DENTAL FLUOROSIS IN SUBJECTS EXPOSED TO FLUORIDE CONTAINING DRINKING WATER AT DIFFERENT AGE

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SUMMARY: The present study was planned in order to gain more information on the age-related susceptibility to dental fluorosis. Fourty children, who had been life-long consumers of water from high-fluoride wells in the county of Hordaland, Western Norway, were identified, together with a similar number of their older siblings, who had been exposed to high-fluoride water at ages varying from 6 months to 6 years. After informed consent had been given, each child and one of the parents were interviewed. Then the children were examined for dental fluorosis. Scorings were given according to the TF-index. Reliability tests were performed. The fluoride content of the relevant drinking water ranged from 0.5 to 7.2 mg/L. Of the 80 children examined, 66 had the upper central incisors erupted. Of these 66, 22, or one third, were without any sign of dental fluorosis. The rest had TF-scores in the range of 1-5. The children were divided into groups, according to the age at which they were exposed to high-fluoride water. As compared to the whole group, the odds ratio for a child to have a maxillary incisor with fluorosis were 7.63 (95% CI = 2.28, 25.58) when the exposure to high-fluoride water took place during the first year of life. These findings indicate that the first year of life is the most important period for the development of dental fluorosis in the maxillary central incisors. An inverse relationship seems to exist between the severity of dental fluorosis and the age at which exposure took place.

Key words: Dental fluorosis; Exposure; Fluoride; Window of maximum sensitivity

INTRODUCTION

The fact that excess fluoride intake causes dental fluorosis in developing teeth is well documented.[1-3] However, studies concerning the induction of dental fluorosis are relatively few, and findings are inconsistent. It has been indicated that on a worldwide basis the prevalence of dental fluorosis is increasing, even in low-fluoride areas. To provide better guidelines for the use of fluoride in caries prevention, and also to avoid negative focusing on fluoride, it is of importance to know the biological aspects of dental fluorosis, and the process leading to its induction.

Most major water-works in Norway rely on low-fluoride surface water reservoirs.[4,5] The possibility of artificial water fluoridation was discussed in the 1960'ies, but due to political reasons fluoridation of drinking water has never been implemented in Norway.[6-8] In stead, realising the cariostatic properties of fluoride,[9-11] national caries prevention programs have focused on the use of alternative fluoride sources such as fluoride containing toothpaste, fluoride tablets, fluoride mouthrinses and professionally applied topical fluoride agents.

Fluoride toothpaste is presently used by 92 % of Norwegian children in the age of 7-15 years, and by 88 % of the total population.[12] The use of fluoride tablets has been recommended for all children from the age of 6 months.[13] Until recently (1996) fluoride tablets have been distributed in child-health care clinics as well as by the school dental service, on request - free of charge. Fluoride tablets and fluoride rinses have been used by 32 % of children in the age of 7-15 years, and by 9 % of the total

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population.[12] Sixty percent of the Norwegian school children (7 to 15 years) have been exposed to local professional fluoride application on a yearly basis.[14]

The use of and choices in fluoride supplements in Norway has increased; so has the consumption of groundwater.[15] Recent investigations have shown that the Norwegian hard-rock groundwater may contain high concentrations of fluoride.[16-18] As fluoride analysis is not automatically included in the testing of new wells, young consumers of the ground waters may, unexpectedly, develop dental fluorosis.

The present study was planned in order to gain more information on the age-related susceptibility to dental fluorosis.

MATERIAL & METHODS

Based on information obtained in previous studies,[18-19] 40 children who had been lifelong consumers of water from high-fluoride (> 0.5 mg F/L) groundwater wells in the county of Hordaland, Western Norway, were identified, together with a similar number of their older siblings, who had been exposed to high-fluoride water at ages varying from 6 months to 6 years.

The fluoride level of the wells was determined, based on the analysis of at least two water samples within a year, and none of the measurements showing a fluoride value < 0.5 mg/L.

Informed consent to partake was given by the participants' parents, or by the participants them selves if 18 years of age, before clinical examination.

