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The relationship between dental caries and dental fluorosis in areas with moderate- and high-fluoride drinking water in Ethiopia

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Abstract – *Objective:* The aim of the study is to assess the relationship between caries and dental fluorosis in Ethiopian children living in Rift Valley areas known for endemic fluorosis. *Method:* A total of 306 children (12–15 years old), selected from areas with moderate (0.3–2.2 mg/l), or high (10–14 mg/l) fluoride concentration in the drinking water were interviewed and examined for caries and dental fluorosis. Scorings were recorded according to the DMF system, and the Thylstrup-Fejerskov (TF) Index. *Results:* Prevalence of dental fluorosis (TF-score ≥1) was 91.8% (moderate area) and 100% (high-fluoride area). The corresponding caries prevalence and mean DMFT in the areas were 45.3% versus 61.6%, and 1.2 versus 1.8, respectively. Age and severity of dental fluorosis were found to be independent predictors for DMFT ≥1. When compared with 12-year olds with TF-scores 0–4, odds ratios were 3.0 (95% CI 1.6–5.7) and 2.0 (95% CI 1.2–3.2) if TF-scores were ≥5 and age 13–15 years, respectively. A positive relationship between caries and fluorosis was observed across tooth types in both areas. The percentage of children with DMFT ≥1 was highest in groups with TF-score ≥5 in the second molar, followed by the first molar. *Conclusion:* The present findings indicate that the second molar is the tooth most severely affected by dental fluorosis and dental caries. Dental caries increased with increasing severity of dental fluorosis, both in moderate- and high-fluoride areas. Thus, a positive relationship between dental caries and dental fluorosis was observed across various tooth types, in both areas.

Key words: dental caries; endemic fluorosis; Ethiopia; Rift Valley villages; school children

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Introduction

In most industrialized countries, the traditional high prevalence of caries among children and adolescents has declined during recent decades (1–3). In sub-Saharan African countries, where the caries prevalence in the child populations is low, the situation is less clear-cut. Some studies report no change (4), other findings indicate an increase or a decline in the prevalence of caries (5, 6). Great variations are seen between and within countries, as well as within different strata of the populations. Thus, the average DMFT scores for a country may hide large geographical variations (7).

Statistically speaking, dental caries does not rank among the more serious diseases in Africa. On an individual level, however, dental caries causes great suffering and, as dentists are in short supply, oral health is a problem of growing concern to most African countries (8).

Epidemiological data on the caries experience of Ethiopian children are scarce. Generally, low levels of dental caries have been reported: Littleton in 1958 (9) found that 82% of persons under the age of 40 years were caries-free, while a similar study by Olsson (10) 20 years later, concluded that 50% of persons of comparable age had no caries. A tendency towards an increase in the hitherto low caries prevalence in Ethiopia has been reported also by other available reports (11–13).

In industrialized countries, the caries decline has been related to the use of fluoride in different forms (14, 15). The therapeutic range of fluoride is, however, narrow, and an association between fluoride in drinking water and the degree of dental fluorosis has been documented worldwide (16–19). Fluorotic teeth have also been found in locations with low levels of fluoride in the water supply (20–22).

According to most reports (8, 23, 24), the caries prevalence tends to be reduced with increasing fluoride level in the drinking water, thus indicating a *negative association* between fluoride and caries. In sub-Saharan Africa, however, various studies have indicated no relation (25), or even a *positive* association between the fluoride concentration in drinking water and the prevalence of dental caries in the permanent dentition (20, 26). Thus, Grobleri et al. (20) identified a strong and positive relationship between caries and dental fluorosis on an individual level, but only among South African children living in high-fluoride areas. Similar results have been reported from Nigeria, where the lowest DMFT scores were observed in areas with fluoride concentrations in the drinking water supplies below 0.4 mg/l (27). Although a number of studies have dealt with the relationship between dental caries and dental fluorosis (28–34), the relationship between them is still undecided. Notably, the relationship between fluorosis and caries in areas of high water fluoride concentrations is not well described. For good reasons, Manji and Fjerskov (8) have appealed for more information.

