Natural history and long-term impact of dental fluorosis: a prospective cohort study

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Abstract

Objective: The study assessed longitudinal changes in the presentation of dental fluorosis and evaluated the impact of fluorosis on the perception of oral health among young adults.

Design and setting: Prospective follow-up study during 2011–12 of a population-based study in South Australia conducted between 2003 and 2004.

Participants: 8–13-year-old children initially examined in 2003 and 2004.

Main outcomes: Dental fluorosis was assessed with the Thylstrup and Fejerskov (TF) Index. The impact on perceptions of oral health by the study participants and their parents was assessed with the Global Rating of Oral Health (GROH). Pairwise comparative analysis of the presentation of fluorosis was conducted at the individual and tooth levels. Multivariable models of changes in fluorosis were generated. An ordinal logistic regression model was used to evaluate the association between GROH with dental fluorosis, caries and other factors.

Result: A total of 314 participants completed the follow-up questionnaires and dental examination. Over 60% of teeth scored as TF 1 at baseline were scored as TF 0 at follow-up; 66% of teeth scored as TF 2 or 3 at baseline were scored as TF 0 or 1 at follow-up. In multivariable models, changes in fluorosis were not significantly associated with socio-economic factors or oral health behaviours, confirming that they were the result of a natural process. Perceptions of poor oral health were significantly associated with the number of untreated decayed tooth surfaces at follow-up, but not with fluorosis.

Conclusion: Very mild and mild dental fluorosis diminished with time. Dental fluorosis did not have a negative impact on perceptions of oral health.

Dental fluorosis is a developmental condition of tooth enamel caused by excessive fluoride exposure during periods of enamel formation (the first 3 years of life). Fluorotic enamel is histologically characterised by subsurface porosity. In clinical terms, fluorosis ranges from barely visible white striations to staining and pitting of the enamel.[1] Systemic fluoride exposure in childhood is the necessary aetiological factor in the development of dental fluorosis.[2-4]

Dental fluorosis is the most common adverse effect of exposure to fluoride used to prevent dental caries.[5] The public health importance of dental fluorosis lies in its role as a population indicator of excessive fluoride exposure. Dental fluorosis, once dismissed as a condition without public health significance, is now an important problem in oral health care for a number of reasons:

- Reports in the scientific literature have recently elevated the prominence of dental fluorosis as an adverse outcome of fluoride use;
- Public opinion about the safety of fluoride now routinely cites dental fluorosis as a specific concern; and
- Recommendations about the use of fluoride should be based on evidence regarding the benefit–risk trade-off between preventing dental caries and the risk of fluorosis.

Judgements about dental fluorosis should be based on a sound understanding of its natural history. Scientific information about dental fluorosis is, however, limited to cross-sectional and case–control studies. It is therefore unknown whether post-eruptive changes in enamel affect the clinical presentation of fluorosis.

Dental fluorosis is potentially an important problem, both for the affected individuals and for public health.[6] Fluorosis can affect perceptions of dental appearance and, consequently, indicators of oral health-related quality of life. However, there have been no prospective studies that document any long-term impact of dental fluorosis on oral health-related quality of life.

The specific aim of this study was to document the natural history of untreated dental fluorosis during a 6-year period, and to assess factors associated with longitudinal changes in dental fluorosis. Our second aim was to investigate the long-term impact of dental fluorosis on perceptions of oral health.

Methods

The baseline study

Our study was a longitudinal follow-up of a population-based study of children aged 8–14 years in South Australia conducted between 2003 and 2004.[7-9] The baseline study collected data on socio-economic status, residential history, oral health-related behaviours, and the oral health status of the children.

A total of 677 children were examined by a specially trained dentist. Fluorosis was initially diagnosed using the Russell differential diagnostic criteria[10] and then scored for severity according to the 10-point Thylstrup and Fejerskov (TF) Index.[1] A total of 1365 fluorotic teeth were identified in 267 children. The prevalence of fluorosis, defined as a maxillary central incisor scored as at least TF 1, was 30%; 11% of the teeth were scored as TF 2 or 3. Maxillary central incisors are commonly assessed when estimating the prevalence of dental fluorosis to ensure comparability across ages. The highest score in our sample was TF 3 (moderate fluorosis).[9]

Study participants and their parents completed the Child Perception Questionnaire (CPQ) and the Parental Perception Questionnaire (PPQ) respectively,[11,12] each of which included a Global Rating of Oral Health (GROH). Dental caries and malocclusion were associated with poor perceptions of oral health, but dental fluorosis was not.[7]

The follow-up study (October 2010 – December 2012)

The baseline study sample was recontacted with the help of their recorded contact details. Tracking attempts were also made through the Australian Electoral Commission, the White Pages, and through third parties for whom contact details had been provided during the baseline study.

