

Weaning food and *magadi* associated with dental fluorosis in Northern Tanzania

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A cross-sectional study of 143 children aged 10–14 years was carried out to identify factors associated with the severity of dental fluorosis in 2 areas (Moshi/Kibosho: $n = 63/80$) with fluoride (F) concentrations < 0.4 mg F/L in the drinking water. Dental fluorosis was recorded under field conditions using the Thylstrup and Fejerskov index (TFI). The score on tooth 21 was used to indicate the severity. The prevalence of dental fluorosis in Moshi at TFI score ≥ 1 was 60% and at TFI score ≥ 5 it was 10%. The corresponding values in Kibosho were 100% and 34%, respectively. Background variables pertained primarily to the child's first 6 years of life. In Moshi and Kibosho, 65% and 97% of children, respectively, used *magadi*, a fluoride-containing food tenderizer. In Moshi, the risk of having TFI score ≥ 2 was significantly higher among users of *magadi* (odds ratio (OR) = 5). *Kiborou*, a traditional homemade weaning food (porridge) cooked with *magadi*, was used only in Kibosho. Users of *kiborou* (36%) were at significantly higher risk (OR = 3) of developing fluorosis at severity TFI ≥ 4 than the users of *lishe*, another type of weaning food. All children in Moshi and 64% in Kibosho used *lishe*, which is cooked without *magadi*. *Magadi* and *kiborou* were significant risk indicators. Thus, it seems that the unexpectedly high prevalence of dental fluorosis and the observed differences in fluorosis prevalence and severity may be partly explained by F exposure from *magadi*. □ *Drinking water; fluoride; risk indicators; urban/rural*

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Dental fluorosis is associated with fluoride (F) exposure during tooth formation, and especially with intake of water with high F concentrations (1–8). A positive relationship between F concentration in drinking water and severity of dental fluorosis has been shown in epidemiological studies and later confirmed when the F exposure data of Dean et al. (4, 6), Richard et al. (7), and Butler et al. (8) were expressed as mg F/kg body weight (9). This relationship between the F concentration in drinking water and dental fluorosis has also been confirmed in Africa (10–16). However, recent studies in Africa have reported high prevalence of dental fluorosis even in areas with low F content (< 0.5 mg F/L) in the drinking water (17–25). These findings have been partly ascribed to high consumption of tea (19), altitude of residence (22, 23), and the use of F-containing trona (*magadi*). *Magadi* is basically $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$, which is commonly found in East Africa as a crude mixture of various salts. It usually contains various amounts of fluoride (24, 25).

The residents of 2 neighboring areas in Northern Tanzania, Moshi and Kibosho, have been reported to have surprisingly high prevalence of dental fluorosis despite the use of drinking water containing < 0.4 mg F/L (17, 20). In these studies, as in most of the papers mentioned above, only bivariate analyses were employed. The purpose of the present analytical study was to identify factors that may be associated with this unexpectedly high prevalence and severity of dental fluorosis in Moshi and Kibosho.

Material and methods

Cultural background/weaning food

Moshi, at 850 m above sea level, is the urban administrative center of the Kilimanjaro region, while neighboring Kibosho, at 1,300 m elevation, is a typical rural community.

In order to reduce cooking time and add taste to the food (20, 25, 26), especially to vegetables and beans, the addition of *magadi* during food preparation is a common practice in Northern Tanzania.

A Tanzanian child is generally breast-fed during the first 4 months of life. The weaning period starts at 4–9 months of age (20). On average, *magadi* is introduced to children from the age of 7 months, either by addition to the infant food or by sharing meals with adults (20). In Moshi, the most common homemade baby food is a liquid porridge, *lishe*, which is made from maize, beans, peanuts, and fishmeal from 'dagaa', a sardine like fish (Table 1). The ingredients are ground together before they are cooked. In Kibosho, the traditional homemade weaning food is a porridge called *kiborou*, which is a mixture of beans and bananas cooked with *magadi*. The ingredients are mashed during cooking.