Focusing on Ethiopian children living in fluorosis-endemic areas (fluoride concentrations in drinking water in the range of 0.3–14.0 mg/l), the aim of this study was:

- To assess caries and dental fluorosis in school children born and raised in areas with moderate- and high-fluoride concentrations in drinking water.
- To assess the relationship between dental fluorosis and caries experience (DMFT ≥1) at different diagnostic cut-off points.
- To assess the frequency distribution of children having DMFT ≥1, according to dental fluorosis at different diagnostic cut-off points and tooth type.

Material and methods

Study area and study population

This study was conducted in 1997 in three neighboring Rift Valley villages (A, K and M) within the Wonji Shoa Sugar Estate (WSSE). The villages are of approximately the same size and socioeconomic standards and were selected purposively for the study. The villages rely on local ground water sources with elevated but different fluoride concentrations. Village A and M rely on ground water with a fluoride concentration in the range of 0.3–2.2 mg/l, and are, in this paper, called the moderate-fluoride area. The ground water well of village K contains fluoride in the range of 10–14 mg/l. Village K, therefore, is called the high-fluoride area. Table 1 summarizes the levels of fluoride (mg F/l) in drinking water in the two areas, assessed between 1982 and 1997.

Sample size and procedures

A census of all children of the resident study population aged 12–15 years was undertaken. A total of 306 children, 152 girls (mean age 13.5 years) and 154 boys (mean age 13.1 years), were included in the study. Informed consent was obtained from the children and their parents, as well as from local authorities.

The children were exposed to a written questionnaire, constructed in English, translated into the local language and – for control purposes – translated back to English. The interviews, performed by trained local assistants, were conducted before the clinical examinations took place. Parents (mothers) were interviewed, in separate rooms by trained interviewers at the time of their children's oral examination.

Table 1. Average fluoride concentration (mg/l) measured in the drinking water of the moderate- and high-fluoride area

Year of assessment	Moderate-fluoride area	High-fluoride area
1982–1983	0.4–1.4	8.9–14.1
1984–1988	0.2–1.6	8.9–14.1
1989–1993	0.5–1.9	10.0–14.1
1997	0.3–2.2	10.0–14.0

The interviews included questions with fixed response alternatives and graphic rating scales. Sociodemographic characteristics were noted, such as father's occupational status [field worker/factory worker versus (occasionally employed) daily laborer]; father's educational status (elementary school only, junior high or high school) and family income level per month: 100 Ethiopian Birr (low), 101–300 Birr (medium), and above 300 Birr (high). Childrens' age at last birthday was dichotomized into 1 = 12 years, 2 = 13–15 years, in order to get closer to the 50% cut-off point between the two categories. Agreement between the parents' (mothers') and the children's answers, was tested as to father's occupational status. Cohen's kappa (κ) was found to be 0.36 and 0.35 for 12- and 13–15-year olds, respectively. Being within the interval of fair value (35), these results allowed the use of father's occupational status – as reported by their children.

Clinical examination

Intra-oral examination was conducted at the health centers of the areas by two examiners (F.W. and A.B.), each with an assistant recording the observations. Caries experience was assessed in accordance with the DMFS indices as described by WHO Oral Health Surveys (36). Dental fluorosis was assessed on vestibular, occlusal and lingual surfaces in accordance with the Thylstrup-Fejerskov Index (TFI) (37). After an initial cleaning of teeth by use of gauze, the dentition was inspected using disposable dental mirrors and probes. Illumination was by indirect sunlight and a headlamp. Except for third molars, all partly or fully erupted teeth were examined. Caries was recorded as being present when a lesion in a pit or fissure or on a smooth tooth surface had a detectable softened floor, undermined enamel or softened wall. A tooth with a temporary filling was also included in this category. On proximal surfaces, the examiner should be certain that the explorer has entered a lesion. Where any doubt existed, caries was not recorded as present. A tooth was considered missing because of caries if the child gave a history of pain and/or the presence of a cavity prior to extraction.

