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Changing risk factors for fluorosis among South Australian children

A. John Spencer and Loc G. Do

Australian Research Centre for Population Oral Health, The University of Adelaide, Adelaide, Australia

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Abstract – *Background:* Research in the last decade has shown changing exposure patterns to discretionary fluorides and declining prevalence of fluorosis among South Australian children, raising the question of how risk factors for fluorosis have changed. *Objective:* To examine and compare risk factors for fluorosis among representative samples of South Australian children in 1992/1993 and 2002/2003. *Methods:* Similar sampling strategies and data collection methods were employed in the Child Fluoride Study (CFS) Marks 1 (1992/1993) and 2 (2002/2003). Participants in each CFS round were examined for fluorosis using the Thylstrup and Fejerskov (TF) Index. Exposure history was collected for fluoride in water, toothpaste, fluoride supplements and infant formula, allowing for a fluorosis risk assessment analysis. Data were re-weighted to represent the child population at each time. Changes in prevalence of fluorosis, defined as having a TF score of 1+ on maxillary central incisors, fluoride exposure and risk factors between the two rounds were evaluated. *Result:* A total of 375 and 677 children participated in the 1992/1993 and 2002/2003 rounds respectively. Prevalence of fluorosis declined significantly from 45.3% to 25.9%. Reduced use of fluoride supplements and increased use of 400–550-ppm children F toothpaste were the most substantial fluoride exposure changes. Early toothpaste use, residence in fluoridated areas and fluoride supplement use were the risk factors in 1992/1993. Early toothpaste use and fluoride supplement use were not risk factors, leaving fluoridated water as the only risk factor among the common variables in 2002/2003. In an analysis stratified by the type of fluoridated toothpaste in 2002/2003, the large amount of toothpaste used was a risk factor in those who used 1000-ppm fluoridated toothpaste, and eating/licking toothpaste when toothpaste use started was a risk factor among children who used either 1000-ppm or 400–550-ppm fluoridated toothpaste. *Conclusion:* Introduction of the 400–550-ppm F toothpaste and use of smaller amount of toothpaste restricted risk associated with early toothpaste use. Less use and possibly a stricter fluoride supplements regimen also restricted fluorosis risk. Periodic monitoring of risk of fluorosis is required to adjust guidelines for fluoride use in caries prevention.

Key words: children; fluoride; fluorosis; risk factors

Dr Loc G Do, ARCPOH, Dental School, The University of Adelaide, 5005 Australia
Tel: +61 8 8303 3964
Fax: +61 8 8303 3070
e-mail: loc.do@adelaide.edu.au

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Fluoride is an essential component in the prevention of caries. While necessary to prevent caries from an early age, the use of fluoride can increase the risk of having fluorosis. Evaluation of that risk is always important in balancing the risk and benefit of fluoride use. The risk of having fluorosis in a population can change over time. Availability and patterns of use of different fluoride sources dictate the level of fluoride ingestion by young children. When Dean (1) reported on the prevalence of fluorosis, different levels of fluoride in water supplies were probably the only explanatory factor for the difference in risk of fluorosis simply because no other fluoride source was available. Numerous fluoride sources have become available since the 1970s, making the risk assessment of fluorosis more

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complicated. Since then, young children may have been exposed to widely varied levels and types of fluoride.

Recommendations on the use of a fluoride source can also have an impact on the risk of fluoride ingestion. Such recommendations reflect the available evidence of risk and benefit of any fluoride vehicle. Any one recommendation may change over time. An example is recommendations on the use of fluoride supplements by children issued during the last several decades. Such change in the pattern of fluoride use is supposed to reduce the risk of fluorosis. However, success or failure of those changes has not often been followed up and documented.

