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ORIGINAL ARTICLE

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Severity of dental caries among 12-year-old Sudanese children with different fluoride exposure

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Abstract The aim of this study was to assess the effect of fluoride on the severity of caries among children exposed to different concentrations of fluoride in the drinking water and living in rural areas in the Sudan. Permanently resident schoolchildren (n =299) aged 11–13 years from three villages were clinically examined under field conditions. The caries criterion was teeth in need of extraction or extracted; only molars were recorded. Dental fluorosis was scored on all buccal tooth surfaces by the Thylstrup and Fejerskov index. The fluoride concentrations of the drinking water were assessed in samples (n =25) collected from wells and households. Predictors of caries were assessed by logistic regression analyses. There was no significant difference regarding age and gender distribution between the areas (P >0.05, df=2, Kruskal-Wallis test). The socio-economic conditions in these villages were presumed to be equal. Significantly different fluoride concentrations in the drinking water were verified by the severity of dental fluorosis. Children in Abu Delaig, drinking water with 1.0–2.0 mg fluoride/L (median = 1.8), had significantly higher caries prevalence (21% versus 8%) than in a 0.4 mg fluoride area. Area was the only significant predictor for caries; odds ratio 3.7 for children in Abu Delaig compared with the low fluoride area. There was no difference in caries prevalence between the lowest and the highest fluoride (2.9 mg) area. This study failed to demonstrate an effect of fluoride in drinking water on caries experience when the end point was molars indicated for extraction or missing because of caries.

Keywords Caries · Drinking water · Fluoride · Rural population · Tooth mortality

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Introduction

Fluoride in drinking water may have a cariostatic effect, but excessive intake of fluoride during the period of tooth mineralization may cause dental fluorosis. The known inverse relationship between the concentration of fluoride in drinking water and caries recorded in industrialised countries [5, 9] is not well documented in developing countries [23]. The lack of consistency of the cariostatic effect of fluoride in East-African countries is demonstrated in Table 1. The fluoride concentration in the drinking water in some of these studies is reflected in dental fluorosis; the severity generally increased with increasing concentration of fluoride in the water.

Manji and Fejerskov [23] requested studies assessing the cariostatic effect of fluoride in Africa, especially the effect on caries progression. Most of the studies above are descriptive rather than analytical. Thus, there is a need for studies employing multivariate analyses in the assessment of an effect of fluoride on caries in these countries. The aim of this study was to assess the effect of fluoride in the drinking water on the severity of dental caries among rural Sudanese children exposed to different sources of fluoride.

Material and methods

Areas

Based on information about the fluoride concentration in the drinking water, three villages at various distances from Khartoum were selected. The village Triet el Biga was located 30 km south of Khartoum, Abu Groon was 50 km

Table 1 Summary of studies of dental caries experience (DMFT) in permanent teeth of 12-year-old East African children according to country and fluoride concentration (milligram fluoride/litre) in drinking water

Country	mg F/L	Mean DMFT	Reference
Ethiopia	0.3; 1.0	1.5	[31]
	3.5	1.7	[33]
	12.4	2.5	[33]
Kenya	0.1–0.4	0.5; 0.8	[13]
	0.2–1.0	1.8	[30]
	0.4	0.2	[25]
Tanzania	0.1	0.8	[26]
	0.2	0.7	[13]
	0.2–0.3	0.1−0.2	[2]
	0.1–0.7	0.5	[35]
	3.5	0.5; 0.8	[26]
	3.5	0.6; 0.4	[25]
	3.6	0.2; 0.7	[2]
Uganda	0.1–0.6	2.3	[21]
	0.5	0; 0.4	[40]
	0.1–3.0	0.2	[28]
	2.5	0.3; 0.5	[40]
Sudan	0.3	0.2	[7]
	0.3	2.9	[20]
	0.3	3.2	[14]
	0.3	2.6	[19]
	2.6	2.0	[19]

east of the capital, and Abu Delaig was 170 km east of the town and about a 3- to 4-h drive in the Butana desert. These villages were presumed to have similar ethnic and socio-economic conditions.

