DENTAL FLUOROSIS IN TWO COMMUNITIES IN KHARTOUM STATE, SUDAN, WITH POTABLE WATER FLUORIDE LEVELS OF 1.36 AND 0.45 mg/L

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ABSTRACT: The prevalence of dental fluorosis in Sudan ranges from 4.5–90% depending on the fluoride ion (F) level in the potable water and the area being studied. The present study, with a total of 800 subjects, was designed to assess the prevalence and severity of dental fluorosis among residents in Tiraat El-Bijah and Um Duwanban. Significantly more dental fluorosis was found in Um Duwanban (mean potable water F 1.36±0.08 mg/L) than in Tiraat El-Bijah (mean potable water F 0.45±0.39 mg/L) (p<0.001). Water wells should routinely be analysed for F level, especially in rural areas. There is a need for regular inspections for dental fluorosis and additional research into the overall fluoride intake from all sources in Sudan. It is recommended that means should be found to decrease the fluoride level in the potable water supplies in the Um Duwanban region and other areas of endemic fluorosis in Sudan.

Keywords: Dental fluorosis; Khartoum State; Potable water; Sudan;

INTRODUCTION

Dental fluorosis is a developmental disturbance of dental enamel caused by excessive fluoride ion (F) intake during the phases of enamel formation and maturation resulting in the formation of hypo-mineralised enamel. In its mild forms, dental fluorosis, often appears as discreet, tiny white streaks or specks in the tooth enamel. In its most severe form, tooth appearance is stained by discolouration or brown markings that may be pitted, rough, and friable. The prevalence of dental fluorosis is dependent upon the fluoride intake in the first years of life.[1]

F a naturally occurring mineral but is not an essential trace element and is not necessary for the formation of healthy bones and teeth.[2] When F ingested in excess it can lead to the chronic condition of fluorosis including dental and skeletal fluorosis.[3,4] Conclusive epidemiological evidence linking dental fluorosis to excessive fluoride in the drinking water was provided by the multiple studies by Dean and co-workers.[5] They concluded that F at the level of 1 ppm of water fluoride would reduce dental caries while having minimal detrimental effects with dental fluorosis.[5] However, it is now considered that any action F has in preventing dental caries occurs predominantly after the eruption of the teeth into the mouth via a topical effect on inhibiting demineralization and enhancing remineralization rather than being incorporated into the teeth following systemic

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ingestion.[2] The World Health Organization (WHO) set, in 1984 and reaffirmed in 1993, a guideline of 1.5 mg F/L as a "desirable" upper limit for F in drinking water.[6] The WHO also allows countries to set country standards[6] and the lower national standards have been set for Senegal, West Africa, (0.6 mg/L), and India (1 mg/L).[7] A rider for the Indian standard is the "lesser the fluoride the better, as fluoride is injurious to health."[7]

Dental fluorosis has always been regarded as a public health problem in areas of the Sudan and other parts of the world where high levels of natural fluoride in drinking water occur. Numerous studies on fluorosis have been done in various regions of the world including India,[8] China,[9] Pakistan,[10] Tanzania,[11] Brazil,[12] Kenya,[13] Taiwan,[14] and Malawi.[15] Comparisons of recent data to historical data indicate a trend towards a higher prevalence of fluorosis which may be related to the increased use of fluoridated dental products over the past few years.[16]

In Sudan, the fluoride level in ground water varies substantially among the different regions. Since the first studies by Smith et al. on dental fluorosis in Sudan, several other studies have been conducted among children in different areas, especially in the Northern, Western, and Central areas of Sudan.[17-23]

According to the National Water Corporation, the two communities of Um Duwanban and Tiraat El-Bijah, both within the State of Khartoum, have different fluoride levels in their potable water. These two communities, located south of the capital Khartoum, are 40 km apart. Except for the differing fluoride levels, these two communities present a remarkable homogeneity regarding ethnicity, habitat, social environment, diet, and oral hygiene. The objective of the present study was to assess the prevalence and severity of dental fluorosis among the residents in the two communities, and to provide baseline data and information about dental fluorosis for use by public health authorities in the planning of appropriate preventive strategies.