The participants and their parents received questionnaires requesting information about their socio-economic situation, oral health behaviours and practices, and their perceptions of oral health-related quality of life (CPQ and PPQ respectively, each with GROH).

Participants who completed the questionnaire were invited for an oral health examination at a local South Australian Dental Service clinic. The examination protocol was the same as that for the baseline study. The three trained and calibrated examiners, including the baseline examiner who trained the other examiners, were blinded to baseline dental fluorosis scores.

Dental caries and malocclusion were assessed.[13] Dental fluorosis was assessed with the TF index,[1] using the same examination procedures as the baseline study.

When tooth discolourations had already been recorded for a participant by the principal examiner, a research assistant invited the child for another visit and randomly assigned them to one of the other two examiners, who were not made aware that the participant was attending for a repeat examination. A total of 12 repeat examinations were undertaken. Inter-rater agreement at the individual and tooth levels was estimated. The estimated weighted kappa (κ) scores were all over 90%.

Statistical analysis

The major demographic characteristics of the follow-up sample were compared with those of the baseline sample to identify any retention bias. The follow-up sample with full data and the group of those who provided only questionnaire data were compared with non-respondents.

Forty-one children with orthodontic treatment and three with tooth bleaching were excluded from the analysis; they did not differ with respect to baseline fluorosis from the included participants (data not shown).

First aim. The main analysis compared dental fluorosis at baseline and follow-up. Separate analyses were conducted at the person and tooth levels using pairwise analysis of fluorosis scores collected at baseline and follow-up. The person-level analysis defined cases of dental fluorosis based on the highest TF scores for maxillary central incisors. The tooth-level analysis compared TF scores of individual teeth in the maxillary arch, from first premolar to first premolar (up to eight teeth per child). The direction and magnitude of changes were reported. The McNemar test assessed the significance of differences in pairwise comparisons, using 2×2 cross-tabulations. Two further analyses were then conducted. First, the PROC CROSSTAB procedure of SUDAAN release 11.01 (RTI International) generated estimates of changes in proportions at the tooth level, with 95% confidence intervals. Second, the MIXED procedure of SAS 9.4 (SAS Institute) used a mixed model for repeated measures to estimate mean scores at follow-up. For tooth-level analysis, individuals were treated as clusters to account for the interdependence of teeth characteristics within individuals.

For the tooth-level comparison, diminished and increased fluorosis were defined as having one or more teeth with respectively a lower or higher TF score at follow-up than at baseline. Two separate log-binomial multivariable regression models were generated for the two directions of change, with explanatory factors being socio-economic factors, dental health behaviours, and fluorosis on the maxillary central incisors. These regression models assessed whether the observed changes in fluorosis reflected a natural process. Prevalence ratios associated with changes and 95% CIs were reported.

Second aim. GROH responses by the children and their parents at follow-up were used to produce two outcome variables, child and parental GROH, with the ordinal categories "excellent/very good", "good" and "fair/poor". These outcomes were regressed in multinomial regression models with baseline factors as explanatory variables. The long-term impact of dental fluorosis recorded at baseline on GROH at follow-up was assessed in models adjusted for other baseline factors, including socio-economic characteristics, occlusal traits measured by the Dental Aesthetic Index, and dental caries. Proportional odds ratios and 95% CIs are reported. The proportional hazards assumption was not violated in our models.

Ethics approval

The study was approved by the University of Adelaide Human Research Ethics Committee (reference H-153-2008).

Results

A total of 409 participants completed the questionnaire (60% of baseline sample), and 314 of the baseline sample (46%) underwent oral examination at follow-up (Box 1). There were no statistically significant differences between those who only completed the questionnaire and those who provided full data at follow-up with respect to the major baseline characteristics, including oral health behaviours and dental fluorosis and caries.