The fluoride concentration of the drinking water from eight wells in Abu Delaig had been reported to range from 0.65 to 4.0 mg fluoride/L [42] or 1.3 and 3.6 (n =5) [41]. The corresponding levels in Triet el Biga and Abu Groon were 0.25 and 2.6 mg fluoride/L, respectively [17]. According to the reported levels of fluoride, Abu Delaig and Abu Groon were to have among the highest concentration in Sudan, whereas Triet el Biga should have one of the lowest values [11, 41]. In order to verify the fluoride concentration, samples of drinking water were collected from wells in these villages and from some households included in the study. These samples were stored in plastic bottles and the fluoride concentration assessed by means of a fluoride ion electrode at the University of Bergen, Norway.

Subjects

Children aged 11–13 years who were permanent residents of the villages were randomly selected among girls and boys at the schools to obtain 50 children of both sexes in each village. A total of 299 children were examined, 147 girls and 152 boys. This gender ratio prevailed in all areas (Table 2). Information about children's age was collected

Table 2 Number of children, ratio girls/boys, mean age of children, mean (and standard deviation) severity of dental fluorosis (TF score) and prevalence of caries, defined as missing/extraction indicated because of caries according to area

Characteristics	Area		
	Triet el Biga	Abu Delaig	Abu Groon
Number of children	103	100	96
Age (years)	11.9±0.7	11.9±0.8	11.8±0.8
Ratio girls/boys	0.94	1.0	0.96
Mean TF score	2.2±0.76	3.1±0.77*	3.7±1.09*
Range TF score	0.1–4.7	1.0–5.9	0.1–6.2
Caries prevalence (%)	8*	21*	5

* p <0.001, df=2

from the school registers. The average age was 11.9 years. Permission to examine the children was obtained from the local school authorities.

Clinical examination

Dental examination was carried out outside the schools, in shaded daylight. The WHO criteria for field surveys [47] were used for the examination in the autumn of 1989. The examination was performed with the subject lying on a bench. Prior to the clinical examination, the children's teeth were wiped with cotton rolls. Cotton rolls were also used to dry the teeth and control saliva. Mirrors, dental probes and a magnifying lens were used during the examination carried out by one examiner (JMB).

Due to the field conditions and in order to assess the end point of caries progression, teeth decayed to an extent indicating need for extraction were recorded as decayed, as well as heavily destroyed teeth primarily due to occlusal cavities involving the pulp. The caries recording was limited to permanent molars and included teeth already extracted because of caries. After the recording of caries, dental fluorosis was assessed on the vestibular surfaces of all permanent teeth present using the modified Thylstrup and Fejerskov (TF) index [12]. An assistant recorded the scores. Instruments were cleaned and sterilised before use.

Background information

Prior to the clinical examination the children were interviewed (YEI) regarding age, place of birth, period of living in the village and source of drinking water. Only children living in the village since the age of 1 year were included in the study.

Analyses

To express the severity of dental fluorosis in a child, the mean TF score was used [40]. In order to estimate the reliability of the recording of dental fluorosis, the internal

Table 3 Number of water samples from wellsand families, median and range of fluoride concentration, milligram fluoride/litre,according to area

Characteristics	Area		
	Triet el Biga	Abu Delaig	Abu Groon
Number of samples	6	11	8
Median mg F/L	0.4	1.8	2.9
Range mg F/L	0.3–1.4	0.8–2.2	2.0–4.2
Range mg F/L majority of samples (*n*)	0.3–0.6(5)	1.0–1.9(8)	2.0–3.0(5)

consistency [37] was measured by comparing the scores on tooth 14 and 24 in a random subsample of the children, n =30. The correlation coefficient between these scores was 0.90, indicating the error of variance to be 9.8% of the total variance of the mean TF scores. The fluoride content of the water samples were reassessed after 1 week and the measurement error was 4%.