MATERIALS AND METHODS

A cross-sectional observation study was conducted in Tiraat El-Bijah and Um Duwanban. Tiraat El-Bijah is supplied with potable water from 7 wells that have an approximate depth of 45 m and Um Duwanban is supplied with potable water from deep rock wells which were made in the late 1940's. The four available wells in Um Duwanban have a depth of approximately140 m. The wells in both communities ultimately feed into a distribution system. Furthermore, the two communities have had no changes in the distribution of the water supply in recent years.

The two communities were selected because their potable water supplies are based on deep wells and each community has, at least, one basic (primary) school and one secondary school, and an adult population willing to participate. Ethical approval was obtained from the State Ministry of Education and the Scientific Research Committee at the University of Khartoum.

The local school authorities, the school principals, and the parents of the children in the schools in the two communities were informed about the study and asked to

allow the participation of their children. Negative consent was adopted without any prejudice being attached to the children who had opted not to participate.

A systematic random sample technique was applied. Each village was divided into two main sectors and a school was randomly selected from each sector followed by systematic random sampling to enrol students, provided that the pupils, and their parents, gave consent to be enrolled in the study. The subjects aged 25 or more yr were recruited from the primary health care centre after dividing each village to two sectors with the sampling representing both sectors from each village. All the study participants consented voluntarily to be enrolled in the study after receiving all the information about the study. The researcher attended daily for ten working days to recruit the required sample.

The study consisted of a total of 800 participants, with 400 randomly selected from each community. The participants were recruited from the pupils and staff of the public primary and secondary schools, and from the local residents. In each community, the participants were divided equally into four age groups, 6–8, 10–12, 15–20, and 25 or more yr. Each age group consisted of an equal number of females and males. To be included in the study, the participants had to have been born and bred in their respective communities and to have least 50% of the crowns of their permanent teeth erupted. None of the participants had been away from their respective public water supply for more than two months during any calendar year.

Dental fluorosis scores were recorded according to the Dean's Index (DI) which was created to show clinically clear descriptions of dental fluorosis in a population and to approximate the actual biologic effects of F on the developing dental enamel. The classification is an acceptable system for dental fluorosis found on two or more teeth. The index classifies dental fluorosis on a six-point ordinal scale as normal, questionable, very mild, mild, moderate, and severe.[5] The questionable score was not scored in this study.

The participants were requested to brush their teeth just before the examination and the teeth were dried with sterile gauze. Then all the teeth were evaluated by visual inspection in the natural morning light, with the aid of a sterile dental mirror and explorer, and other materials necessary to guarantee the bio-security measures. The scoring of dental fluorosis was based on the two most affected teeth.

During the study period, potable water samples were collected in polyethylene bottles which had been previously washed with 10% HCl and rinsed with distilled water. The potable water samples bottles were labelled with a sample number, date, time, and point of collection. The potable water samples bottles were transported at a temperature of 4ºC (39.2ºF) in an icebox and refrigerated until analysis.

Once in the laboratory, precautions were taken to avoid contamination. The water samples were distilled according to standard methods before the F levels were determined to eliminate any interference due to colour, turbidity, or the presence of other substances. The concentration of F in the water was determined

using a digital pH/mV meter, (Consort P 903T, Sentek Ltd., Unit 6-7 Crittall Court, Crittall Drive, Springwood Industrial Estate, Braintree, Essex, CM7 2 SE, England), with a combination F Direct Ion Selective Electrode (3221) according to the recommendations of the Sentek company.