Participants

In order to obtain a fairly homogeneous sample, subjects were chosen from 10–14-year-old children of

Table 1. Ingredients of cooked homemade liquid weaning food (*lishe* and *kiborou*)

<i>Lishe</i>	<i>Kiborou</i>
Beans	Beans
Ground maize	—
Peanuts	—
Fishmeal from <i>dagaa</i>	—
—	Bananas
Water	Water
—	Magadi

the Wachagga tribe who had lived in the study areas during the first 6 years of life. One hundred and forty-three children from classes 3–5 at primary schools in Moshi and Kibosho were included in this study, which was carried out in August and September 1996. Schools in both areas were randomly selected (at the district education administrator's office). In Moshi (97,000 inhabitants), every third child from the relevant grades in the 3 schools was randomly selected from the schools' attendance registers, whereas in Kibosho (20,000 inhabitants), all children attending the corresponding grades at 1 school were included. Based on the available information from Moshi (17), a sample of 105 was estimated. Due to the sampling procedure in Kibosho, a sample of 100 was obtained. Although the total number of potential participants was 205, 62 had to be excluded: 35 did not satisfy the criteria of permanent residence, 26 were below 10 or above 14 years of age and 1 child's parent refused to allow the child to participate in the study.

The male to female ratio was ~1:1. The mean age of the subjects differed significantly between Moshi (11.1 ± 0.8 yrs, $n = 63$) and Kibosho (12.4 ± 1.2 yrs, $n = 80$) ($t = 6.5$, $df = 141$).

Ethical clearance

Clearance to perform the study was issued by the Tanzanian National Institute of Medical Research on behalf of the Ministry of Health (Ref. No. NIMR/HQ/R.8a/VOL.VI/10). Permission to use the selected schools was granted by the district education administrators and the respective headmasters. Subjects and accompanying parents gave verbal consent.

Interview

A research assistant (dentist) interviewed subjects and accompanying parent(s) according to a structured questionnaire before the clinical examination. The parents, mainly mothers, answered questions related to the child's first 6 years of life. The interview included questions on the supply and handling of drinking water, and the use of tea and weaning food. Independent variables for this study are listed in Table 2.

Dental fluorosis

Examination for dental fluorosis was carried out with the child seated on a chair in the shade outside the school. The teeth were cleaned, dried with gauze, and isolated with cotton rolls. The severity of fluorosis was assessed on

Table 2. Distribution of subjects ($n = 63$ in Moshi and $n = 80$ in Kibosho) according to dietary practice and habits, and use of toothpaste during the first 6 years of life

Variable	Categories	Moshi		Kibosho		Total
		<i>n</i>	%	<i>n</i>	%	
Tea ¹	Don't use	—	—	3	4	3¶
	Use	62	100	76	96	138
Milk	Breast feeding	22	35	72	90	94*
	Breast feeding + other	41	65	8	10	49
Homemade porridge ²	<i>Lishe</i>	61	100	51	64	112¶
	<i>Kiborou</i>	—	—	29	36	29
Meals/day	≤2	—	—	1	1	1¶
	>2	63	100	78	98	141
	No information	—	—	1	1	1
Fish	Don't use	4	6	5	6	9
	Use	59	94	75	94	134
Meat	Don't use	—	—	12	15	12¶
	Use	63	100	68	85	131
Magadi	Don't use	22	35	2	3	24*
	Use	41	65	78	97	119
Toothpaste	Never/seldom	2	3	49	61	51*
	≥ once/day	61	97	31	39	92

¹ Information was lacking for 1 subject in each area.

² Two subjects were omitted from this category in Moshi, as they had used infant formulae.

¶ χ^2 could not be computed because of an empty cell.

* $P < 0.05$.

Table 3. Fluoride concentration (mg F/L) in drinking water according to area, source and number of subjects reporting reliance on each source

Source	Moshi (<i>n</i> = 63)				Kibosho (<i>n</i> = 80)			
	<i>n</i>	Range (mg F/L)	Mean (mg F/L)	Subjects <i>n</i> (%)	<i>n</i>	Range (mg F/L)	Mean (mg F/L)	Subjects <i>n</i> (%)
Tap	2	0.20–0.40	0.30	62 (99)	2	0.19–0.21	0.20	42 (53)
Well	*				1	0.17	0.17	1 (1)
Stream	*				1	0.08	0.08	3 (4)
Spring	5	0.15–0.37	0.24	1 (1)	2	0.14–0.20	0.17	33 (41)
River	5	0.24–0.33	0.27		1	0.21	0.21	1 (1)
Borehole	2	0.20–0.26	0.23		*			

* Information was not collected.

the vestibular surfaces of all the permanent teeth by 1 examiner (AKA), according to the Thylstrup and Fejerskov Index (TFI) (27). In case of doubt about the severity, the lower score was recorded. Teeth < 50% erupted were excluded. In order to control for variability in severity of fluorosis in different teeth, the TFI score of the upper left central incisor (tooth 21) was used to describe fluorosis in each subject and used in the statistical analyses.