The Kruskal-Wallis test was used to compare the variables caries prevalence, severity of dental fluorosis, age and gender between the three areas, whereas the Mann-Whitney U test was used to check for significant differences in the distribution of variables between two areas. The Mann-Whitney test was applied on one pair of data only, thereby controlling for multiple comparisons. Multiple logistic regression analyses were used to assess the independent effect of predictor variables on caries prevalence while controlling for confounding. The enter option was used. For these analyses caries was categorised as no teeth missing/indicated for extraction = 0, one or more teeth missing or indicated for extraction = 1 (end point); severity of dental fluorosis as low = 0 (mean TF score <3.0) or severe = 1 (mean TF score ≥3.0). Age was dichotomised as low = 0 (11 years of age) or high = 1 (12–13 years of age), whereas gender was 0 = girls and 1 = boys. The villages, Triet el Biga, Abu Groon and Abu Delaig, were categorised as 1, 2, and 3, respectively. Estimated model fit of the logistic regression models was provided by Nagelkerke's R^2. Data were analysed using the statistical package for social science (SPSS for PC, version 11.0). The level of significance was set at 5%.

Results

Descriptive findings

There was a significant difference in caries prevalence and severity of dental fluorosis between the areas (p <0.001, df=2, Kruskal-Wallis test), but not in age and sex distribution (p >0.34) (Table 2). The different caries prevalence, 21% versus 8%, was also evident when the number of teeth indicated for extraction was recorded, a total of 41 (range 1–4 per person) in Abu Delaig compared with 10 (1–2 per person) in Triet el Biga. Primarily, mandibular first molars were severely decayed; they comprised 74% of the teeth to be extracted. In Triet el Biga some molars had received dental treatment; two teeth had occlusal fillings and two molars were extracted. One molar had been extracted in Abu Groon while no evidence of dental treatment was observed in Abu Delaig.

The fluoride concentration of the water samples from the wells and families in the villages varied widely (Table 3). The median concentrations were 0.4, 1.8 and 2.9 mg fluoride/L. In Triet el Biga the majority, 83%, of the samples contained between 0.3 and 0.6 mg fluoride/L. The corresponding values in Abu Delaig and Abu Groon were 1.0–1.9 mg and 2.0–3.0 mg fluoride/L, respectively. The measurement error of these analyses was independent of the fluoride concentration in the water samples.

The significantly different fluoride concentrations of the drinking water in the areas were reflected in the severity of dental fluorosis (Table 2). The difference in severity of dental fluorosis was evident also between children in the two high fluoride villages, Abu Groon and Abu Delaig (P <0.001, df=1, Mann-Whitney U test).

Analytical findings

Only area was a significant predictor of caries following dichotomization of the variables and including each village in the multinominal regression analyses (Table 4). Living in Abu Delaig (1.8 mg fluoride/L) increased the risk of having a severely decayed tooth by 3.7 times compared with living in the low fluoride (0.4 mg) village Triet el

Table 4 Multiple logistic regression analysis showing odds ratio and 95% confidence intervals (CI) for predictors of caries (1= missing teeth/extraction indicated because of caries; 0 = no missing teeth/needfor extraction) among children permanently resident in three villages in the Sudan

Variable	Categories	P -value	Odds ratio	95% CI
Age	11/12–13 years, 94/205	0.88	-	-
Sex	girls/boys, 147/152	0.63	-	-
Dental fluorosis	<3.0/≥3.0, 123/176	0.62	-	-
Area	Triet el Biga/ Abu Delaig, 103/100	0.015	3.7	1.3–10.6
	Abu Groon/ Abu Delaig, 96/100	0.003	4.8	1.7–13.3

Biga. The explained variance in this model amounted to 9% (Nagelkerke's R^2%).

Discussion

Methodological comments

The extraction rate due to caries and the partial recording caused a substantial underestimation of caries experience compared with a clinical examination under optimal illumination and drying conditions. Even the caries criterion, cavity, as described by WHO, causes under-recording of caries compared with inclusion of pre-cavitated lesions [e.g. 25, 34]. The extent of the underscoring may be illustrated by the following three studies. In Ethiopian 13- to 14-year-old children with an average of 1.5 DMFT, 9% were in need of tooth extraction [31], whereas missing teeth made up 12% of the DMFT (1.8) when pre-cavitated lesions were also recorded in 13- to 15-year-olds in Kenya [29]. Review of studies from Africa indicates that the average M-component of the DMFT score amounted to 20% in 11- to 13-year-old Africans with carious teeth [8]. The underestimation of caries is likely to be greatest in caries active children. Thus the present findings may favour Abu Delaig compared to the other areas, and the difference in caries prevalence between the villages may be underestimated.