Clinical Examination. Clinical examinations were conducted at the county dental health service clinics, while the participant was seated in a dental unit under standard clinical illumination. Teeth were cleaned with pumice and rotating rubber cups, rinsed with water and dried (air-jet) for approximately 30 seconds, before the examination. Each participant was examined for dental fluorosis, and scorings were recorded according to the modified TF-index.[3,20] All fully erupted teeth were given a score. Dental fluorosis was assessed by one examiner (AB) without previous knowledge of the children's fluoride exposure or time of residency in the area. Clinical photographs were taken of the anterior teeth in all the participants, using a Dental Eye camera (Yashica) and Kodak colour slides (EPN 200).

Reliability tests for the scoring of dental fluorosis were carried out, and showed excellent agreement (Kappa = 0.85, $p < 0.01$).[21] No statistically significant systematic error was found using Student's T-test for paired observations ($p = 0.49$).

Questionnaire. Before clinical examination, the participants and their parent(s) were interviewed. For participants without any parent present, the questionnaire was sent home to be completed by the parents. Following information was requested: area of residence and length of residency as well as type of water supply. Other questions were related to start and duration of the use of fluoride supplements, commencement and use of fluoride toothpaste and oral hygiene. Information on the frequency of intake of various beverages; history of breast- and baby bottle feeding as well as previous and present diet was also obtained. Information concerning traumatic injuries to the tooth/teeth or their predecessors was taken from the participant's dental record. Some of the obtained information is shown in Table 1, given as divided (mostly dichotomised) variables.

Data Analysis. The data were coded, computerised and analysed using the Statistical Program for Social Science (SPSS-PC Inc.).[22] Descriptive analyses were performed and frequency distributions compared using chi-square tests (significance level set at 5 %). The Pearson correlation coefficient was used to look for direct relation between severity of dental fluorosis on the maxillary permanent central incisors and the age (in months) when exposed to high-fluoride water, as well as between TF-score on the same tooth-group and fluoride content in the high-fluoride water.

The variables (dependent and independent) used in this study were divided - most of them dichotomised - in order to facilitate interpretation of the results (Table 1). Multiple logistic regression analysis including independent variables having a statistically significant bivariate effect, was carried out to assess the effect of each variable after adjusting for the effect of all others in the model. The 95% confidence interval of the odds ratio (OR) was calculated using Wolf's equation.[23]

TABLE 1. Frequency distribution on the divided variables.

Variable		n*	%
Sex	Female	30	46
	Male	36	54
Use of breast milk substitutes	No	22	33
	Yes	41	62
F-tablet intake	Less than once a day	25	38
	Once a day or more	41	62
Use of F-toothpaste	Once a day or less	19	29
	More than once a day	47	71
Age at start using F-tablets	One year or younger	30	46
	Older than one year	20	30
Age at start using F-toothpaste	One year or younger	33	50
	Older than one year	33	50
Amount of fluoride used on the toothbrush	Up to 1/3 of the length of the head of the toothbrush	2	3
	More than 1/3 of the length of the head of the toothbrush	64	97
Age when introduced to high-fluoride groundwater	0 - 12 month	33	50
	13 - 24 month	11	17
	25 - 36 month	8	12
	37 - 84 month	14	21

*Number of subjects answering the relevant question (range: 50-66)

RESULTS

Participation. A total of 30 families were involved in the study, each with 2 to 4 children. Of the selected group of 80 individuals, 66 had their upper central incisors present without any filling, orthodontic brackets or any history of traumatic injuries to the tooth/teeth or the predecessors (83%). The age of participants ranged from 8 to 18 years. No significant difference in gender distribution were observed (Table 1).

Fluoride Exposure. The mean fluoride content of the drinking waters was 2.2 mg/L, and the fluoride content of the relevant drinking water sources ranged from 0.5 to 7.2 mg/L (25^{th} percentile; 0.7 mg F/L, and 75^{th} percentile 3.3 mg F/L).

Dental Fluorosis. In the present study, 44 out of 66 participants (67 %) had TF-scores in the range of 1 to 5 on the maxillary permanent central incisors. The distribution of TF-scores according to age when exposed to high-fluoride groundwater is shown in Table 2. Some of the children who had been exposed to high-fluoride water only after 1 year of age had milder forms of dental fluorosis (TF-score 1 and 2), while eight out of nine children who had TF-scores 3-5 had been exposed to high-fluoride water before the age of 9 months. The exception was an individual who had been exposed to high-fluoride water only at the age of 14 months.