DMFT scores for each individual were established by summing the highest DMFS scores across all permanent teeth. For logistic regression analyses, dental caries was assessed as 0: DMFT = 0 and 1: DMFT ≥1. A median TF-score was constructed for each individual, based on the highest TF-score on each permanent tooth. Moreover, a TF-score for each tooth type (second molars, first molars, premolars, canines, incisors) was based on the median score of teeth in that tooth group. The severity of fluorosis was assessed as 0 = TF-score 1–4 and 1 = TF-score ≥5. Ten subjects were re-examined by both examiners for intra-examiner agreement, and furthermore, another 10 subjects were re-examined for inter-examiner agreement. The intra-examiner agreement was, respectively, $\kappa = 0.79$ and 0.86, while inter-examiner agreement for TF-scores was 0.82. Similarly, the intra-examiner scores for caries were $\kappa = 0.81$ and 0.91, while the inter-examiner score was 0.83. These values are considered substantial to almost perfect, according to the scale of Landis and Koch (38).

Statistical analyses

Data were computerized and analyzed using the Statistical Package for the Social Sciences (SPSS version 10.0). Bivariate analyses were performed using cross-tabulation, chi-square statistics, independent sample *t*-test, one-way ANOVA, Spearman's correlation coefficient (r_s) and the Kruskal–Wallis test. Dental caries prevalence (DMFT ≥1) was regressed on TF-scores and area of residence, controlling for possible confounding factors by the use of multiple logistic regression analyses. Ninety-five percent confidence interval (95% CI) was given for the odds ratios.

Results

Sample profile

The percentage distribution of participating school children according to sociodemographic characteristics and area of residence is shown in Table 2. Boys and girls were equally represented in the total sample: 50.3% versus 49.7%. As demonstrated in the table, however, boys and girls were unevenly represented in the two areas: boys constituting 42.2% in the moderate-fluoride area and 64.2% in the high-fluoride area. The corresponding figures for girls were 57.7% and 35.7% ($P < 0.05$). The frequency distribution of age by area of residence is given in Table 3.

Dental fluorosis and dental caries

Figure 1 summarizes the percentage distribution of adolescents according to median TF-score (for all teeth) in the moderate- and the high-fluoride area. As demonstrated by the figure, individual median TF-scores in the range 0–3 were more prevalent in

Table 2. Frequency distribution (%) of children's sociodemographic characteristics by area of residence

	Moderate-fluoride area (n = 194)	High-fluoride area (n = 112)	Total (n = 306)
Age (years)			
12	87 (44.8)	56 (50.0)	143 (46.7)
13–15	107 (55.1)	56 (50.0)	163 (53.2)
Gender			
Male	82 (42.2)	72 (64.2)*	154 (50.3)
Female	112 (57.7)	40 (35.7)	152 (49.7)
Father's occupation			
Field/factory worker	146 (75.2)	96 (85.7)	242 (79.0)
Others/daily laborer	48 (24.7)	16 (14.3)	64 (20.9)
Father's education			
Elementary school	51 (26.2)	28 (25.0)	79 (25.8)
Junior high-school	37 (19.0)	16 (14.3)	53 (17.3)
High-school	106 (54.6)	68 (60.7)	174 (56.8)
Monthly income			
<100 Birr (low)	35 (18.0)	26 (23.2)	61 (19.9)
101–300 Birr (medium)	123 (63.4)	74 (66.0)	197 (64.3)
>301 Birr (high)	36 (18.5)	12 (10.7)	48 (15.6)

*$P < 0.05$.

Table 3. The frequency distribution (%) of participants' age by area of residence

Age (years)	Moderate-fluoride area	High-fluoride area	Total
12	87 (44.8)	56 (50.0)	143 (46.7)
13	46 (23.7)	19 (17.0)	65 (21.2)
14	30 (15.5)	22 (19.6)	52 (17.0)
15	31 (16.0)	15 (13.4)	46 (15.0)
Total	194	112	306