The caries criterion and the partial recording based on molars were applied for several reasons.

1. The occlusal surfaces of permanent molars are known to include most of the caries lesions found in African children [e.g. 2, 8, 24, 25, 31, 40] and students [18].
2. Dean et al. [9] and Møller [28] reported the extraction rate for the first molars when assessing the cariostatic effect of fluoride in the drinking water. At community level the rate was negatively related to the fluoride concentration in the drinking water and positively to the DMFT scores. If regression analyses were applied to the aggregated American data (n =21) [9], the correlation coefficient was 0.9 between the mortality rate and the DMFT scores. A marked difference in the extraction rate of the first molars has also been recorded after water fluoridation [3]. Furthermore, the first molars mirror alterations in the caries experience of adolescents included in different fluoride programs [4].
3. The mean DMFT scores in most of the studies included in Table 1 are based on the criteria described by WHO. A dental probe sticking in a fissure may have indicated a cavity in some studies [e.g. 16, 33], not the least as "sticking on probing" was included in a former description of the criteria [46]. This risk of over-recording may explain the different intra-dentition distribution of occlusal caries in first and second molars of 20-year-old students from Sierra Leone compared with students from Tanzania, Kenya and Sudan. The Sierra Leonean students had frequently filled the first molars, whereas fillings were rare in the other students. Contrary to the findings in the first molars, there was no difference in the number of carious lesions in the second molars between the two groups of students [18].
4. The final outcome of caries progression, the extraction rate, seems to be more sensitive than earlier stages in the caries process when assessing the cariostatic effect of fluoride [17]. The criterion, teeth in need of extraction, should improve the reproducibility compared to the use of more refined criteria in field studies. For logistic reasons, reliability tests could not be carried out regarding caries.

The fluoride concentration of the water samples varied within and between the areas (Table 3). The measurement error in these analyses had no impact on the inter-area fluoride levels. The intra-area findings, on the other hand, demonstrate the need for several water samples in order to determine the fluoride concentration of the drinking water in an area with different water sources. The fluoride levels in the water in the areas were verified by the different severity of dental fluorosis (Table 2).

Caries trend data for adolescents from Africa indicate no significant decrease or increase between 1967 and 1997 [8]. The present data were collected during this period and indicates that the material may be appropriate for the analyses carried out.

Logistic regression analyses were used to identify risk indicators while controlling for confounding, e.g. from variables such as age and gender. The caries scores were skewed (Table 2) compared with the distribution of dental fluorosis (Table 4). The skew distribution of the caries variable may account for the low explained variance of the analyses (Nagelkerke's R^2=9%).

Comments on findings

Both the prevalence and the extent of caries were significantly higher in the high fluoride Abu Delaig than in the other areas (Table 2). The similar caries prevalence in low fluoride Triet el Biga and high fluoride Abu Groon confirms previous DMFT findings [19]. The fluoride concentration in the drinking water in Abu Delaig reflects previous recordings in the area [11, 41, 42], indicating a fairly stable level over time. The caries prevalence, on the other hand, may have increased as "only 3 small carious lesions in the first molars" of 137 children 7–14 years old were recorded in 1952 [42]. The age distribution of these children was not reported.

Area was the only significant predictor of caries when controlling for other factors (Table 4). Some studies from African countries have reported higher caries scores among Asian than African children when controlling for age and area [e.g. 21, 27]. The subjects in this study were all Africans. In recent studies, including multivariate analyses, area in an African setting reflects urbanisation [2] and an effect of sugar on caries [40] when controlling for fluoride exposure. Urbanisation may reflect variation in diet and socio-economic conditions, variables previously associated with caries in Africa [2, 21, 28, 30, 33].

