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Saudi Dental Journal

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ORIGINAL ARTICLE

Comparison of oral health indicators between two places of endemic dental fluorosis in Jordan

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Received 10 January 2020; revised 3 April 2020; accepted 4 April 2020

KEYWORDS

Dental fluorosis;
 Altitude;
 Dean's index;
 DMFT index;
 Oral hygiene

Abstract *Introduction:* Excessive fluoride intake during tooth development causes dental fluorosis.

Aim: This study aimed to (1) determine the prevalence of dental fluorosis in association with fluoride concentrations in drinking water, (2) explore the effects of altitude on the severity of fluorosis in two towns with high fluoride levels in the drinking water, and (3) assess decayed, missing, and filled teeth (DMFT) and oral hygiene practices among participants.

Material and methods: The sample consisted of 100 and 141 schoolchildren, aged 15.3 ± 1.4 and 16.1 ± 1.3 years, living in Ruwaished and Kuraymah, respectively. Oral examinations were carried out, and dental fluorosis was assessed using the Dean's index. The DMFT index was also used for assessment. Samples of drinking water were analyzed using a fluoride-ion selective electrode. SPSS was used to analyze the data.

Results: Two-thirds (68.8%) of adults from Kuraymah had moderate to severe fluorosis, with only 7% being unaffected. In Ruwaished, 50% of the sample had severe fluorosis, 22% showed moderate fluorosis, and none were unaffected. The average DMFT scores were 3.18 ± 1.81 and 3.81 ± 1.41 for Kuraymah and Ruwaished, respectively. In both towns, males had significantly higher caries scores than females. Oral hygiene was poor, as 64% and 57% of the participants from Kuraymah and Ruwaished, respectively, did not brush their teeth. A significant correlation was found between poor oral hygiene and increased DMFT scores.

Conclusions: This study concluded that higher fluorosis incidence and severity were present in the higher-altitude location (Ruwaished). Moreover, this study also indicated that fluorosed teeth

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Peer review under responsibility of King Saud University.



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are not immune to caries, and the preventive management of dental fluorosis should be directed to de-fluoridation of drinking water in endemic areas.

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1. Introduction

Fluoride (F) in drinking water remains the cornerstone of public caries prevention programs. Other F sources, including dietary F supplements (tablets, lozenges, and drops), self-used fluoridated toothpaste and mouthrinse, and professionally-applied topical F agents (solutions, gels, foams, varnishes) significantly contribute to caries prevention (Murray, 1986; Marinho, 2009; Twetman and Keller, 2016). However, these sources of F may cause dental fluorosis if their applications are not well controlled. Excessive F intake during tooth development causes dental fluorosis, which is characterized by defective enamel matrix formation and subsequent hypomineralization. After the enamel is completely formed, dental fluorosis cannot develop even if excessive F is ingested. It has been observed that the pitting and staining of moderate to severely fluorosed enamel is induced by prolonged excessive F ingestion from drinking water supplies containing 2 ppm F and higher. The optimal intake of F in children has been widely accepted as being between 0.05 and 0.07 mg F/kg of body weight (Wei and Hattab, 1988; Burt and Eklund, 2005) (see Fig. 1).

Epidemiological studies in the Western world indicate that dental caries among children and young adults has declined by 50% since the early 1980s (Glass, 1986; Marthaler, 2004). The reason behind this decline is the availability of F from multiple sources, particularly dentifrices. However, there has been an increase in the incidence of dental fluorosis. According to the United Nations' Environment Programme/World Health Organization (UNEP/WHO, 1992), dental fluorosis is endemic in at least 25 countries across the world, with millions of people affected, particularly in tropical regions. The World Health Organization (WHO, 2019) recommends that F levels in drink-

ing water should not exceed 1.5 ppm F. Reports from Africa, southeast Asia, Jordan, and Saudi Arabia revealed a prevalence of dental fluorosis among residents in areas with drinking water containing 1 ppm F or more (Hattab et al., 1997a; Akpata et al., 1997). Furthermore, the consumption of dietary F supplements during the first years of life has been associated with an increased risk of fluorosis (Ismail and Hasson, 2008).

Evidence indicates that F levels in the drinking water differ between countries and within the same country, depending on the geology of the area. The long-term ingestion of excess F, mostly from drinking water, can cause fluorosis, which affects the teeth and bones (Wei and Hattab, 1988; WHO, 1994). Atmospheric temperature and altitude are additional factors that contribute to the severity of fluorosis (Galagan and Vermillion, 1957). Furthermore, despite a sub-optimal F concentration in drinking water, an increased incidence of dental fluorosis was found among inhabitants of high altitudes in Kenya (Manji et al., 1986), Nigeria (Akoso and Zoakah, 2008), and Mexico (Pontigo-Loyola et al., 2008).