For the statistical analysis, the frequency percentages, the means, and the standard deviations were used in Chi-square and one-way ANOVA testing for significant differences. The t-test and Mann-Whitney U tests were used for parametric and non-parametric data, respectively, The Pearson Correlation was used to correlate the variables using the SPSS version 21 (IBM SPSS Statistics IBM North America, 590 Madison Avenue, New York, NY 10022. United States, E-mail:www.ibm.com) to analyse the data. The level of significance was set at $p<0.05$ or $p<0.001$

RESULTS

For the two communities of Um Duwanban and Tiraat El-Bijah, the data on the ages were mean=17.43, median=13.5, and range=6–63 yr and mean=16.9, median=11.8, and range=6–63 yr, respectively ($p= 0.327$).

The mean F level of the potable water in Um Duwanban was 1.36±0.08 mg/L, range 1.29–1.43 mg/L. In Tiraat El-Bijah, the mean F level of the potable water was 0.45±0.39 mg/L, range 0.24–1.31 mg/L. The Um Duwanban community had a significantly higher mean F level in their potable water ($p<0.001$) (Table 1).

Table 1. Mean fluoride level in potable water supplies of Tiraat El-Bijah and Um Duwanban

Community	No. of water samples	Mean±SD (mg/L)	Range (mg/L)
Um Duwanban	4	1.36±0.08*	1.29–1.43
Tiraat El-Bijah	7	0.45±0.39*	0.24–1.31

Comparing the means in the two communities: *$p<0.001$

In Um Duwanban, 70.0% of the participants demonstrated varying degrees of dental fluorosis compared to 42.5% of the participants in Tiraat El-Bijah. More very mild fluorosis was present in Tiraat El-Bijah compared to Um Duwanban, 45.9 and 31.8%, respectively, while for the combination of mild, moderate, and severe fluorosis, the prevalence was higher in Um Duwanban than in Tiraat El-Bijah, 68.3 and 54.2%, respectively ($p<0.001$) (Table 2).

Table 2. Prevalence of dental fluorosis in Um Duwanban and Tiraat El-Bijah

Degree of dental fluorosis	Prevalence of dental fluorosis	
	Um Duwanban (Potable water F level 1.36±0.08 mg/L) N (%)	Tiraat El-Bijah (Potable water F level 0.45±0.39 mg/L) N (%)
No fluorosis	120 (30.0)	230 (57.5)
Fluorosis present	280 (70.0)	170 (42.5)
For those with fluorosis:		
Very mild	89 (31.8)*	78 (45.9)*
Mild	126 (45.0)*	55 (32.4)*
Moderate	57 (20.4)*	36 (21.2)*
Severe	8 (2.9)*	1 (0.6)*
Total with fluorosis	280 (100)	170 (100)
Total with and without fluorosis	400 (100.0)	400 (100.0)

Comparing the prevalence of the various degrees of severity of dental fluorosis in the two communities: *χ^2=73.3, p<0.001.

Comparing the females with the males in each of the two communities, no significant differences were present between females and males in the prevalence of the various degrees of severity of dental fluorosis in each community. Within both the high and low F communities, the rates of fluorosis did not differ significantly between females and males (Table 3).

Table 3. Prevalence of the various degrees of severity of dental fluorosis in females and males in each of the communities, Um Duwanban and Tiraat El-Bijah

Degree of dental fluorosis	Prevalence of dental fluorosis			
	Um Duwanban (Potable water F level 1.36±0.08 mg/L)		Tiraat El-Bijah (Potable water F level 0.45±0.39 mg/L)	
	Females N (%)	Males N (%)	Females N (%)	Males N (%)
Very mild	50 (35.5)*	39 (28.1)*	34 (47.2)†	44 (44.9)†
Mild	57 (40.4)*	69 (49.6)*	23 (31.9)†	32 (32.7)†
Moderate	30 (21.3)*	27 (19.4)*	15 (20.8)†	21 (21.4)†
Severe	4 (2.9)*	4 (2.9)*	0 (0)†	1 (1)†
Total	141 (100)	139 (100)	72 (100)	98 (100)

Comparing the prevalence of the various degrees of severity of dental fluorosis in females and males in each of the two communities: *χ^2=2.65, p=0.80; †χ^2=0.449, p=0.85.