Since the 1970s, there have been reports of a significant increase in the prevalence of fluorosis in western countries (2–4). The increase coincided with the widespread availability of discretionary fluorides such as fluoridated toothpaste, fluoride supplements and fluoride applications in the dental office. The main risk factors for fluorosis were water fluoridation, fluoride toothpaste use, fluoride supplement use and infant formula (5). The prevalence of fluorosis in Australia also increased during that period. Studies in Western Australia (6, 7) reported the prevalence offluorosis – defined as having a TF score of 1+ on the upper right central incisor – as over 40% in a fluoridated area and 33% in a nonfluoridated area. Water fluoridation, use of fluoridated toothpaste and early use of infant formula were identified as risk factors. Our own study in South Australia using the same case definition reported a high prevalence of fluorosis in both fluoridated and nonfluoridated areas (48.7% and 30.3% respectively) (8).

Policy recommendations were introduced in Australia in the early 1990s to control exposure to discretionary fluorides in order to reduce the risk of fluorosis among children. Two studies aimed at evaluating the effectiveness of those policy recommendations compared the prevalence of fluorosis reported in studies conducted in the early 1990s and early 2000s. A sharp decline in the prevalence of fluorosis in Western Australia (9) and South Australia (10) was observed during those 10 years. The question that is raised is whether risk factors for fluorosis in the population have also changed during that period.

The aim of the present study was to examine and compare risk factors for fluorosis among representative samples of South Australian children conducted by researchers at the University of Adelaide in 1992/1993 and 2002/2003.

Methods

The data for the present study are derived from two separate cross-sectional studies among the South Australian child population (Fig. 1). The Child Fluoride Study Mark 1 (CFS M1) in 1992/1993 involved a stratified random sample of children enrolled in the School Dental Service (SDS). The SDS in South Australia provided free dental care to schoolchildren regardless of their socioeconomic status and oral health status. Enrolment to the SDS was as high as 89% of the South Australian child population.

Study design and data collection of the CFS M1 are detailed elsewhere (11). Parents of children in the main study provided the child’s fluoride

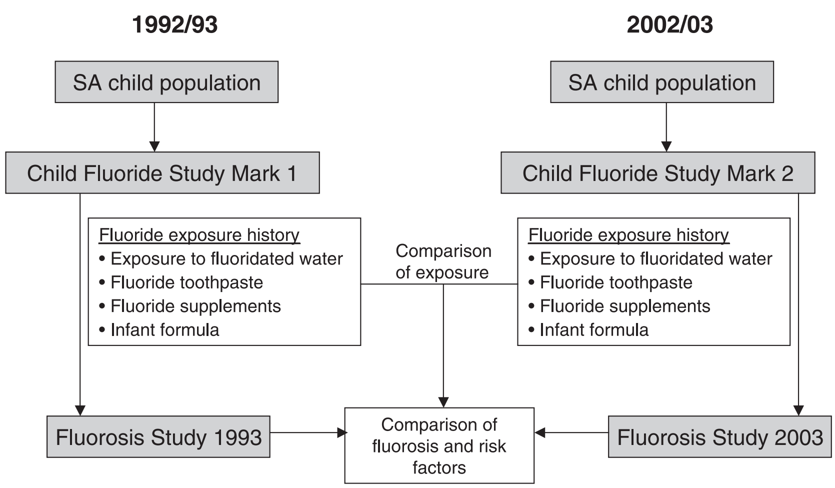

Fig. 1. Schematic design of the study.

exposure history data through a self-completed questionnaire. Residential locations where a child had lived and the time period the child had lived at the location were collected and linked with a fluoride database to estimate exposure to fluoridated water. Patterns of toothbrushing practice such as age in months when a child started fluoridated toothpaste use were collected. Data on use of fluoride supplements and infant formula were also collected. A subsample selected on the basis of the fluoride exposure patterns of these children was recruited to a further nested study on fluorosis and examined using the TF Index by two calibrated dentists (12).