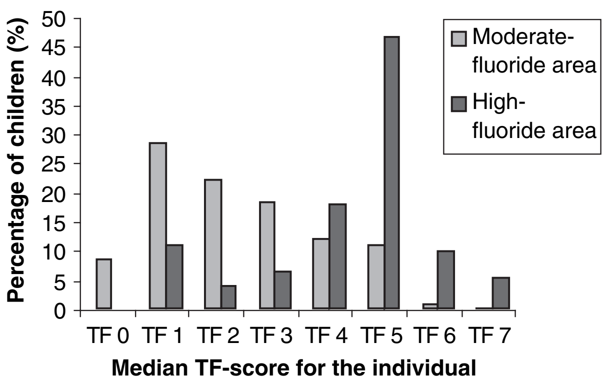

Fig. 1. The percentage distribution of adolescents according to median TF-score for the individual (all teeth) in moderate- and high-fluoride areas.

the moderate-fluoride area, while severe fluorosis (TF-score ≥5) was most prevalent in the high-fluoride area.

Prevalence of dental fluorosis (TF-score ≥1) was 91.8% and 100% in the moderate- and high-fluoride areas, respectively. The corresponding mean TF-scores were 1.91 ± 0.27 (range 0–1.00) and 2.00 ± 0.00 (range 0–0.00) in the moderate- and high-fluoride areas, respectively. The mean DMFT scores were 1.2 ± 1.9 and 1.8 ± 2.1 ($P < 0.05$), and the corresponding prevalence rates (DMFT ≥1) were 45.3% and 61.6%, in the moderate- and high-fluoride area. Of the DMFT scores, decayed teeth contributed 97.1%, missing teeth 2.6% and filled teeth 0.3%.

Relationship between dental fluorosis and dental caries in the moderate- and high-fluoride area

Table 4 summarizes the frequency distribution of caries-free children (DMFT = 0), children having both dental caries and dental fluorosis (DMFT ≥1 and TF-score ≥1) and those having dental caries only (TF-score = 0 and DMFT ≥1) according to area. As shown in the table, a total of 157 children (51.3%) had DMFT ≥1. Of these 157 children, the great majority (151, 96.1%) had dental fluorosis at TF-score ≥1. Only six children (3.8%) were diagnosed to have dental caries only. The lowest rate (38.4%) of caries-free children and the highest rate (100%) of children having both caries and dental fluorosis were found in the high-fluoride area.

Table 5 shows the results of the one-way ANOVA analysis with mean DMFT scores according to dental fluorosis at different diagnostic cut-off points, separately for the areas. As shown by the table, the mean DMFT scores increased substantially with increasing median TF-scores from TF = 0 to TF = 5–7 in both the moderate- and the high-fluoride area. Bonferroni *post hoc* test revealed that mean DMFT scores differed statistically significant

Table 4. Frequency distributions (%) of caries-free children, children with caries, children with both caries and dental fluorosis and children with caries only and DMFT scores according to area of residence

	Caries-free	Caries	Both caries and fluorosis	Caries only	DMFT
Moderate-fluoride area (n = 194)	106 (54.6)	88 (45.3)	82 (84.3)	6 (15.6)	1.26 ± 1.98
High-fluoride area (n = 112)	43 (38.4)	69 (61.6)	69 (100)	–	1.83 ± 2.10
Total (n = 306)	149 (48.7)	157 (51.3)	151 (96.1)	6 (3.8)	1.47 ± 2.04

Table 5. Mean DMFT scores and standard deviation by dental fluorosis at different diagnostic cut-off points in moderate- and high-fluoride areas

	Moderate-fluoride area		High-fluoride area		Total	
Median TF-score	n	DMFT	n	DMFT	n	DMFT
TF 0	16	0.75 ± 1.34	–	0 ± 0	16	0.75 ± 1.34
TF 1–2	98	0.86 ± 1.45	16	0.31 ± 0.70	114	0.78 ± 1.38
TF 3–4	58	1.48 ± 2.05	29	1.58 ± 1.91	87	1.51 ± 1.99
TF 5–7	22	2.86 ± 3.18*	67	2.31 ± 2.23*	89	2.44 ± 2.49*
Total	194	1.26 ± 1.98	112	1.83 ± 2.10	306	1.47 ± 2.04

*$P < 0.05$.