1 Characteristics of the study participants at baseline and follow-up

	Non-respondents		Respondents with questionnaire only		Respondents with full data	
Baseline factors	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)
Total number	268		95		314	
Birth cohort						
Born 1989–1990	72	26.9% (21.5–32.2)	32	33.7% (24.2–43.2)	67	21.3% (16.8–25.9)
Born 1991–1992	94	35.1% (29.3–40.8)	29	30.5% (21.2–39.8)	101	32.2% (27.0–37.3)
Born 1993–1994	102	38.1% (32.2–43.9)	34	35.8% (26.1–45.5)	146	46.5% (41.0–52.0)
Sex						
Male	143	53.0% (47.0–58.9)	50	52.6% (42.6–57.4)	156	49.7% (44.1–55.2)
Female	125	47.0% (41.1–53.0)	45	47.4% (37.3–57.4)	158	50.3% (44.8–55.9)
Income at baseline						
Low	94	40.9% (34.5–47.2)	37	44.6% (33.9–55.3)	116	40.7% (35.0–46.4)
Medium	101	43.9% (37.5–50.3)	37	44.6% (33.9–55.3)	133	46.7% (40.9–52.5)
High	35	15.2% (10.6–19.9)	9	10.8% (4.1–17.6)	36	12.6% (8.8–16.5)
Parental education*						
Low	104	43.3% (37.0–49.6)	36	41.4% (31.0–51.8)	132	44.0% (38.4–49.6)
Medium	72	30.0% (24.2–35.8)	24	27.6% (18.2–37.0)	59	19.7% (15.2–24.2)
High	64	26.7% (21.1–32.3)	27	31.0% (21.3–40.8)	109	36.3% (30.9–41.8)
Brushing frequency						
Less than twice a day	79	33.8% (27.7–39.8)	28	32.6% (22.6–42.5)	84	28.9% (23.6–34.1)
At least twice a day	155	66.2% (60.2–72.3)	58	67.4% (57.5–77.4)	207	71.1% (65.9–76.4)
Dental caries						
Baseline DMFS	268	1.02 (0.76–1.29)	95	0.81 (0.47–1.15)	314	0.96 (0.72–1.20)
Baseline dental fluorosis						
TF 1	36	14.2% (9.9–18.5)	15	16.3% (8.7–23.9)	37	12.3% (8.5–16.0)
TF 2 or 3	29	11.5% (7.5–15.4)	4	4.3% (0.2–8.5)	24	7.9% (4.9–11.0)

DMFS = decayed, missing or filled tooth surface; TF = Thylstrup and Fejerskov Index score. All percentages are column percentages. * $P < 0.05$ (χ^2 comparison). ◆

Box 2 summarises pairwise comparisons of dental fluorosis at baseline and follow-up at the person and tooth levels. At the person level, 87% of individuals who scored TF 0 at baseline also did so at follow-up; about 12% were scored as TF 1 at follow-up. For those scored as TF 1 at baseline, 46% were scored as TF 0 at follow-up, and the others were unchanged. For half of those with a TF score of 2 or 3 at baseline, the fluorosis score was lower at follow-up — five were scored as TF 0, seven as TF 1 — while the scores for 10 children were unchanged.

At the tooth level, 91% of examined teeth with TF 0 at baseline were also scored as TF 0 at follow-up. More than 60% of teeth scored as TF 1 at baseline were scored as TF 0 at follow-up, and only two of 79 teeth deteriorated to TF 2 or 3. Two-thirds of the 58 teeth scored as TF 2 or 3 at baseline received a lower score at follow-up. After adjustment for clustering within individuals, tooth-level mean TF scores at follow-up were significantly lower than the actual scores recorded at baseline (mean score changes for teeth with baseline score of TF 1: 0.26 [95% CI, 0.20–0.32]; TF 2: 0.39 [95% CI, 0.27–0.51]; TF 3: 0.97 [0.76–1.18]).

Factors potentially associated with either reduced or increased dental fluorosis were evaluated in two multivariable regression models (Box 3). More frequent teeth brushing was associated with a non-significantly greater reduction in fluorosis. Household income at baseline was not significantly associated with changes in fluorosis score. Urban residents and those whose parents had medium levels of education were more likely to have increased fluorosis. The baseline fluorosis score was statistically correlated with reduced but not with increased fluorosis.

Associations between the socio-economic, behavioural and clinical factors measured at baseline and the rating of oral health by participants and their parents at follow-up were regressed in two multinomial regression models (Box 4). Baseline fluorosis was not significantly associated with poorer rating of oral

2 Changes in dental fluorosis scores at the person and tooth levels

	Follow-up fluorosis score					
	TF 0		TF 1		TF 2–3	
Baseline fluorosis score	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)
A Person-level changes*						
TF 0 (207 children)	181	87.4% (82.9–92.0)	24	11.6% (7.2–16.0)	2	1% (0.0–2)
TF 1 (35 children)	16	46% (29–62)	19	54% (38–71)	0	NA
TF 2 or 3 (22 children)	5	23% (5–40)	7	32% (12–51)	10	46% (25–66)
B Tooth-level changes†						
TF 0 (1270 teeth)	1157	91.1% (89.5–92.7)	103	8.1% (6.6–9.6)	10	1% (0–1)
TF 1 (126 teeth)	79	62.7% (54.2–71.1)	45	35.7% (27.3–44.1)	2	1.6% (0.0–3.8)
TF 2 or 3 (58 teeth)	18	31% (19–43)	20	35% (22–47)	20	35% (22–47)