The Child Fluoride Study Mark 2 (CFS M2) in 2002/2003 followed a similar method. Children were selected through a random stratified sampling selection process. A detailed questionnaire was used to collect each child's fluoride exposure history, which was based on the previous questionnaire. More details were collected with regard to consumption of drinking water. Patterns of toothbrushing practice were specifically collected for the time when a child started toothpaste use. Again a subsample, selected on the basis of exposure to fluoridated water and urban/rural residence, was recruited to a further nested study on fluorosis and examined using the TF Index by one calibrated dentist who was blind towards questionnaire data. The calibration of the examining dentists was against at least one common 'standard' examiner for both cross-sectional studies. Details on study design, sampling strategies and data collection are described elsewhere (10).

Study populations

In 1992/1993, a total of 9690 5- to 17-year-old children participated in the CFS M1 and 797 10- to 15-year-old children were selected for the nested study based on fluoride exposure. Children were initially approached to complete an oral health perception questionnaire. Respondents were invited to attend a clinical examination at their school dental clinic. Data on fluorosis experience was collected by two trained and calibrated examiners. A total of 375 10- to 15-year-old children were examined for dental fluorosis, a response rate of 47%.

In 2002/2003, a total of 6259 5- to 17-year-old children participated in the CFS M2. All 1401 8- to 13-year-old children from fluoridated Adelaide and three nonfluoridated regional cities were approached for the nested fluorosis study. Children and their parents were approached initially to complete a child/parent oral health perception questionnaire. Then, respondents were invited to attend a clinical examination at their school dental clinic. Clinical examinations were conducted under standard clinical lighting using standardized instruments. Fluorosis experience was recorded by one trained examiner (LGD) using the TF Index. A total of 677 8- to 13-year-old children were examined for dental fluorosis, yielding an adjusted response rate of 52% (adjusted for noncontactable addresses/phone number or being excluded from fluorosis examination for reasons such as having orthodontic braces).

Data re-weighting

It was important to make the two study populations comparable as the studies utilized multi-staged stratified sampling strategy with different sampling ratios. The data were re-weighted to produce population estimates for each of the time point. Sampling ratios, sex and age distribution of the samples and the populations at each time were used to calculate sample weights. In the tables and figures, numbers of subjects are unweighted, whereas mean and percentage are weighted. Therefore, multiplying the number of subjects by percentage will not necessarily produce an integer.

Data management and analysis

The data were analysed as two independent cross-sectional surveys. Only comparable exposure measures could be analysed at both times. Residence in a fluoridated area from birth to age 3 years was used as an indicator of exposure to water fluoridation. Use of infant formula (defined as 'ever used'), fluoride supplements (defined as 'ever used') and age when fluoridated toothpaste use started were the other common potential risk factors. The CFS M1 did not collect several aspects of the pattern of toothbrushing when a child started toothpaste used, i.e. during a high-risk period for fluorosis on maxillary central incisors. Other fluoridated toothpaste use measures were available only in the CFS M2. They were used to extend the analysis of risk factors for fluorosis in 2002/2003.

The analysis was conducted in several steps. First, the prevalence of fluorosis, defined as a TF1+ on one or both maxillary central incisors, were compared between the studies. Secondly, fluoride exposure histories were compared. Thirdly, bivariate associations between the prevalence of fluorosis and fluoride exposures were tested. Fourthly, fluorosis risk was modelled using logistic regression between the prevalence of fluorosis and comparable fluoride exposures documented at both times. Finally, the relationship between type of toothpaste used and age started, frequency and amount of toothpaste used was investigated in a stratified analysis of fluorosis risk in 2002/2003 only.

Results

Population estimates of the prevalence of dental fluorosis for each of the periods are presented (Fig. 2). The fluorosis cases mostly had TF scores of 1 or 2. The CFS M1 had 2.2% of cases with TF score of 3 and higher, with the maximum score of TF 6. The CFS M2 had a highest score of TF 3, which was found among 1.9% of the population. Overall, there was a significant decline in the prevalence of fluorosis during the decade (from 45% to 26%). The prevalence of fluorosis declined by one-third in fluoridated areas and by half in nonfluoridated areas. Absolute values of the decline were almost identical for fluoridated and nonfluoridated areas (19% and 15% respectively).