($P < 0.05$) between children having TF-scores 0 and those with TF-scores 1–2, 3–4 and 5–7. The ANOVA results were confirmed using Kruskal–Wallis test. Thus, there was a strong positive association between the TF- and DMFT scores, varying between $r_s = 0.49$ in the moderate-fluoride area and $r_s = 0.63$ in the high-fluoride area. DMFT scores in both areas varied systematically and positively also with age (r_s, $P < 0.001$ and 0.05).

To control for possible confounding variables, caries experience (DMFT ≥1) was regressed on median TF-scores adjusting for age, gender, socio-economic status and area of residence, using multiple logistic regression analysis. When compared with children with median TF-scores of 0–4 and 12 year olds, the odds ratio (OR) for having DMFT ≥1 was 3.0 (95% CI 1.6–5.7) and 2.0 (95% CI 1.2–3.2), respectively, if having TF-score ≥5 or being in the age range 13–15 years. No statistically significant interaction effect on caries experience was identified for the term TF-scores and place of residence, indicating that the strength of the association between dental caries and dental fluorosis did not vary systematically between the moderate- and high-fluoride areas.

Figure 2a,b shows the percentage of adolescents with caries (DMFT ≥1) according to dental fluorosis at different diagnostic cut-off points across various tooth types in the moderate- and high-fluoride areas, respectively. Second molars were the teeth most frequently affected by dental caries (DMFT ≥1, 42%) and dental fluorosis (TF ≥1, 95%), followed by first molar (DMFT ≥1, 35% and TF ≥1, 92%). In both moderate- and high-fluoride area, the percentage of children with DMFT ≥1 was highest at TF score 5–7 across the various tooth types, except for the incisors. The percentage of adolescents having dental caries at TF-score ≥5 was statistically significantly higher in the high-fluoride area when compared with the moderate-fluoride area (74.4% versus 34%).

Discussion

According to the classification of the World Health Organization (WHO) (36), the mean DMFT scores recorded in the study were low; regardless of the fluoride concentrations of the drinking water. The rates of children with dental caries (45.3% and 61.6% in the moderate- and high-fluoride areas, respectively), correspond fairly well with previously reported findings among Ethiopian children (10, 12, 13), but are lower than recently published findings in comparable groups of children in other East African countries (22, 39). A possible explanation for the difference may be the fact that Okullo et al. (39) included enamel caries into the decayed component of the DMFT scores. More studies are needed in order to get a clear picture of the caries situation and its development among adolescents in different East African countries.

More studies are also needed to establish the relationship between dental fluorosis and caries. It