In Um Duwanban, very mild fluorosis was found in 19.5% of the male participants and 25.0% of the females. Mild fluorosis was present in 34.5% of the males and 28.5% of the females. Moderate fluorosis was shown by 13.5% of the males and 15.0% of the females. Severe fluorosis was present in 2.0% of both sexes. In contrast, in Tiraat El-Bijah very mild fluorosis was seen in 22.0% of the males and 17.0% of the females. Mild fluorosis was present in 16.0% of the male participants and 11.5% of the females. Moderate fluorosis was demonstrated mild fluorosis in 10.5% of the males and 7.5% of the females. Severe fluorosis was exhibited in 0.5% of the males but was absent in the females. Statistical comparison between the females in Um Duwanban and in Tiraat El-Bijah and the males in Um Duwanban and in Tiraat El-Bijah demonstrated a highly statistical significance ($p<0.001$). (Table 4).

Table 4. Prevalence of dental fluorosis in females in Um Duwanban and Tiraat El-Bijah and in males in Um Duwanban and Tiraat El-Bijah

Degree of dental fluorosis	Prevalence of dental fluorosis			
	Females (N) (%)		Males (N) (%)	
	Um Duwanban (Potable water F level 1.36±0.08 mg/L) (N = 200)	Tiraat El-Bijah (Potable water F level 0.45±0.39 mg/L) (N = 200)	Um Duwanban (Potable water F level 1.36±0.08 mg/L) (N = 200)	Tiraat El-Bijah (Potable water F level 0.45±0.39 mg/L) (N = 200)
No fluorosis	59 (29.5)*	128 (64.0)*	61 (30.5) †	102 (51.0) †
Very mild	50 (25.0)*	34 (17.0)*	39 (19.5)†	44 (22.0) †
Mild	57 (28.5)*	23 (11.5)*	69 (34.5) †	32 (16.0) †
Moderate	30 (15.0)*	15 (7.5)*	27 (13.5) †	21 (10.5) †
Severe	4 (2.0)*	0 (0.0)*	4 (2.0) †	1 (0.5) †
Total	200 (100)	200 (100)	200 (100)	200 (100)

Comparing the prevalence of the various degrees of severity of dental fluorosis in females in Um Duwanban and in Tiraat El-Bijah, and males in Um Duwanban and in Tiraat El-Bijah: $*\chi^2=51.96$, $p<0.001$; $^{\dagger}\chi^2=26.72$, $p<0.001$.

The prevalence of dental fluorosis in the combined totals for both communities was 56.3%. The prevalence of dental fluorosis usually increased as the age increased ($p<0.001$) (Table 5).

Table 5. Prevalence of dental fluorosis in Um Duwanban and Tiraat El-Bijah according to age group

Age group (yr)	Prevalence of dental fluorosis		
	Um Duwanban (Potable water F level 1.36±0.08 mg/L) (N with fluorosis=280)	Tiraat El-Bijah (Potable water F level 0.45±0.39 mg/L) (N with fluorosis=170)	Um Duwanban and Tiraat El-Bijah Σ (N with fluorosis=450)
	N (%)	N (%)	N (%)
6–8	46 (16.4)*	18 (10.6)†	64 (14.2)‡
10–12	77 (27.5)*	30 (17.6)†	107 (23.8)‡
15–20	82 (29.3)*	56 (32.9)†	138 (30.7)‡
≥25	75 (26.8)*	66 (38.8)†	141 (31.3)‡
Total	280 (100)	170 (100)	450 (100)
Prevalence of dental fluorosis in the total sample for each community (N=400) and for both communities combined (N=800)	280 in 400 (70)	170 in 400 (42.5)	450 in 800 (56.3)

Comparing the prevalence of dental fluorosis in various age groups in Um Duwanban, in Tiraat El-Bijah, and both communities combined: *χ^2=37.8, $p<0.001$; †χ^2=61.0, $p<0.001$; ‡χ^2=78.1, $p<0.001$.