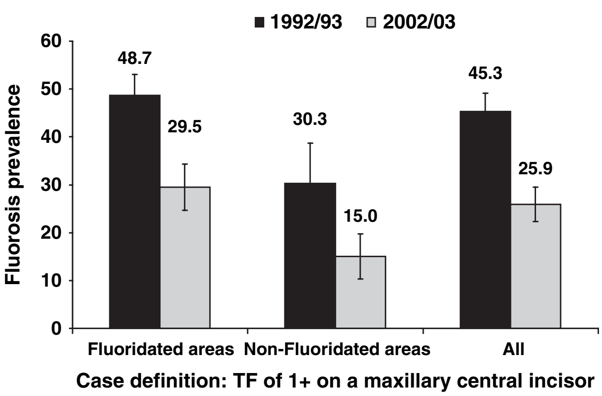

Fig. 2. The prevalence of fluorosis in South Australian child populations in 1992/1993 and 2002/2003 (weighted percentages).

Four fluoride exposure variables were available in the CFS M1 while eight such variables were collected in the CFS M2 (Table 1). Over 70% of children were residents in fluoridated areas from birth to age 3 years in both studies. The proportion of children who used fluoride supplements reduced from 9.4% to 4.9%. That change was of borderline statistical significance. There was a nonsignificant decline in the proportion of children who used infant formula between the two studies. The proportion of children who reportedly started toothpaste use before their second birthday was significantly increased by almost 10% from the CFSM1 to the CFS M2. Almost all children in the CFS M1 used a standard 1000-ppm fluoridated toothpaste while this proportion was 35% in the CFS M2 when low-concentration fluoridated toothpaste (400–550 ppm F) had become available for use. Almost half of the children reportedly had had a habit of eating/licking toothpaste when they first started toothpaste use.

The bivariate associations of the prevalence of fluorosis and exposures to fluoride in the two studies are presented in Table 2. Children who had lived in fluoridated areas from birth to 3 years of age were significantly more likely to have fluorosis compared with children who did not in either

Table 1. Exposure to fluoride of the two South Australian child populations in 1992/1993 and 2002/2003 (unweighted *n*, weighted percentages)

	Fluorosis study 1992/1993			Fluorosis study 2002/2003		
	n	Weighted %	95% CI	*n*	Weighted %	95% CI
Residence in fluoridated area from birth to age 3 years	200	72.1	67.5–76.5	321	74.7	71.7–78.3
Use of fluoride supplements (ever used)[a]	79	9.4	6.5–12.4	48	4.9	3.3–6.5
Use of infant formula (ever used)	236	61.0	56.1–65.9	399	57.2	53.3–60.7
Started toothpaste use ≤24 months	261	62.3	57.1–66.9	439	72.9	70.0–76.3
Brushing 2+ times/day when toothpaste use started	NA			230	40.1	36.3–43.7
Used 1000-ppm F toothpaste when toothpaste use started	375		100.0	208	35.6	32.4–39.6
Used large amount of toothpaste when toothpaste use started	NA			202	31.8	28.5–35.5
Eating/licking toothpaste when toothpaste use started	NA			317	48.9	45.2–52.8

NA: not available – those variables were not collected in the 1992/1993 fluorosis study.
95% CI: 95% confidence interval, calculated based on sample size of each study.
[a]Among children who had spent their first 3 years in nonfluoridated areas

Table 2. Prevalence of fluorosis by exposure to fluoride of the two South Australian child populations in 1992/1993 and 2002/2003 (weighted estimates)