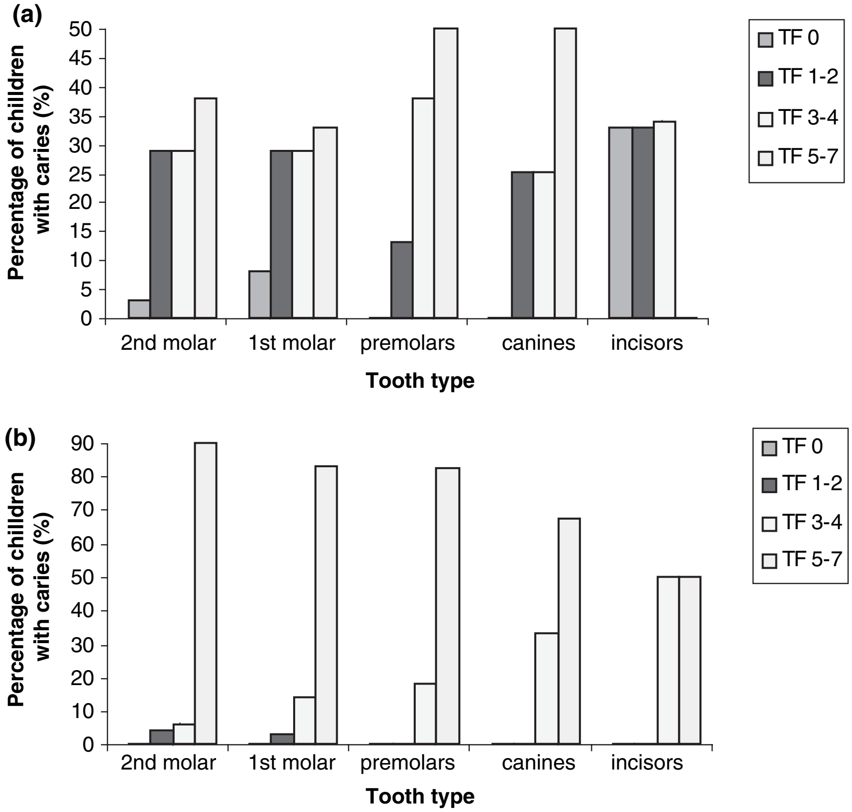

Fig. 2. The percentage distribution of adolescents according to DMFT scores and TF-scores by tooth type in the moderate- (a) and high-fluoride (b) areas.

is of interest, however to note that the present findings are consistent with previous studies from Africa (20, 32). This strongly indicate that – within the levels of 'moderate' and 'high' fluoride concentrations, dental caries experience in the permanent dentition increases significantly with increasing fluoride content of the drinking water.

Studies from Tanzania (40) have, however, documented additional fluoride sources such as 'magadi', and the rationale of relating dental caries to fluoride content in drinking water only has been questioned.

In the present study, the mean DMFT scores increased with increasing age, corroborating the age effect reported in several East African studies (39). Moreover, the mean DMFT scores increased significantly by increasing TF-scores in both moderate- and high-fluoride areas (Table 5). These results, indicating a positive relationship between the severity of dental fluorosis and dental caries, were also confirmed after having sociodemographics forced into the equation. Stepwise multiple regression analyses controlling for age, gender, and area of residence revealed a significant explanatory effect of age and TF-scores on the caries experience. Moreover, lack of a significant interaction effect indicates that the strength of the association between dental fluorosis and dental caries did not vary across moderate- and high-fluoride areas. In contrast, some studies have found less caries in fluorotic teeth independent of the fluoride concentration in drinking water (8, 23, 24). Thus, Yoder et al. (22), in a study of Tanzanian children (9–19 years of age), showed that the majority of caries (60%) was detected in the least fluorosed teeth (TF-scores 0–1) whereas only 16% was detected in the most severely fluorosed teeth (TF-scores 8–9). Nevertheless, in the present study, the pattern of a positive relationship between dental fluorosis and dental caries remained consistent across different tooth types, in moderate- as well as high-fluoride areas (Fig. 2a,b).

Independent of the fluoride concentration in drinking water, caries prevalence increased consistently with increasing severity of dental fluorosis in the second molars, first molars, premolars and canines. Two possible explanations may be offered: First, in more severe forms of dental fluorosis, posteruptive changes lead to the loss of outer enamel or formation of pits in teeth. Plaque and food debris may be retained in these areas, contributing to an increased susceptibility to caries. Secondly, because of the presence of subsurface hypo mineralization, teeth with severe forms of diffuse opacities may be inherently at risk of caries (34).

Various studies from Sub-Saharan Africa have reported a higher number of carious teeth as well as higher caries scores in the second when compared with the first molars (26, 31, 41, 42). This pattern was, by and large, confirmed in the present study. Among the hypotheses proposed to explain the differences between the molars are: genetic variation (43), malnutrition during mineralization of the second molars (41), differences in the fissure system (21), poorer tooth cleaning (44) and the degree of post eruptive maturation when subjected to a cariogenic diet (42, 43). The degree of fluorosis was, according to our findings, significantly higher in the second than in the first molars. This, then, may also have contributed to the difference in caries experience.

To conclude, according to WHO's international standards, the caries experience (mean DMFT scores) was low among 12–15-year olds, in areas with moderate- as well as high-fluoride drinking water. However, our results suggest a positive association between fluoride levels and dental caries. The present results and those of a few previous studies (29, 30, 32–34) thereby strengthen the notion that there is a systematic and positive relationship between the fluoride content of drinking water and the prevalence and degree of dental fluorosis. Furthermore, dental fluorosis – above a certain level – also seems to vary systematically and positively with dental caries in the permanent dentition, as a whole and across various tooth types. Under the given conditions, second molars are the teeth most frequently affected with dental caries and severe dental fluorosis.

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