Reproducibility

The right maxillary central incisor of 32 children was re-examined after 1 week. The weighted kappa was 0.88, and paired *t* test revealed no significant systematic error (*t* = 0.77, *df* = 31, *P* = 0.45).

Water samples and total liquid intake

To facilitate comparison of the F concentration of drinking water with previous measurements in these areas (17, 20, 30), samples of water were collected in airtight plastic bottles from the relevant sources. The F concentration of the samples was determined using the F-ion electrode (ORION 96–09–00) according to standard procedures (28).

After a drinking glass of 250 ml had been shown to the parents, the children's intake of water as well as tea was estimated at the subject's present age in terms of the number of glasses consumed per day. The estimates were expressed in liters.

Statistical analysis

The statistical package for social sciences (SPSS for PC version 7.5) was used in the analyses. Differences in the distribution of subjects according to age, gender, and dietary habits were assessed using χ^2 tests (with Yates's continuity correction). The mean age of the children in the 2 areas was compared using Student's *t* test for independent samples.

The Mann-Whitney U test was used when comparing the severity and selected independent variables. Bivariate associations were assessed using Spearman's rank correlation

(r_s). Stepwise multiple linear regression analyses (SMLRA) were employed to control for confounding and to identify factors explaining variation in the TFI scores within and between the areas. Independent variables significantly correlated with the TFI score on tooth 21 were entered into SMLRA.

Multiple logistic regression analyses were used to assess the risk for more severe dental fluorosis. TFI scores were dichotomized as 0 = TFI ≤ 2 or 1 = TFI ≥ 3 for the whole material. For the intra-area analyses, the 'cut-off' point was TFI ≤ 1 in Moshi, while in Kibosho it was TFI ≤ 3. These 'cut-off' points resulted in an approximately equal number of subjects in each subgroup. Independent variables significantly associated with the TFI score (χ^2 test) were included in the logistic regression analyses, and 95% confidence intervals (CI) for odds ratios (OR) were calculated.

The level of significance was set at 5% in the analyses unless otherwise stated.

Results

Water F concentration and total liquid intake

The F concentration of water samples in Moshi varied from 0.15 to 0.40 mg F/L (mean 0.26, *n* = 14), whereas

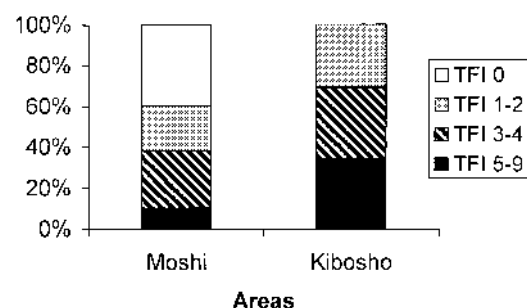


Fig. 1. The frequency distribution of children according to the TFI score on tooth 21 in Moshi, *n* = 63 (0.26 mg F/L) and Kibosho, *n* = 80 (0.17 mg F/L in drinking water).

Table 4. Severity of dental fluorosis on the upper left central incisor according to selected variables ($n = 143$)

Variable	Category	<i>n</i>	Median TFI	Range
Area*	Moshi	0 63	2	0–9
	Kibosho	1 80	4	1–9
<i>Magadi</i> *	No	0 24	0	0–3
	Yes	1 119	3	0–9
Homemade porridge*	<i>Lishe</i>	0 112	2	0–9
	<i>Kiborou</i>	1 29	4	1–9
Toothpaste*	Never/seldom	0 51	4	0–9
	≥once/day	1 92	2	0–9

* All of the above variables were significant at $P < 0.05$.

¶ Two subjects had used infant formulae and were excluded from the analyses.

the samples from Kibosho contained between 0.08 and 0.21 mg F/L (mean 0.17, $n = 7$; Table 3). All participants in Moshi and 86% of participants in Kibosho had used the same sources of water since birth. Tap water was used by 99% of participants in Moshi compared to 53% in Kibosho.