	Fluorosis study 1992/1993		Fluorosis study 2002/2003	
	Weighted %	95% CI	Weighted %	95% CI
Total	45.9	41.0–51.0	26.9	23.7–30.3
Residence in fluoridated area from birth to age 3 years				
Yes	50.8**	46.0–56.0	30.2*	26.6–33.5
No	27.8	23.5–32.5	16.8	14.2–19.8
Use of infant formula				
Yes	49.2	43.9–55.0	27.4	23.7–30.3
No	40.8	36.0–46.0	23.5	20.8–27.2
Use of fluoride supplement[a]				
Yes	40.6*	32.6–50.0	25.0*	18.4–31.6
No	23.9	15.8–32.2	14.4	8.7–19.3
Age when toothbrushing with toothpaste started				
≤24 months	52.0**	47.0–57.0	30.0*	26.6–33.5
24+months	34.8	30.3–40.0	20.9	17.9–24.1
Frequency of brushing when toothpaste use started				
2+ times/day	NA		28.9	25.6–32.4
<2 times/day	NA		24.7	21.7–28.3
Type of toothpaste when toothpaste use started				
1000-ppm fluoride toothpaste	45.3	40.0–50.0	29.6	26.6–33.5
400–550-ppm fluoride toothpaste	NA		25.8	22.7–29.3
Amount of toothpaste when toothpaste use started[b]				
Large amount	NA		34.2	30.4–37.6
Small amount	NA		24.5	21.7–28.3
Eating/licking toothpaste when toothpaste use started				
Yes	NA		33.3**	29.5–36.5
No	NA		22.5	19.8–26.2

Case definition for fluorosis: Having a TF score of 1+ on one or both maxillary central incisors.
[a]Among children who had spent their first 3 years in nonfluoridated areas.
[b]Amount of toothpaste used per brushing: large amount: pea-sized or larger; small amount: smear size.
Chi-squared test: $*P < 0.05$; $**P \leq 0.001$.
NA: not available (not collected in the CFS M1).

studies. However, children in the recent CFS M2 (either with or without residence in fluoridated areas during their first 3 years of life) had significantly lower prevalence of fluorosis when compared with the respective groups in the previous CFS M1. Children who used fluoride supplements in the CFS M1 were more likely to have fluorosis compared with children in that study who did not use supplements and children in the recent CFS M2. Commencing fluoridated toothpaste use before the second birthday was associated with a significantly higher prevalence of fluorosis in both studies.

Logistic regression models were generated for the prevalence of fluorosis with the four common fluoride exposures as explanatory variables in each study (Table 3). Residence in fluoridated areas, fluoride supplement use and commencement of fluoridated toothpaste use before age of 25 months were risk factors for fluorosis in the CFS M1 while only exposure to fluoridated water was significant in the CFS M2 among the four investigated variables. Odds ratio for having fluorosis with exposure to fluoridated water was lower in the CFS M2 (2.01 versus 4.33).

Two logistic regression models were generated for children in the CFS M2 stratified by type of toothpaste used when toothbrushing started (Table 4). Residence in fluoridated areas from birth to age 3 years was significant in both models, with the odds ratio considerably higher among children who used standard fluoridated toothpaste. Amount of toothpaste was associated with a higher risk of fluorosis among children who used a standard 1000-ppm fluoridated toothpaste, but not among children who used low-concentration fluoridated toothpaste. The habit of eating/licking toothpaste was associated with a higher risk of fluorosis in either group.

Discussion

This paper evaluates change in risk of dental fluorosis among South Australian children during

Table 3. Risk factors for fluorosis of the two South Australian child populations in 1992/1993 and 2002/2003

	Fluorosis study 1992/1993		Fluorosis study 2002/2003	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Residence in fluoridated area from birth to age 3 years				
Yes	4.33 (2.17–8.63)	<0.001	2.01 (1.18–3.41)	0.01
No	1		1	
Infant formula				
Used	1.12 (0.71–1.76)	0.60	1.01 (0.67–1.48)	0.80
Not used	1		1	
Fluoride supplements				
Used	2.86 (1.08–7.57)	0.044	1.16 (0.48–2.83)	0.74
Not used	1		1	
Age when brushing with F toothpaste started				
≤24 months	2.17 (1.36–3.45)	0.001	1.52 (0.95–2.45)	0.08
24+months	1		1	

Logistic regression models for the cases of fluorosis. Separately generated for each study sample.
Case of fluorosis: Having a TF score of 1+ on one or both maxillary central incisor.
OR (95%CI): odds ratios (95% confidence intervals).