Jordan has a combination of Mediterranean and subtropical arid climates and is usually warm, with dry summers and relatively cold winters. The annual average temperature ranges from 10 to 35 °C, with relative humidity ranging from 35% in summer to 70% in winter. Jordan also has both the highest and lowest points relative to sea level. For example, Jebal Rum is 1734 m above sea level, while the surface and shores of the Dead Sea are about 430 m below sea level—Earth's lowest elevation on land (Royal Jordanian Geographic Center, 2012). However, it is noteworthy that the summit of Jebal Rum is not inhabited and that the inhabited surrounding the desert plain is about 900 m above sea level (Royal Jordanian Geographic Center, 2012).



Fig. 1 Examples of fluorosis severity in Ruwaished and Kuraymah. A. normal. B. very mild. C. mild. D. moderate. E. severe.

Moreover, few studies have reported the prevalence rate of dental fluorosis among Jordanians. Hamdan (2003) found that 18.5% of the 12-year-old school children in the southern region of Jordan presented with dental fluorosis. Furthermore, F concentrations in the drinking water of eleven Jordanian provinces varied considerably, ranging from 0.10 to 2.15 ppm. Higher F concentrations in drinking water were found in the northeast (Mafraq), far north (Irbid), and central (Madaba) regions of Jordan (Hattab et al., 1997a). Fluoride in bottled water ranged from 0.08 to 0.23 ppm and beverages from 0.16 to 0.67 ppm (Hattab et al., 1997b).

For infants, powdered milk formulas were the main source of F when prepared with fluoridated water. When infant powder formulas (contained 0.12–1.08 µg/g) were diluted in a ratio of 1:1, with water containing 0.7 or 1 ppm F, the dose of F was about 55- and 70-times more than that obtained from cow's milk (Hattab and Wei, 1988). No studies were carried out in Jordan to explore the influence of altitude on the prevalence of dental fluorosis in areas with high fluoride levels in the drinking water.

The main aims of the present study were (1) to determine the prevalence of dental fluorosis in association with F concentrations in drinking water, (2) to explore the effects of altitude on the severity of dental fluorosis in two towns with high fluoride levels in the drinking water, and (3) to assess decayed, missing, and filled teeth (DMFT) scores and oral hygiene practices in individuals living in both towns.

2. Materials and methods

The towns chosen for this study were Ruwaished (MAPS, 2019a) and Kuraymah (MAPS, 2019b); these two towns were chosen because they vary substantially in their altitude from the sea level and had high F concentrations in the drinking water supplied from wells. Ruwaished, located 240 km to the east of Amman, administratively belongs to Mafraq Governorate. The town is elevated 685 m above sea level, with a population of 14,400. Kuraymah is located 50 km from the capital, Amman, and administratively belongs to Irbid Governorate in the extreme north-west; the town is 195 m below sea level, with a population of 19,500.

Forty drinking water samples were collected from five shallow and five deep wells in each town. Four samples from each well were collected into labeled plastic bottles. Water from the taps was allowed to flow for 1 to 2 min before the bottles were filled. The F concentrations in the water samples were determined with a combination F-selective electrode (Orion model 960900), coupled with an ionalyzer (Orion mode 1901, Cambridge, U.S.A.). Prior to fluoride determination, water samples were mixed with 10% by volume of TISAB III (Total Ionic Strength Adjustment Buffer). The water analysis was carried out at the Research Center at the University of Jordan.

One-hundred students were randomly selected from Ruwaished, including 40 females with a mean age of 15.35 ± 1.3 years and (60) males with an average age of 15.98 ± 1.5 years. The sample from Kuraymah was comprised of 141 students, 56 females with an average age of 16.30 ± 1.2 years and 85 males aged 15.90 ± 1.4 years. Examinations were carried out by direct visual inspection in school rooms while students were sitting in their school chairs under the sunlight, without using artificial light. The teeth of the students were swabbed with

dental gauze to obtain good visibility. The severity of dental fluorosis was evaluated using the Dean's index (Table 1). The DMFT index was charted using a dental mirror and probe, using the WHO criteria. For the prior examination, the examiners were calibrated for caries and fluorosis criteria in order to eliminate inter- and intra-examiner bias. The reliability was greater than 0.85, using the Spearman correlation coefficient.

The necessary ethical approval for this study was obtained from the Ethical Committee of the University of Jordan (Ethical Approval number: 117). Procedures on human subjects were conducted in accordance with the ethical standards of the Institutional and National Research Committee and the Helsinki Declaration of 1964 and its later amendments. Informed consent was signed by all the individuals who participated in the study.

The Statistical Package for the Social Sciences (SPSS) was used to analyze the data (SPSS, Version 17.0, Inc., Chicago, IL). Comparisons between mean DMFT scores were calculated using a *t*-test. The association between the DMFT score and the other variables (i.e. oral hygiene habits and the severity of fluorosis) was evaluated using the Spearman correlation coefficient (r_s) test. A non-parametric test was used to assess the statistical significance of the difference in fluorosis distribution between the Kuraymah and the Ruwaished samples since the data were not normally distributed. Two independent samples *t*-tests were used to compare the mean water consumption between the Kuraymah and the Ruwaished samples. Statistical significance was set at the 0.05 level.