A negative correlation was found between the severity of dental fluorosis on the maxillary permanent central incisors and the age - in months - when the individuals first were exposed to high-fluoride water ($r = -0.54$, $p < 0.01$). No statistically significant correlation was found between the TF-score on the maxillary permanent central incisors and the fluoride content of the drinking water ($r = 0.09$, $p = 0.48$).

Three of the independent variable from Table 1 had a significant bivariate effect on the prevalence of dental fluorosis: (i) age when exposed to high-fluoride water, (ii) intake of fluoride tablets and (iii) frequency of the use of fluoridated toothpaste.

TABLE 1. TF-score on maxillary permanent central incisors according to age when introduced to high-fluoride groundwater.

Age when exposed to high-fluoride water	**TF-score**							
							Total	
	0	**1**	**2**	**3**	**4**	**5**	**1 -5**	**%**
0 – 12 month	3	14	8	4	1	3	30	91
13 - 24 month	4	6	-	1	-	-	7	64
25 - 36 month	2	5	1	-	-	-	6	75
37 - 84 month	13	1	-	-	-	-	1	7

TABLE 2. Regression coefficient and odds ratios for participants (n = 66) with the dependent variable: Dental fluorosis or not on the maxillary permanent central incisors (coded; 0 = TF-score 0, 1 = TF-score ≥ 1).

Independent variables		Regression coefficient	Odds ratio	95 % confidence interval
Age when introduced to high fluoride groundwater	0 - 12 month vs. the average of all groups	2.03	7.63	2.28 - 25.58
	13 - 24 month vs. the average of all groups	0.44	1.56	0.43 - 5.63
	25 - 36 month vs. the average of all groups	0.88	2.40	0.48 - 11.88
F-tablet intake	≥ once a day vs. < once a day	-1.91	0.15	0.02 - 1.35
Use of F-toothpaste	> once a day vs. ≤ once a day	-0.42	0.66	0.11 - 3.97

The final multiple logistic regression model for fluorosis on the maxillary permanent central incisors is shown in Table 3. In this analysis with TF-score as the dependent

variable (0 = TF-score 0, 1 = TF-score ≥ 1) and the above three variables as the independent variables, only one variable had a statistically significant risk of giving dental fluorosis. Participants which were exposed to high-fluoride water within the first 12 months of life showed an odds ratio of 7.63 (95% CI = 2.28 - 25.58) for dental fluorosis (≥ TF-score 1) on the maxillary permanent central incisors as compared to the average risk for the whole group.

DISCUSSION

Several reviews have been written regarding the mechanisms by which fluoride can affect mineralising tissues.[24-26] The authors seem to agree that the severity of enamel fluorosis depends on the amount of fluoride ingested, but the duration of exposure and critical stage of amelogenesis is not established.

Even before fluoride was found to be the causative element for dental fluorosis, estimates for the period of greatest susceptibility of enamel damage to the maxillary central incisors were implicitly established by McKay[27, 28] who noted that the risk of mottling enamel to maxillary central incisors ceased after the age of five years. At the same time, Ainsworth[29] carried out a study in Essex, England, and concluded that upper central incisors were not susceptible to mottling after the age of three years. Larsen *et al*[30] support Ainsworth's findings, and find the dental enamel to be most susceptible to fluoride in late secretory- and early maturation phase. Ishi and Suckling[31] and Evans and Stam[32] found the development of dental fluorosis to be an enamel maturation phenomena. Then Holm and Andersen[33] and Ismail and Messer[34] found the enamel secretion phase to be of most importance for the development of dental fluorosis. DenBesten and Thariani[35] concluded that it is likely that enamel fluorosis can result from a number of mechanisms; animal and human studies indicate that the transition/early maturation stage is particularly susceptible to fluoride. But exposure to high levels of fluoride during the secretory stage may also increase the risk of fluorosis by increasing the fluoride concentrations locally during enamel development.

Conclusion

These findings indicate that the first year of life is the most important period for the development of dental fluorosis in the maxillary permanent central incisors. An inverse relationship seems to exist between the severity of dental fluorosis and the age at which exposure took place.

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