Table 4. Risk factors for fluorosis in the South Australian child population in 2002/2003 – stratified by type of toothpaste

	Fluorosis study 2002/2003			
	Children with 1000-F toothpaste		Children with 400–550-ppm F toothpaste	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Residence in fluoridated area from birth to age 3 years				
Yes	5.69 (1.85–17.45)	0.002	1.55 (1.01–2.89)	0.048
No	1		1	
Infant formula				
Used	0.87 (0.43–1.77)	0.700	1.05 (0.60–1.84)	0.858
Not used	1		1	
F supplements				
Used	4.79 (1.16–19.89)	0.031	0.60 (0.15–2.44)	0.48
Not used	1		1	
Age started F toothpaste use				
<24 months	1.78 (0.64–4.95)	0.266	1.20 (0.67–2.16)	0.54
24+months	1		1	
Brushing frequency when toothpaste use started				
2+ times/day	1.25 (0.61–2.56)	0.534	1.70 (0.98–2.2.89)	0.056
<2 times/day			1	
Amount of toothpaste used when toothpaste use started[a]				
Large amount	3.63 (1.77–7.51)	0.001	1.45 (0.84–2.51)	0.187
Small amount	1		1	
Eating/licking toothpaste when toothpaste use started				
Yes	2.30 (1.09–4.85)	0.029	2.60 (1.51–4.48)	0.001
No	1		1	

Logistic regression model for the cases of fluorosis in the 2002/03 CFS M2 population. Separately generated for children who used standard concentration F or low concentration F toothpaste.
Case of fluorosis: Having a TF score 1+ on one or both maxillary central incisor.
OR (95%CI): odds ratios and its 95% confidence intervals.
Patterns of toothbrushing when a child started fluoridated toothpaste use.
[a]Amount of toothpaste used per brushing: large amount: pea-sized or larger; small amount: smear size.

a 10-year period from 1992/1993 to 2002/2003. Estimates of risk for fluorosis of two population-representative samples were compared. The data were collected in both studies using similar methodologies to enable comparability of the estimates.

There was unequal number of fluoride exposures collected in the two studies that limited the comparison that could be made. The first study, the CFS M1, collected four fluoride exposures compared with eight in the second study, the CFS

M2. If the additional four variables of the fluoride exposure had been available at both times, further variance in the prevalence of fluorosis might have been further explained. However, inclusion of four common variables still revealed change in the risk of fluorosis in the study populations. A slight difference in collection of information on water consumption between the two studies made it difficult to calculate comparable percent lifetime exposure to fluoridated water. Therefore, continuous residence in fluoridated or nonfluoridated areas in the first 3 years of life was used as a comparable indicator of exposure to fluoridated water.

The sample of the CFS M1 was slightly older than that in the CFS M2 (10–15 years versus 8–13 years). Age-related change of fluorotic enamel has not been documented longitudinally. Fejerskov et al. (13) speculated that mild fluorosis (TF score 1 to 3), as observed in these study populations, would experience gradual 'regression' because of attrition and abrasion. In that case, the age effect, if any, would work towards a null finding, that is there is no difference in the prevalence of fluorosis of the two populations. Nevertheless, a statistically significant difference in the prevalence of fluorosis was still observed when comparing the two populations.

The examiners of the two studies were not the same. However, one of the two examiners of the first CFMS 1 participated in training and calibrating sessions for the single examiner of the CFMS 2. Moreover, one of the authors (AJS) was involved in the training and calibration exercises for both studies.