NA = not applicable; TF = Thylstrup and Fejerskov Index score. * Maximum TF scores on maxillary central incisors. Forty-four participants were excluded because they had had orthodontic treatment or tooth bleaching; six children were excluded because they did not have any erupted permanent teeth at the time of the baseline examination. † TF scores of individual maxillary permanent teeth: first premolars, canines and incisors. ◆

3 Factors associated with longitudinal changes in dental fluorosis

	Reduced TF score*		Increased TF score†	
Baseline factors	*n* (row %)	Adjusted PR (95% CI)	*n* (row %)	Adjusted PR (95%CI)
Birth cohort				
Born 1989–1990	22 (33.9%)	0.92 (0.59–1.43)	14 (21.5%)	0.94 (0.54–1.61)
Born 1991–1992	39 (39.4%)	1.18 (0.81–1.72)	16 (16.2%)	0.76 (0.46–1.28)
Born 1993–1994	43 (30.3%)	1	25 (17.6%)	1
Sex				
Male	53 (34.6%)	0.89 (0.64–1.24)	27 (17.7%)	1.19 (0.77–1.84)
Female	51 (33.3%)	1	28 (18.3%)	1
Income at baseline				
Low	33 (29.5%)	1	19 (17.0%)	1
Medium	47 (35.9%)	1.06 (0.73–1.53)	31 (23.7%)	1.00 (0.63–1.59)‡
High	16 (47.1%)	1.16 (0.68–1.97)	1 (2.9%)	
Parental education				
Low	45 (34.6%)	1	17 (13.1%)	1
Medium	16 (28.6%)	0.90 (0.56–1.44)	20 (35.7%)	2.47 (1.48–4.12)
High	40 (37.7%)	1.16 (0.78–1.72)	16 (15.1%)	0.89 (0.49–1.60)
Brushing frequency				
Less than twice a day	23 (27.7%)	1	19 (22.9%)	1
At least twice a day	77 (38.3%)	1.26 (0.85–1.87)	33 (16.4%)	0.77 (0.49–1.21)
Residence type				
Urban	59 (45.0%)	1	35 (26.7%)	1
Rural	45 (25.7%)	0.70 (0.50–1.00)	20 (11.4%)	0.54 (0.34–0.85)
Baseline TF scores on central incisors				
TF 0	54 (22.4%)	1	37 (15.4%)	1
TF 1	25 (67.6%)	2.78 (1.86–4.15)	9 (24.3%)	1.27 (0.72–2.24)
TF 2 or 3	23 (95.8%)	3.91 (2.53–6.04)	8 (33.3%)	1.65 (0.86–3.18)

PR = prevalence rates estimated by multivariable regression models; TF = Thylstrup and Fejerskov Index score. * One or more teeth with a lower TF score at follow-up. † One or more teeth with a higher TF score at follow-up. ‡ Medium and high income categories combined for this calculation because of low numbers. ◆

4 Factors associated with poor perception of oral health at follow-up (proportional odds ratios with 95% CIs)*

Baseline factors	Study participants	Parents
Income at baseline		
Low	0.71 (0.32–1.58)	1.12 (0.40–3.14)
Medium	0.83 (0.39–1.78)	0.92 (0.34–2.50)
High	1	1
Parental education		
Low	0.83 (0.49–1.45)	1.53 (0.78–3.03)
Medium	0.92 (0.49–1.71)	1.18 (0.54–2.58)
High	1	1
Brushing frequency		
Less than twice a day	1.40 (0.87–2.27)	2.07 (1.19–3.63)
At least twice a day	1	1
Residence type		
Urban	0.82 (0.52–1.30)	1.49 (0.86–2.59)
Rural	1	1
TF scores†		
TF 0	1	1
TF 1	1.13 (0.63–2.03)	1.32 (0.52–3.38)
TF 2 or 3	0.99 (0.39–2.53)	1.00 (0.31–3.20)
Malocclusion‡		
Normal	1	1
Severe malocclusion	0.88 (0.52–1.30)	1.99 (1.05–3.77)
Moderate malocclusion	0.91 (0.51–1.63)	1.09 (0.52–2.28)
DMFS score	1.27 (1.12–1.44)	1.14 (1.01–1.28)

DMFS = decayed, missing or filled tooth surface; TF = Thylstrup and Fejerskov Index score. * Ordinal logistic model for perception of oral health. Other included factors (age, sex) are not presented. Proportional odds ratios indicate probabilities of having the lower ordered values (poorer Global Rating of Oral Health). † Highest dental fluorosis scores on maxillary central incisors. ‡ Assessed with the Dental Aesthetic Index. ◆

health. Infrequent teeth brushing (less than twice daily), dental caries and malocclusion at baseline were significant predictors of a poorer rating of oral health at follow-up.