The average daily intake of drinking water at the time of the study was 0.6 ± 0.3 L ($n = 63$) and 0.4 ± 0.2 L ($n = 80$) for Moshi and Kibosho, respectively. The corresponding average intake of tea was 0.4 and 0.3 L, giving a total liquid intake of 1.0 ± 0.4 L and 0.7 ± 0.2 L, respectively.

Background factors (feeding habits)

Significantly more subjects in the rural area, Kibosho, than in the urban area, Moshi, practiced exclusively breast-feeding during infancy (Table 2). All parents in Moshi and 2 out of 3 in Kibosho reported the use of *lishe* as a weaning food. *Kiborou* was only used in Kibosho ($n = 29$). Tea and fish were consumed by almost everyone in both areas.

A higher proportion of respondents' parents in Kibosho than in Moshi reported the use of *magadi*. About 40% of the respondents' parents in Kibosho reported that the subject regularly used toothpaste during preschool age. The corresponding value in Moshi was 97% (Table 2).

Dental fluorosis

The prevalence of dental fluorosis was significantly lower in Moshi (60%, 95% CI = 47.7–72.3%) than in

Kibosho (100%) (Fig. 1). The same was observed for scores of severity TFI ≥ 5 : 10 and 34% ($\chi^2 = 10.3$, $df = 1$). Neither in the prevalence nor in the severity of dental fluorosis was there a significant gender difference.

Dental fluorosis and background factors

Areas combined. Users of *kiborou* had significantly higher TFI scores than users of *lishe* (Table 4). Significantly higher prevalence and higher frequency of dental fluorosis at severity of TFI score ≥ 5 were observed among *magadi* users than among non-users.

The following factors correlated significantly with the severity of dental fluorosis: total fluid intake ($r_s = -0.19$), toothpaste use (-0.30), homemade porridge (0.30), age (0.33), use of *magadi* (0.42), and area of residence (0.44). Except for age (continuous variable) and fluid intake (< 1 L, ≥ 1 L), the independent variables were dichotomized as shown in Table 4. In the stepwise multiple linear regression analysis (SMLRA), the total explanatory effect of the variables in the final equation was 20%; area explained 15% and *magadi* increased the explained variance by 6% (Table 5). The model explained a significant part of the variance ($F = 18.8$). When controlling for area in SMLRA, the total explained variance was 19%, where *magadi* explained 15% and homemade porridge increased the explained variance by 5%. In a collinearity check, total fluid intake ($r_s = -0.45$), toothpaste use (-0.60), use of *magadi* (0.43) and homemade porridge (0.45) explained 58% of the variance due to area of residence. The variance inflation factor was 1.5; values above 10 indicate collinearity of concern (29). Among the *magadi* and *lishe* users ($n = 90$, excluding *kiborou* users and *magadi* non-users), except for area of residence, none of the other independent variables were found to explain variation in the severity of dental fluorosis.

In multiple logistic regression analysis, the risk of having a TFI score ≥ 3 was higher for *magadi* users (OR = 5.5, CI = 1.7–18.3) and for children residing in Kibosho (OR = 2.3, CI = 1.1–4.8; Table 6). Controlling for area increased OR for users of *magadi* from 5.5 to 7.0 (CI = 2.2–21.0) and *kiborou* became a significant risk indicator (OR = 3.0, CI = 1.1–7.5).

Within areas. In Moshi, the severity of dental fluorosis among the users of *magadi* was significantly higher than among non-users: the median TFI scores for tooth 21 were 3 ($n = 41$) and 0 ($n = 22$), respectively. Use of fish ($r_s = 0.28$) and *magadi* (0.35) were significantly correlated with the TFI

Table 5. Stepwise multiple linear regression analysis with the TFI score on the upper left central incisor as the dependent variable ($n = 143$)

Independent variable	Regression coefficient (B)	Standard error (B)	Beta (β)	R ² change	P
Area	1.30	0.37	0.28	0.15	<0.01
<i>Magadi</i>	1.68	0.51	0.27	0.06	<0.01
Constant	−0.40	—	—	—	—

Adjusted R² = 20.4%.