The response rates of the fluorosis examination in the two studies were around 50%. A factor affecting the response rate was that children were approached in two rounds. First, to complete a oral health perception questionnaire, and secondly, to participate in a clinical examination for fluorosis. The data were re-weighted to account for different sampling ratios and possible differences in response. The respondents were compared with nonrespondents for caries status, socioeconomic status and fluoride exposure history. No statistically significant difference was found (data not shown).

The introduction of the policy measures in early 1990s to control exposure to discretionary fluorides has resulted in significant decline in the prevalence of fluorosis (9, 10). There is no current benchmark to decide if the prevalence of fluorosis among South Australian children in 2002/2003 was moderate or still high. A comparison with the historical benchmark reported by Dean may be difficult because of the difference in the fluorosis indices used. However, only around 2% of the populations had more severe fluorosis (TF score of 2 or higher). Mild fluorosis as observed in the South Australian population appeared not to negatively impact oral health-related quality of life of the children (14). Therefore, the current level of fluorosis experience among South Australian children did not present a significant public health problem according to criteria proposed by Burt and Eklund (16). The criteria are: (a) there is a condition or situation that is widespread and has an actual or potential cause of morbidity or mortality; (b) there is a perception on the part of the public, government or public health authorities that the condition is a public health problem.

The policy changes also led to change in risk profile for fluorosis of the population. Changes in patterns of exposure to fluoride have led to change in risk of fluorosis. Children who were born after the introduction of the policy measures were found to have a lower risk of having fluorosis. Fluoride supplement use and age of toothbrushing with fluoridated toothpaste commencement were no longer risk factors for fluorosis.

Fluoridated toothpaste has been found to be one of the main risk factors for fluorosis (18). Fluoridated toothpaste use during the period from birth to 36 months has been reported to contribute to a significant proportion of total fluoride intake (17). The first 3 years of life is considered the risk period for fluorosis on early erupting teeth such as maxillary central incisors (18, 19). Controlling intake of fluoride from fluoridated toothpaste during this period restricts the risk of fluorosis on these most aesthetically important maxillary central incisors.

The introduction of low-concentration fluoridated toothpaste for children in Australia (containing 400–550 ppm fluoride) has led to change in the pattern of exposure to fluoride early in life. Two-thirds of children in the 2002/2003 CFS M2 reportedly used this type of fluoridated toothpaste when they first started brushing. The use of low-concentration fluoridated toothpaste was found to lower risk of fluorosis in a clinical trial (20, 21). Use of this type of toothpaste could lower the risk of fluorosis associated with early commencement of fluoridated toothpaste use or use of larger amounts of toothpaste for young children.

A habit of eating and/or licking toothpaste when toothpaste use began was found to be a strong risk factor for fluorosis, regardless of the type of toothpaste used. A similar finding was reported elsewhere (7). This habit was highly prevalent in this study population. Targeting this habit may lead to a further reduction in the risk of fluorosis in this child population.

Our results suggest that living in a fluoridated area and using standard-strength fluoridated toothpaste would have some cumulative effect on the risk of fluorosis. Possible explanation for this finding is that both fluoridated water and fluoridated toothpaste used in early childhood are substantial contributors to fluoride intake during these early ages. Hence, the risk of having fluorosis would be higher when compared with that in children who used lower strength fluoridated toothpaste. This finding was supported by the currently available evidence (17, 21).

Fluoride supplement use was found to be a risk factor for fluorosis in the 1992/1993 CFS M1. However, its use was not found to be associated with the prevalence of fluorosis in the 2002/2003 CFS M2. This change in risk of the use of fluoride supplements might be explained by the lower percentage of fluoride supplement users as well as stricter regimes for their use introduced in the policy measures in early 1990s. Similar results were reported in a study from another Australian state during the similar time period (9) that provides further supports for our findings.

Interestingly, use of infant formula was not found to be a risk factor for fluorosis in both studies even when some infant formula powders in Australia were found to have a high level of fluoride in the 1990s (22). The null finding persisted even when method of reconstitution was taken into account in analyses (data not shown). A possible explanation for this finding was that most of children who had infant formula were reportedly fed with formula only during the first year of life. The risk of fluorosis on maxillary central incisors may occur somewhat later in early childhood (18).