In the Um Duwanban community, except for the 25 yr and above age group, which demonstrated only 26.8% prevalence of dental fluorosis, there was an increase in the prevalence of dental fluorosis with age. In the 6–8 yr age group, 16.4% of those examined demonstrated varying degrees of dental fluorosis. In the

10–12 yr age group 27.5% showed varying degrees of severity of dental fluorosis. In the 15–20 yr age group, 29.3% had dental fluorosis. ($p<0.001$) (Table 5).

The Tiraat El-Bijah community demonstrated a gradual increase in the prevalence of dental fluorosis with age. Only 10.6% of the 6–8 yr age group showed some degree of dental fluorosis. The 10–12 yr age group had a prevalence of dental fluorosis of 17.6% while in the 15–20 yr age group 32.9% demonstrated dental fluorosis of varying severity. The highest prevalence of dental fluorosis of 38.8% was shown in the 25 yr and above age group ($p<0.001$) (Table 5).

DISCUSSION

The dilemma of a high fluoride concentration in groundwater sources has become one of the most important toxicological and geoenvironmental issues globally. Excessive fluoride in potable water causes dental, skeletal, and non-skeletal fluorosis which is encountered in endemic proportions in several parts of the world.[24]

Potable water is the primary source of fluoride and, although Dean et al. suggested that in temperate climates the optimal fluoride content in potable water was approximately 1 mg/L,[25] the present World Health Organization guideline of 1.5 mg F/L is a "desirable" upper limit for F in drinking water rather than a recommendation for a particular level of F in drinking water.[6] The Indian standard of 1 mg F/L includes the rider "lesser the fluoride the better, as fluoride is injurious to health.[7] The US Department of Health and Human Services Federal Panel on Community Water Fluoridation have replaced their earlier recommendation for community water systems, based on the outdoor air temperature of geographic regions and involving a range of 0.7–1.2 mg F/L, with a new recommendation of a level of 0.7 mg F/L.[26]

In tropical countries, where people drink more water due to the hot climate, the "desirable" upper limit fluoride content of potable water may be as low as 0.5 mg/L. A national standard of 0.6 mg/L has been set for Senegal, West Africa.[7] In Sudan, in a recent study, Ramadan et al. determined the fluoride concentration should not be above 0.35 mg/L to avoid the risk of fluorosis.[27]

Eight hundred participants were examined in the present study. All the participants were lifelong residents in each of their respective communities of Um Duwanban and Tiraat El-Bijah. Seventy percent of the participants of Um Duwanban, where the mean water F level was 1.36±0.08 mg/L, demonstrated varying degrees of dental fluorosis as compared to 42.5% of the participants from Tiraat El-Bijah where the mean water fluoride level was 0.45±0.39 mg/L. The findings in the present study on dental fluorosis and fluoride concentrations, although showing lower rates of dental fluorosis and lower levels of F in potable water, are in agreement with reports on the presence of dental fluorosis in Sudan.[17-23]

Comparable studies in Sudan have reported widespread dental fluorosis with varying degrees of prevalence and severity. In one study, a prevalence of dental fluorosis of 80.6% in schoolboys in the Butana area of the Sudan was found, and

the water fluoride concentration was reported to be in the range of 1.1–4.0 mg/L.[21] A dental fluorosis prevalence as high as 90% and a water fluoride concentration of 5 mg/L were reported in the Sudan.[22] The prevalence and severity of dental fluorosis depend on the total amount of fluoride ingested during the critical period of enamel formation.[28] In addition to water, various other fluoride sources have been identified, such as toothpaste,[29] fish and seafood in coastal areas, and tea.[30,31]

The lower dental fluorosis prevalence rates and the water fluoride concentrations found in the present study could be attributed in part to a difference in the accuracy of the thorium nitrate titration method,[32] used in the analysis by Smith, Emslie, and Hussein. Furthermore, the differences in the prevalence of fluorosis could also partly indicate differences in the handling of the diagnostic standards, the sampling method, or the total amount of fluoride consumed from several other sources.