Table 6. Regression coefficient, odds ratio, and 95% confidence interval for subjects ($n = 143$) in multiple logistic regression analysis. The dependent variable (TFI score on tooth 21) categorized as $0 = \text{TFI} \leq 2$ and $1 = \text{TFI} \geq 3$

Independent variables		Value	n	Regression coefficient	se	Odds ratio	95% CI
Area	Moshi	0	63	—	—	—	—
	Kibosho	1	80	0.83	0.39	2.3	1.1–4.8
Use of <i>magadi</i>	No	0	24	—	—	—	—
	Yes	1	119	1.70	0.61	5.5	1.7–18.3

score. In SMLRA, *magadi* explained 11% and use of fish 6% when the total explained variance was 16%. In the logistic regression analysis, only subjects who had used *magadi* had an elevated risk of developing fluorosis of severity TFI score ≥ 2 (OR = 5.0, CI = 1.4–16.3).

In Kibosho, nearly all subjects (97%) were reported to have used *magadi*, and hence its effect could not be assessed. Based on SMLRA, none of the background variables were significantly associated with the severity of fluorosis. In the logistic regression analysis, *kiborou* was found to be a significant risk indicator (OR = 3.0, CI = 1.1–10.4) for developing fluorosis of TFI score ≥ 4 .

Discussion

Comments on methodology

The material was homogeneous with respect to lifelong residence in the areas and even to ethnicity. This is done because the prevalence and severity of dental fluorosis may be related to ethnicity (11). Variation due to post-eruptive influences was minimized by restricting the age range to 10–14 years, and by basing the severity of dental fluorosis on the score of tooth 21. A maxillary central incisor was used because it restricted the F exposure to a limited period of time during the first years of life, and because it minimized variation due to differences in severity of fluorosis within the dentition (27).

The severity of fluorosis was related to factors known or assumed to be associated with the development of dental fluorosis. The F concentration in the drinking water, at the time of survey, was low in both areas, and at the same level, even in Kibosho where several sources were utilized (Table 3). The F levels we report corroborate earlier findings in the 1970s in Moshi (17) and in the 1990s in Kibosho (20, 30). This indicates a fairly stable and low F concentration in the local waters, at least in Moshi. When the severity of fluorosis in Kibosho was related to water source (tap versus other), the source had no impact. In Moshi, all except 1 subject received water from the same source.

Information about the independent variables was obtained by interviews carried out by 1 interviewer. We were not able to validate the respondents' answers, but there is no reason to expect systematic errors affecting the comparisons, at least not within the areas.

The severity of dental fluorosis on tooth 21 caused a

slight, systematic, but non-significant ($P = 0.04$, $n = 143$) over-recording compared to the median score for the whole dentition. To offset an effect of clustering when the score on tooth 21 was compared to the subject's median score, the significance level was set at 1%. Since the severity scores of dental fluorosis are measured on an ordinal scale, non-parametric tests were applied in statistical analyses related to fluorosis. Due to the differences in severity of fluorosis in Moshi and Kibosho, and to meet the requirement of equal number of subjects when dichotomizing (29), different cut-off points were adopted when dichotomizing variables for the logistic regression analyses.

Three types of analyses were performed to relate the severity of dental fluorosis to selected variables: bivariate correlation, stepwise multiple linear regression, and logistic regression analyses. The correlation analyses indicate the strength of association and are a prerequisite to limit the number of independent variables included in linear regression (29).

In the bivariate analyses, the subject's age and area of residence correlated significantly with the severity of fluorosis. When other variables were controlled, age was insignificant in both linear and logistic regression analyses, while area of residence remained significant. Linear regression shows the effect of 1 variable while controlling for the effect of others, whereas the logistic model may indicate an increased/reduced risk associated with a certain factor while controlling for other indicators. The linear regression analyses explained up to 20% of total variance, indicating substantial effect of factors not considered. This applied even when the multivariate analyses were carried out with a less stringent criterion ($P < 0.10$) for entry of independent variables into the models.

Comments on findings

Although the fluoride content of the drinking water and the intake of water and tea at present were somewhat lower in Kibosho than in Moshi, the prevalence and severity of dental fluorosis was significantly higher in Kibosho than in Moshi. The present severity of dental fluorosis indicates a level similar to the mean Dean's index of 2.0 in Moshi (17) and in Kibosho a mean TFI score of 4.4 (30). The median scores for all teeth calculated for Moshi and Kibosho were 2 and 4, respectively.