Discussion

This is the first study to evaluate the natural history of dental fluorosis and its long-term impact on individual perceptions of oral health.

The study found that mild and very mild dental fluorosis (TF score, 1–3) in children had a tendency to diminish with time. Increased fluorosis was associated with medium parental education and an urban place of residence, for which there is no obvious explanation. However, the proportion of teeth in which fluorosis increased was small, so that the changes may simply reflect the natural progression of mild and very mild dental fluorosis in this adolescent population. The implication of this finding is that this level of dental fluorosis, as a side effect of fluoride used to prevent dental caries, may not have a significant dental public health impact.

Enamel is not static, and its appearance can be affected by post-eruptive changes, exaggerating or reducing the clinical presentation of fluorosis. Physical forces in the mouth during mastication and teeth brushing can cause fluorotic porous surfaces to be worn away, exposing enamel that does not appear fluorotic. Further, enamel continues to mature after eruption, and during adolescence this can lead to the closing of the microporosities observed in very mild or mild dental fluorosis. Expectations of these directions of change, especially in mild forms of fluorosis, are, however, based largely on cross-sectional findings or laboratory assessments.[14] Our study has confirmed the reduction of dental fluorosis with age in a real-life, population-based sample.

The study also found that dental fluorosis did not have any negative effect on perceptions of oral health. Dental fluorosis at this low level has only an aesthetic impact, if any.[15] Our finding was consistent with our earlier cross-sectional findings,[7] as well as with those of other cross-sectional studies.[16-18]

The public perception of fluorosis has attracted increasing attention in recent major reviews.[5,19] There is overwhelming support for the use of fluoride as part of oral health policy because of its role in the substantial decline in the prevalence of dental caries. However, the currently relatively low level of dental caries among children may alter attitudes to the balance between caries prophylaxis and fluorosis. The community deserves a thorough explanation of the nature of fluorosis, as well as consideration of their perceptions of oral health and wellbeing. The findings of our investigation of the natural history of dental fluorosis will help inform the public about the condition and evidence-based clinical recommendations for its treatment.

Balancing risks and benefits is a problem associated with any intervention. In the case of fluoride, the benefit of preventing dental caries has always been associated with some risk of fluorosis. Evaluation of the risk–benefit balance provides scientific information upon which to base recommendations for the use of fluorides. Evaluation of the trade-off must include clinical experience of both sides of the balance. More importantly, it must include evaluation of the potential impact that each outcome has on the health and wellbeing of individuals and of the population as a whole.

Dental caries causes permanent destruction of dental tissue, leading to pain and discomfort that may require treatment which is costly for both the individual and society. Caries was found in cross-sectional studies to have a negative impact on the oral health-related quality of life of children and their families studies.[7,20,21] Our study confirmed that dental caries in childhood has a negative impact on perceptions of oral health 6–7 years later. After controlling for other factors, dental caries during childhood significantly increased the probability of a lower rating of oral health in young adulthood. Preventing dental caries from a young age is therefore of the utmost importance in evaluating the value of fluoride use.

Possible limitations to this study include the low retention rate between baseline and follow-up, the influence of parental education, inter-rater variability, and the use of the TF index. Systematic retention bias was unlikely. Dental fluorosis at baseline did not influence participation at follow-up. Parental education was a factor that was of mild statistical significance in determining participation at follow-up. There is, however, no theoretical background or empirical evidence suggesting that parental education influences the natural course of dental fluorosis. Only 12 participants were available for rating inter-rater reliability, so we assessed this at the tooth level, using more than 200 teeth. It might be argued that the TF index assesses dental fluorosis under unnatural conditions, but we believe it ensured that the examination conditions were standardised, enabling data at the two time points to be compared.

In conclusion, our study provides strong evidence about the natural history of mild and very mild dental fluorosis during the period between adolescence and young adulthood. Dental fluorosis during childhood diminishes over time. Further, dental fluorosis at this low level had no impact on perceptions of oral health, in contrast to dental caries. It is, therefore, preferable to emphasise the beneficial effect of fluoride in preventing dental caries rather than the risk of dental fluorosis.

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