The results of this study are not dissimilar to those of another study that reported a prevalence of dental fluorosis 64% of boys and 50% of girls examined in Omdurman.[17] No information was provided, however, on the water fluoride concentration to which these children were exposed.[17]

The consumption by the participants in Um Duwanban of water with an average fluoride concentration of 1.36 mg/L resulted in a prevalence of dental fluorosis, of various degrees of severity, of 70%. This finding is substantiated by numerous investigations that have revealed a quantitative relationship between water fluoride levels and dental fluorosis prevalence rates of up to 96–100%.[33-35]

The comparison of the fluorosis prevalence in this study with the results reported from some Arab countries also showed some variation. A Jordanian study reported an 80% prevalence of fluorosis[36] while studies in Saudi Arabia among 14-yr-old schoolchildren in the Riyadh and Hail regions reported prevalence rates of 83% and 90%, respectively.[37] In contrast, a Kuwaiti study in a low fluoride area found the prevalence of dental fluorosis among the 12–15-yr-old children examined was 6%.[38]

In Tiraat El-Bijah, the mean fluoride concentration in the potable water was 0.45 mg/L and the prevalence of dental fluorosis was 42.5%. This figure for the dental fluorosis prevalence was higher than expected and baffling due to the low water fluoride concentration in the potable water. However, the prevalence of dental fluorosis was less than in a study that reported a higher prevalence rate of 91% with an even lower water fluoride concentration of 0.25 mg/L.[23] The authors of the study noted that the cause of the high prevalence was due to other factors than the drinking water F level, postulating that it could be attributed to the feeding habits during the critical weaning period, and the ingestion of fluoride from sources other than water.[23]

A Kenyan report found that children 14 yr of age had a daily fluid intake of about 1.1 L, about half of which was from tea.[39] According to Jenkins,[31] the average fluoride concentration of tea is 2.2 mg/L, but wide variations exist,

depending on the tea brand and the tea-making technique. Tea is a very popular beverage in Sudan and is given to children from a very young age. Consequently, tea is a factor to be considered in the pathogenesis of dental fluorosis in low-fluoride areas.

In Sudan, the high fluorosis prevalence can be attributed to the presence of the fluoride in the potable water. Potable water plays a significant role for the Sudanese, and it is the primary source of fluid. The annual high temperature means that children consume more water and thus have a higher fluoride intake. In the Sudan, dental fluorosis may be high because of the high annual mean temperature, of 35.58ºC.[27] As in other countries, the drinking of bottled water, juices and carbonated beverages,[40,41] has increased in Sudan. Some children may receive a substantial fluoride intake from carbonated soft drinks and tea.

In the present study, the severity of the dental fluorosis was increased in the older age groups compared to the younger ones. No significant different difference was found in the prevalence of dental fluorosis in females and males. A lower prevalence of dental fluorosis among girls was found in another report.[42] Girls tend to consume less water than boys and further research is required to consider further the occurrence of sex-related differences.

Dental fluorosis develops at the time of the mineralization of teeth from infancy and therefore, the fluoride exposure during this period is significant. With the present study being cross-sectional, the fluoride exposure during mineralization of teeth could not be measured. However, it is believed that the water sources were constant and had not changed in recent years. The association of dental fluorosis with other risk factors needs to be reviewed.

CONCLUSIONS

The results indicate that Um Duwanban is a community with both a high F content in its wells of 1.36±0.08 mg/L and a high percentage of dental fluorosis morbidity of 70.0%. Ground water wells in all communities should be routinely analysed for fluoride levels and partial de-fluoridation implemented for those with a high F content.

It is not too early to suggest a need to change high F potable water supplies, such as in the Um Duwanban community, by using a cheap and technologically simple process for the small-scale removal of F from F–rich groundwater or of developing alternative sources of the potable water supply

The factors related to the prevalence and severity of dental fluorosis in Sudan need to be studied further. Dental fluorosis is a public health problem in the different areas of Sudan. There is a need for continuous monitoring of mottling and further investigation into the total fluoride intake from all sources in Sudan.

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