Except for 2 children, all used *magadi* in Kibosho. The

users of both *magadi* in Moshi and *kiborou* in Kibosho had significantly increased risk of developing fluorosis when controlling for area. *Magadi* is included in the traditional weaning food *kiborou*, while *lishe*, which is recommended to avoid protein deficiency and malnutrition, is made without *magadi*. Only the latter weaning food was used in Moshi. Malnutrition has been mentioned as a factor related to fluorosis in Kibosho where, according to the Regional Maternal and Child Health Offices, 44% of children of the same age as the subjects of this study could have been malnourished in the 1980s (30). However, recent findings from Brazil showed no association between malnutrition and dental fluorosis (31). Whether or not the increased risk of fluorosis among users of the weaning food, *kiborou*, is related to its *magadi* content is unknown at present.

The fluoride content of *magadi* from Tanzania varies (20, 25, 30, 32), but different methods of reporting make it difficult to compare the F levels. Some estimates are based on solid weight (32), while others report only mg F/L (25, 30) or ppm F (20). An average of 1.5 mg F/g *magadi* and a suggested intake of 0.44 g *magadi*/day by adults gives 0.7 mg F/day (32). Greater amounts of *magadi* added during food preparation (20) and at frequencies from daily to once a week have been reported (20, 32); however, to our knowledge, no estimates of the intake of *magadi* by young children are available.

In addition to the difference in altitude, breast-feeding habits, weaning food, use of toothpaste, and fluid intake were significantly different in the two areas (Table 2). Significantly more respondents in the urban than in the rural area used toothpaste, fluoridated or not, during the preschool period of life. Few Tanzanian adolescents in the rural areas seem to use toothpaste at present (25). Except for area, breast-feeding habits, use of toothpaste, and fluid intake at present were found to have no significant effect on the prevalence and severity of dental fluorosis. The difference in altitude of 450 meters may favor more severe fluorosis in Kibosho (22, 23, 30), but the altitude *per se* cannot explain the difference in dental fluorosis between the areas. On the other hand, the different weaning foods and the use of *magadi* may affect the severity of dental fluorosis. People in rural areas tend to stick to their traditions, e.g. weaning, nursing, and even cooking habits, i.e. the way they cook, cooking utensils used, etc. (Dr. Liv Haram, personal communication). Thus, the use of *kiborou* in the rural area only can be explained by adherence to a traditional way of life.

Conclusions

The type of weaning food and use of *magadi* added during food preparation were significantly related to the severity of dental fluorosis. Fluoride from *magadi* and use of the traditional homemade weaning food *kiborou* may partly explain the surprisingly high prevalence and severity of dental fluorosis in these areas with < 0.4 mg F/L in the drinking water.

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References

1. Dean HT. Classification of mottled enamel diagnosis. *J Am Dent Assoc* 1934;21:1421–6.
2. Dean HT. Endemic fluorosis and its relation to dental caries. *Public Health Rep* 1938;53:1443–52.
3. Dean HT, Elvove E. Some epidemiological aspects of chronic endemic dental fluorosis. *Am J Public Health* 1936;26:567–75.
4. Dean HT, Jay P, Arnold FA, Elvove E. Domestic waters and dental caries. II. A study of 2,832 white children ages 12–14 years of eight suburban Chicago communities, including *Lactobacillus acidophilus* studies of 1,761 children. *Public Health Rep* 1941;56:761–92.
5. Dean HT. The investigation of physiological effects by the epidemiological method. In: Moulton FR, editors. *Fluorine and dental health*. Washington, DC: American Association for the Advancement of Science; 1942. p. 23–31.
6. Dean HT, Arnold FA, Elvove E. Domestic waters and dental caries. V. Additional studies of the relation of fluoride domestic waters to dental caries in 4,425 white children, age 12–14 years, of 13 cities in 4 states. *Public Health Rep* 1942;57:1155–79.
7. Richards LF, Westmoreland WW, Tashiro M, McKay CH, Morrison JT. Determining optimum fluoride levels for community water supplies in relation to temperature. *J Am Dent Assoc* 1967;74:389–97.
8. Butler WJ, Segreto V, Collins E. Prevalence of dental mottling in school-aged lifetime residents of 16 Texas communities. *Am J Public Health* 1985;75:1408–12.
9. Fejerskov O, Bælum V, Richards A. Dose-response and dental fluorosis. In: Fejerskov O, Ekstrand J, Burt B, editors. *Fluoride in dentistry*. 2nd ed. Copenhagen: Munksgaard; 1996. p. 153–66.
10. Macquillan CJ. Chronic fluoride poisoning in the Arusha district, Tanganyika territory. *East Afr Med J* 1944;21:131–4.
11. Ockerse T. Chronic endemic dental fluorosis in Kenya, East Africa. *Br Dent J* 1953;95:57–60.
12. Williamson MM. Endemic dental fluorosis in Kenya, a preliminary report. *East Afr Med J* 1953;30:217–33.
13. Grech P, Latham MC. Fluorosis in the northern region of Tanganyika. *Trans R Soc Trop Med Hyg* 1964;58:566–74.
14. Fejerskov O, Thylstrup A, Larsen MJ. Clinical and structural features and possible pathogenic mechanisms of dental fluorosis. *Scand J Dent Res* 1977;85:510–34.
15. Olsson B. Dental findings in high-fluoride areas in Ethiopia. *Community Dent Oral Epidemiol* 1979;7:51–6.
16. Manji F, Bælum V, Fejerskov O. Dental fluorosis in an area of Kenya with 2 ppm fluoride in the drinking water. *J Dent Res* 1986;65:659–62.
17. Mosha HJ, Langebaek J. Dental caries, oral hygiene, periodontal disease and dental fluorosis among school children in Northern Tanzania. *Odontostomatol Trop* 1983;6:149–60.
18. Manji F, Bælum V, Fejerskov O, Gemert W. Enamel changes in two low fluoride areas of Kenya. *Caries Res* 1986;20:371–81.
19. Ibrahim YE, Affan AA, Bjorvatn K. Prevalence of dental

