's methods of projecting long-term relative efficacy of products exhibiting small short-term efficacy. Am J Dent 1993;6(Spec Iss):51–4.
12. Haugejorden O. Using the DMF gender difference to assess the 'major' role of fluoride toothpastes in the caries decline in industrialized countries: a meta-analysis. Community Dent Oral Epidemiol 1996;24:369–75.
13. Schwarz E, Vigild M, Skak-Iversen L. Danish child oral health status in two decades of organized child oral health care. Tandlaegebladet 1994;98:612–8.
14. Bjarnason S, Finnbogason SY, Holbrook P, Köhler B. Caries experience in Icelandic 12-year-old urban children between 1984 and 1991. Community Dent Oral Epidemiol 1993;21:194–7.
15. Helsedirektoratet/Statens Helsetilsyn. Tannhelsetjenesten i Norge. Årsmeldingene 1985–1994. Oslo: Helsedirektoratet/ Statens Helsetilsyn; 1986–1995.
16. Kaste LM, Selewitz RH, Oldakowski RJ, Brunelle JA, Winn DM, Brown LJ. Coronal caries in the primary and permanent dentition of children and adolescents 1–17 years of age: United States, 1988–1991. J Dent Res 1996;75(Spec Iss):631–41.
17. Stephen KW, McCall DR, Tullis JI. Caries prevalence in northern Scotland before, and 5 years after, water defluoridation. Br Dent J 1987;163:324–6.
18. Attwood D, Blinkhorn AS. Dental health in schoolchildren 5 years after water fluoridation ceased in south-west Scotland. Int Dent J 1991;41:43–8.
19. Okawa Y, Takahashi Y, Sazuka J, Matsukubo T, Takaesu Y. Decline in caries prevalence in 6–14-year-old schoolchildren during 1975–85 in Shizuoka, Japan. Community Dent Oral Epidemiol 1992;20:246–9.
20. Rise J, Haugejorden O, Wold B, Aarö LE. Distribution of dental health behaviors in Nordic schoolchildren. Community Dent Oral Epidemiol 1991;19:9–13.
21. Sjögren K. Toothpaste technique. Studies of fluoride delivery and caries prevention [thesis]. Göteborg: Göteborg University; 1995.
22. Haugejorden O, Nord A. Caries incidence after topical application of varnishes containing different concentrations of sodium fluoride: 3-year results. Scand J Dent Res 1991;99:295–300.
23. Haugejorden O, Slack GL. Progression of approximal caries in relation to radiographic scoring codes. A pilot study. Acta Odontol Scand 1975;33:211–7.
24. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.

25. Armitage P, Berry G. Statistical methods in medical research. 3rd ed. Oxford: Blackwell Science; 1994. p. 386–92.
26. Wold B, Aasen H, Aarö LE, Samdal O. Helse og livsstil blant barn og unge i Norge. Bergen: Senter for forskning og helsefremmende arbeid, miljø og livsstil; 1995. Hemil-Rapport nr. 14-1995.
27. Jackson D, Sutcliffe P. Clinical testing of a stannous fluoride-calcium pyrophosphate dentifrice in Yorkshire school children. Br Dent J 1967:123:40–8.
28. James PMC, Anderson RJ. Clinical testing of a stannous fluoride-calcium pyrophosphate dentifrice in Buckinghamshire school children. Br Dent J 1967;123:33–9.
29. Naylor MN, Emslie RD. Clinical testing of stannous fluoride and sodium monofluorophosphate dentifrices in London school children. Br Dent J 1967:123:17–23.
30. Stamm JW, Disney JA, Graves RC, Bohannan HM, Abernathy JR. The University of North Carolina Caries Risk Assessment study. I. Rationale and content. J Public Health Dent 1988;48:225–32.
31. Graves RC, Abernathy JR, Disney JA, Stamm JW, Bohannan HM. University of North Carolina Caries Risk Assessment Study. III. Multiple factors in caries prevalence. J Public Health Dent 1991;51:134–43.
32. Amarante EC. Prevalence of dental caries and periodontal disease in 5-, 12- and 18-year-old children in Bergen, Norway [thesis]. Bergen: University of Bergen; 1995.
33. Disney JA, Graves RC, Stamm JW, Bohannan HM, Abernathy JR, Zack DD. The University of North Carolina Caries Risk Assessment study: further developments in caries risk prediction. Community Dent Oral Epidemiol 1992;20:64–75.
34. Kuusela S, Honkala E, Rimpelä A. Toothbrushing frequency between the ages of 12 and 18 years—longitudinal prospective studies of Finnish adolescents. Community Dent Health 1996; 13:34–9.
35. Burt BA, Eklund SA. Dentistry, dental practice, and the community. 4th ed. Philadelphia: WB Saunders Company; 1992. p. 90–112.
36. Fédération Dentaire Internationale. Review of methods of identification of high caries risk groups and individuals. Technical Report No. 31. Int Dent J 1988;38:177–89.
37. Marthaler TM. The prevalence of dental caries in Europe 1990–1995. ORCA Saturday Afternoon Symposium 1995. Caries Res 1996;30:237–55.

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