To conclude, the introduction of 400–550-ppm fluoridated toothpaste restricted the overall risk and risk factors associated with toothpaste use. The decrease in the use of fluoride supplements, and possibly stricter fluoride regimens, also restricted the risk of fluorosis. Periodic monitoring of the prevalence and risk factors for fluorosis is required to adjust guidelines for the appropriate use of fluoride in caries protection and prevention of fluorosis.

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References

1. Dean HT. The investigation of physiological effects by the epidemiological methods. In: Moulton F editor. Fluorine and dental health. Washington DC: American Association for the Advancement of Science.
2. 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.
3. Clark DC. Trends in prevalence of dental fluorosis in North America. Community Dent Oral Epidemiol 1994;22:148–52.
4. Rozier RG. The prevalence and severity of enamel fluorosis in North American children. J Public Health Dent 1999;59:239–46.
5. Mascarenhas AK. Risk factors for dental fluorosis: a review of the recent literature. Pediatr Dent 2000;22:269–77.
6. Riordan PJ, Banks JA. Dental fluorosis and fluoride exposure in Western Australia. J Dent Res 1991;70: 1022–8.
7. Riordan PJ. Dental fluorosis, dental caries and fluoride exposure among 7-year-olds. Caries Res 1993;27:71–7.
8. Puzio A. Dental fluorosis: assessment of risk factors associated with fluoride exposure. In: Dental School, Adelaide: The University of Adelaide; 2000. p. ix, 132.
9. Riordan PJ. Dental fluorosis decline after changes to supplement and toothpaste regimens. Community Dent Oral Epidemiol 2002;30:233–40.
10. Do LG, Spencer AJ. Decline in the prevalence of dental fluorosis among South Australian children. Community Dent Oral Epidemiol 2006.
11. Slade GD, Spencer AJ, Davies MJ, Burrow D. Intraoral distribution and impact of caries experience among South Australian school children. Aust Dent J 1996;41:343–50.
12. Spencer AJ, Slade GD, Davies M. Water fluoridation in Australia. Community Dent Health 1996;13 (Suppl. 2):27–37.
13. Fejerskov O, Manji F, Baelum V. Dental fluorosis: a handbook for health workers. Copenhagen: Munksgaard; 1988.

14. Do LG, Spencer AJ. Oral health-related quality of life of children by dental caries and fluorosis experience. J Pub Health Dent 2007;in press.
15. Burt BA, Eklund SA. Dentistry, dental practice and the community, 5th edn. Philadelphia, PA: WB Saunders; 1999.
16. Mascarenhas AK, Burt BA. Fluorosis risk from early exposure to fluoride toothpaste. Community Dent Oral Epidemiol 1998;26:241–8.
17. Levy SM, Warren JJ, Davis CS, Kirchner HL, Kanellis MJ, Wefel JS. Patterns of fluoride intake from birth to 36 months. J Public Health Dent 2001; 61:70–7.
18. Evans RW, Darvell BW. Refining the estimate of the critical period for susceptibility to enamel fluorosis in human maxillary central incisors. J Public Health Dent 1995;55:238–49.
19. Bardsen A. ''Risk periods'' associated with the development of dental fluorosis in maxillary permanent central incisors: a meta-analysis. Acta Odontol Scand 1999;57:247–56.
20. Winter GB, Holt RD, Williams BF. Clinical trial of a low-fluoride toothpaste for young children. Int Dent J 1989;39:227–35.
21. Holt RD, Morris CE, Winter GB, Downer MC. Enamel opacities and dental caries in children who used a low fluoride toothpaste between 2 and 5 years of age. Int Dent J 1994;44:331–41.
22. Silva M, Reynolds EC. Fluoride content of infant formulae in Australia. Aust Dent J 1996;41:37–42.