Sreebny [43] and Woodward and Walker [45] reported a positive association between the per capita intake of sugar and dental caries based on data from either 47 or 90 countries. This relationship was evident in developing rather than industrialised countries [45]. The association between sugar consumption and caries at a national level [43, 45] is also documented at community level. A substantial caries decline among Norwegian children during World War II (35%) was related to a restricted sugar intake [44] and variation in caries scores in the Sudan has been ascribed to differences in consumption of sugar [11]. At the individual level, however, the association is less obvious, although the findings were based on detailed diet recordings [6, 36, 38]. Besides fluoride and carbohydrates, oral hygiene has been related to caries, but an effect of oral hygiene practices on caries is mainly determined in field trials [e.g. 1]. Thus, area as predictor for caries in the present study is likely to reflect variation in carbohydrate and fluoride exposure rather than changes in oral hygiene procedures.

The presumed similar living and socio-economic conditions in these villages may have been different. The distance from the capital may be associated with differences in living conditions among the three villages, in decreasing order Triet el Biga, Abu Groon and Abu Delaig. Some dental care carried out among Triet el Biga children suggests such a difference. On the other hand, breeding of racing camels for sale abroad may have improved the purchasing power in Abu Delaig compared with the other villages. A higher socio-economic level in Abu Delaig may have increased the availability of fermentable carbohydrates and explain the higher caries prevalence in this high-fluoride area compared with the other villages.

The tooth mortality rate in Abu Delaig indicates a high caries experience compared with data from Africa for this age group. Caries data indicate no marked change in African children 11–13 years old over the last 30 years; on average, a DMFT score about 0.9 and a MT component about 20% of the DMFT score [8]. Accordingly, the MT component would be about 0.1–0.2 because the recorded number of filled teeth was low. The score for missing teeth due to caries was 0.1 in Triet el Biga. In contrast, the corresponding average of 0.4 MT in Abu Delaig exceeds several of the total DMFT scores in Table 1.

Most studies from Africa assessing the effect of fluoride on caries have been limited to bivariate analyses and some of them have shown higher caries score in high (3.0 mg) than in low (0.5 mg) fluoride areas [e.g. 15, 16]. Bivariate analyses indicated little variation in cariostatic effect between 2.1 and 4.1 mg fluoride/L drinking water in the USA, but on the other hand, good effect compared to 1.1 mg [10]. The lack of a difference in caries prevalence between children in areas with 0.4 and 2.9 mg fluoride in the drinking water and a higher prevalence in a 1.8 mg area than in a low fluoride area was confirmed by multivariate analyses (Table 4). These findings confirm the lack of consistency of a cariostatic effect of fluoride in drinking water in African countries [23]. Part of this inconsistency may be due to insufficient control of the cariogenic challenge, a slow caries progression rate (e.g. Table 1) and moderate difference in cariostatic effect between concentrations of 0.5 mg and 2.6 mg fluoride in the drinking water [9]. Thus, the low caries prevalence in Triet el Biga and Abu Groon children may conceal a cariostatic effect of the 2.9 mg fluoride/L drinking water compared to the 0.4 mg fluoride. On the other hand, the 1.8 mg fluoride in the water did not control caries progression among children in Abu Delaig.

Conclusions

Area was the only predictor of caries among children, 11–13 years old, living in villages at different distances from Khartoum and consuming drinking water containing 0.4, 1.8 or 2.9 mg fluoride /L (median values). Based on permanent molars indicated for extraction or missing because of caries, children in the 1.8 mg fluoride area had 3.7 times greater risk (odds ratio) of caries than children in the 0.4 mg area. The socio-economic conditions in the villages were presumed to be equal. However, the purchasing power in the 1.8 mg area furthest from Khartoum may have been greater than in the other areas. The 1.8 mg fluoride in the drinking water failed to control progression of caries. This study confirms the inconsistency of the cariostatic effect of fluoride in African countries.