- fluorosis in Sudanese children from two villages with 0.25 and 2.56 ppm fluoride in the drinking water. *Int J Paediatr Dent* 1995;5:223–9.
20. Van Palenstein Helderman WH, Mkasabuni E, Mjengera HJ, Mabelya L. Severe dental fluorosis in children consuming fluoride containing magadi salt. *Tanzania Dent J* 1997;8:16–20.
 21. El-Nadeef MAI, Honkala E. Fluorosis in relation to fluoride levels in water in central Nigeria. *Community Dent Oral Epidemiol* 1998;26:26–30.
 22. Manji F, Baelum V, Fejerskov O. Fluoride, altitude and dental fluorosis. *Caries Res* 1986;20:473–80.
 23. Rwenyonyi CM, Bjorvatn K, Birkeland JM, Haugejorden O. Altitude as a risk indicator of dental fluorosis in children residing in areas with 0.5 and 2.5 mg fluoride per liter in drinking water. *Caries Res* 1999;33:267–74.
 24. Mabelya L, Konig KG, van Palenstein Helderman WH. Dental fluorosis, altitude and associated dietary factors. *Caries Res* 1992;26:65–7.
 25. Mabelya L, van Palenstein Helderman WH, van't Hof MA, Konig KG. Dental fluorosis and the use of a high fluoride-containing trona tenderizer (magadi). *Community Dent Oral Epidemiol* 1997;25:170–6.
 26. Malentlema TN. The likely increase of fluoride uptake due to type of diet of the people of Tanzania. Dar es Salaam: Tanzania Food and Nutrition Centre Report no. 737; 1980.
 27. Thylstrup A, Fejerskov O. Clinical appearance of dental fluorosis in permanent teeth in relation to histologic changes. *Community Dent Oral Epidemiol* 1978;6:315–28.
 28. Orion Research Inc. Instruction Manual. Fluoride electrodes model 94-09-00 and model 96-09-00. Cambridge, MA: Orion Research; 1991.
 29. Altman DG. Practical statistics for medical research. London: Chapman & Hall; 1997 (reprint). p. 268–69.
 30. Yoder KM, Mabelya L, Robison VA, Dunipace AJ, Brizendine EJ, Stookey GK. Severe dental fluorosis in a Tanzanian population consuming water with negligible fluoride concentration. *Community Dent Oral Epidemiol* 1998;26:382–93.
 31. Sampaio FC, von der Fehr FR, Arneberg P, Gigante DP, Hatloy A. Dental fluorosis and nutritional status of 6- to 11-year-old children living in rural areas of Paraiba, Brazil. *Caries Res* 1999;33:66–73.
 32. Nielsen JM. Fluoride contaminated magadi in Tanzania: occurrence, formation and purification [thesis]. Copenhagen: Technical University of Denmark; 1997. p. 28–9.

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