References

1. Axelsson P, Lindhe J (1977) The effect of a plaque control program on gingivitis and dental caries in schoolchildren. J Dent Res 56(Spec. Iss. C): 142–148
2. Awadia AK, Birkeland JM, Haugejorden O, Bjorvatn K (2002) Caries experience and caries predictors—a study of Tanzanian children consuming drinking water with different fluoride concentrations. Clin Oral Invest 6:98–103
3. Backer Dirks O (1974) The benefits of water fluoridation. Caries Res 8[Suppl 1]: 2–15
4. Birkeland JM, Jorkjend L, Broch L (1975) An approach to objective assessment of caries prophylactic measures in a dental health program. Community Dent Oral Epidemiol 3:126–131
5. Bratthall D, Hänsel-Petersson G, Sundberg H (1996) Reasons for the caries decline: what do the experts believe? Eur J Oral Sci 104:416–422
6. Burt BA, Szpunar SM (1994) The Michigan study: the relationship between sugar intake and dental caries over three years. Int Dent J 44:230–240
7. Carlsson P, Ghandour IA, Olsson B, Richardson B, Abbas K (1987) High prevalence of Mutans Streptococci in a population with extremely low prevalence of dental caries. Oral Microbiol Immunol 2:121–124
8. Cleaton-Jones P, Fatti P (1999) Dental caries trends in Africa. Community Dent Oral Epidemiol 27:316–320
9. Dean HT, Arnold FA, Elvove E (1942) Domestic water and dental caries. V. Additional studies of the relation of fluoride domestic waters to dental caries experience in 4,425 white children, aged 12 to 14 years, of 13 cities in 4 states. Pup Health Rep 57:1155–1179
10. Driscoll WS, Horowitz HS, Meyers RJ, Heifetz SB, Kingman A, Zimmerman ER (1983) Prevalence of dental caries and dental fluorosis with optimal and above-optimal water fluoride concentrations. J Am Dent Assoc 107:42–47

11. Emslie RD (1966) A dental health survey in the republic of the Sudan. Br Dent J 120:167–178
12. Fejerskov O, Baelum V, Manji F, Møller IJ (1988) Dental fluorosis. A handbook for health workers. Munksgaard, Copenhagen
13. Frencken J, Manji F, Mosha H (1986) Dental caries prevalence amongst 12-year-old urban children in East Africa. Community Dent Oral Epidemiol 14:94–98
14. Ghandour IA, Ibrahim FA, Shehata AH (1988) The prevalence of dental caries, fluorosis, and dental attitudes among primary school children in Omdurman – Sudan. Odontostomatol Trop 11:103–106
15. Grobler SR, Louw AJ, Kotze TJ van W (2001) Dental fluorosis and caries experience in relation to three different drinking water fluoride levels in South Africa. Int J Paediatr Dent 11: 372–379
16. Grobler SR, van Wyk CW, Kotze D (1986) Relationship between enamel fluoride levels, degree of fluorosis and caries experience in communities with a nearly optimal and a high fluoride level in the drinking water. Caries Res 20:284–288
17. Groeneveld A (1985) Longitudinal study of prevalence of enamel lesions in a fluoridated and non-fluoridated area. Community Dent Oral Epidemiol 13:159–163
18. Ibrahim YE, Birkeland JM, Bjorvatn K, Haugejorden O (1991) Caries prevalence in 20-year old students in Kenya, Sierra Leone, Sudan and Tanzania. J Dent Res 70:833 (abstract)
19. Ibrahim YE, Bjorvatn K, Birkeland JM (1997) Caries and dental fluorosis in a 0.25 and a 2.6 ppm fluoride area in Sudan. Int J Paediatr Dent 7:161–166
20. Ibrahim YE, Ghandour IA, Udani TM (1986) The prevalence of dental caries among urban, semi-urban and rural school-children in the Sudan. Odontostomatol Trop 9:157–162
21. Jensen K, Kizito EK, Langebaek J, Nyika TA (1973) Dental caries, gingivitis, and oral hygiene among schoolchildren in Kampala, Uganda. Community Dent Oral Epidemiol 1:74–83
22. Manji F (1983) The prevalence of dental caries in children of African and Asian origin in Nairobi, Kenya. Odontostomatol Trop 6:27–33
23. Manji F, Fejerskov O (1990) Dental caries in developing countries in relation to the appropriate use of fluoride. J Dent Res 69(Spec Iss): 733–741
24. Manji F, Mosha H, Frencken J (1988) The pattern of dental caries amongst 12-year-old rural children in Kenya and Tanzania. East Afr Med J 65:753–758
25. Mosha HJ, Fejerskov O, Langebaek J, Thylstrup A, Baelum V, Manji F (1988) Caries experience in urban Tanzanian children 1973–84. Scand J Dent Res 96:385–389
26. Mosha HJ, Langebaek J (1983) Dental caries, oral hygiene, periodontal disease and dental fluorosis among school children in northern Tanzania. Oral health surveys. Odontostomatol Trop 6:149–156
27. Møller IJ (1965) Dental fluorose og caries. Rhodos International Science Publishers, Copenhagen
28. Møller IJ, Pindborg JJ, Roed-Petersen B (1972) The prevalence of dental caries, enamel opacities and enamel hypoplasia in Ugandans. Arch Oral Biol 17:9–22
29. Ng'ang'a PM, Valderhaug J (1992) Dental caries in primary school children in Nairobi, Kenya. Acta Odontol Scand 50:269–272
30. Normark S (1993) Social indicators of dental caries among Sierra Leonean schoolchildren. Scand J Dent Res 101:121–129
31. Olsson B (1978) Dental findings in high-fluoride areas in Ethiopia. Community Dent Oral Epidemiol 6:338–343
32. Olsson B (1979) Dental health situation in privileged children in Addis Ababa. Community Dent Oral Epidemiol 7:37–41
33. Olsson B (1979) Dental caries and fluorosis in Arussi province, Ethiopia. Community Dent Oral Epidemiol 7:51–56
34. Pitts NB, Fyffe HE (1988) The effect of varying diagnostic thresholds upon clinical caries data for a low prevalence group. J Dent Res 67:592–596
35. Rugarabamu P, Frencken JE, Amuli JA, Lihepa A (1990) Caries experience amongst 12- and 15-year-old Tanzanian children residing on a sugar estate. Community Dent Health 7:53–58
36. Rugg-Gunn AJ, Hackett AF, Appleton DR, Jenkins GN, Eastoe JE (1984) Relationship between dietary habits and caries increment assessed over two years in 405 English adolescent school children. Archs Oral Biol 29:983–992
37. Rugg-Gunn AJ, Holloway PJ (1974) Methods for measuring the reliability of caries prevalence and incremental data. Community Dent Oral Epidemiol 2:287–294
38. Ruottinen S, Karjalainen S, Pienehäkkinen K, Lagström H, Niinikoski H, Salminen M, Rönnemaa T, Simell O (2004) Sucrose intake since infancy and dental health in 10-year-old children. Caries Res 38:142–148
39. Rwenyonyi CM, Birkeland JM, Haugejorden O (2000) Assessment of the validity and consequences of different methods of expressing the severity of dental fluorosis in a subject. Acta Odontol Scand 58:148–154
40. Rwenyonyi CM, Birkeland JM, Haugejorden O, Bjorvatn K (2001) Dental caries among 10- to 14-year-old children in Ugandan rural areas with 0.5 and 2.5 mg fluoride per liter in drinking water. Clin Oral Invest 5:45–50
41. Shehata AH, Ghandour IAA (1990) A map of natural fluoride in drinking water in Sudan. Odontostomatol Trop 13:17–21
42. Smith DA, Harris HA, Kirk R (1953) Fluorosis in the Butana, Sudan. J Trop Med Hyg 56:57–58
43. Sreebny LM (1982) Sugar availability, sugar consumption and dental caries. Community Dent Oral Epidemiol 10:1–7
44. Toverud G (1957) The influence of war and post-war conditions on teeth of Norwegian school children. Milbank Mem Fund Q 35:127–196
45. Woodward M, Walker ARP (1994) Sugar consumption and dental caries: evidence from 90 countries. Br Dent J 176:297–302
46. World Health Organization (1971) Oral health surveys: Basic methods. World Health Organization, Geneva
47. World Health Organization (1987) Oral health surveys: Basic methods. 3rd ed. World Health Organization, Geneva