3. Results

The average fluoride concentration of the water supply in Ruwaished was 1.38 ppm and 1.10 ppm in Kuraymah. The grades and frequencies of fluorosis in students residing in both tested towns are presented in Table 2. Sixty-eight-point eight percent of the Kuraymah sample had moderate and severe fluorosis, and only 7.1% had no fluorosis. One-fourth of participants exhibited very mild and mild fluorosis. In Ruwaished, 72% of participants had moderate and severe fluorosis, with

Table 1 Criteria for the fluorosis index score by Dean's index (Dean, 1942).

Score	Classification	Criteria-Description
0	Normal	The enamel is smooth, glossy, pale creamy-white translucent surface
1	Questionable	A few white flecks or white spots mainly on the edge of the incisors and canines
2	Very Mild	Small, opaque, paper-white areas covering less than 25% of the tooth surface
3	Mild	Opaque white areas covering less than 50% of the tooth surface
4	Moderate	All tooth surfaces are affected; marked wear on biting surfaces (attrition); brown stains may be present
5	Severe	All tooth surfaces are affected and have discrete or confluent pitting. Brown stains are present; teeth often show a corroded-like appearance

Table 2 Fluorosis data estimated according to the Dean's Fluorosis Index (Dean, 1942).

Town	Index Score	Frequency	Percentage
Kuraymah	Normal	10/141	7.1%
	Very mild	13/141	9.2%
	Mild	21/141	14.9%
	Moderate	51/141	36.2%
	Severe	46/141	32.6%
Ruwaished	Normal	0/100	0%
	Very mild	9/100	9%
	Mild	19/100	19%
	Moderate	22/100	22%
	Severe	50/100	50%

50% exhibiting severe fluorosis. The remaining participants suffered from mild (19%) or very mild (9%) fluorosis. None of the participants from the Ruwaished sample were free of fluorosis.

The average DMFT score for Kuraymah participants was 3.18 ± 1.81 (SD), and 3.81 ± 1.41 (SD) for Ruwaished participants. In both Kuraymah and Ruwaished, males had significantly higher caries scores than females ($P < 0.01$). Oral hygiene among both sample groups was poor. In Ruwaished, 57% of the sample population did not brush their teeth, and only 21% brushed once a day; however, the rest of the population brushed more often. Overall, females had better oral hygiene than males. In Kuraymah, 82% of males did not brush their teeth at all, and 13% only brushed once a day. For females, 36% did not brush at all, and only 27% brushed once a day. The majority (87%) of the subjects had gingivitis, which had manifested by gum bleeding. The association between oral hygiene and the DMFT score was evaluated using the Spearman correlation coefficient (r_s) test. A significant correlation between the two parameters with values of $r_s = 0.455$, $P < 0.01$ for the Kuraymah sample and $r_s = 0.685$, $P < 0.01$ for the Ruwaished was observed.

A Spearman correlation coefficient was used to assess any association between the severity of fluorosis and the DMFT score. A significant correlation was found between the severity of dental fluorosis and an increased DMFT score. The correlation coefficient (r_s) for Kuraymah sample was 0.542 ($P < 0.01$) and 0.718 ($P < 0.01$) for the Ruwaished.

Data that was collected on the amount of water consumption in the two towns revealed that residents in Kuraymah consumed significantly more water than those in Ruwaished (P -value = 0.001). This could be attributed to the fact that the average temperature in Kuraymah is higher than in Ruwaished.

Interviews and consultations with medical personals in the two towns showed that older residents complained of abdominal distress, diarrhea, constipation, neurological symptoms such as tingling and numbness, muscle pain, increased tendency to urinate, increased thirsty, and weakness. The tap water in these towns was used in the preparation of powder milk formula for infants and in cooking; bottled water was not commonly used. It is also noteworthy to mention that skeletal problems were not apparent among the samples of the study from both towns and that these problems were not reported by the medical personals who were interviewed.

4. Discussion

The results of this study, which showed a strong association between high altitude and the severity of dental fluorosis, compared to low altitude, proved an alternative hypothesis that disputes the null hypothesis that there is no relationship between the two variables. It has been reported that individuals residing in areas of high altitude are subject to increased water intake, lower humidity, and increased water loss through respiration (Van Vynckt V, Tandurust). However, the altitudes given in these reports are considerably higher than they are in Ruwaished.

Epidemiologic reports indicated that a positive relationship may exist between the prevalence and severity of dental fluorosis and residence at high altitude, even when sub-optimal concentrations of fluoride were present in the drinking water. The association between F in drinking water, caries, and fluorosis was studied in 12,200 Saudi subjects aged 6–7, 12–13, and 15–18 years, stratified according to water F concentrations. Examination revealed no significant difference in the prevalence of caries and dental fluorosis when F levels in drinking water increased from 0.3 ppm to 0.6 ppm. At an F concentration above 0.6 ppm, caries experience was relatively low, while the severity of fluorosis was significantly increased (Al Dosari et al., 2010). The relationship between F levels in well drinking water and the severity of fluorosis was also determined in 2355 rural children aged 12–15 years in the Hail region of Saudi Arabia. The findings of this study showed that over 90% of the children had dental fluorosis. A strong association ($P < 0.001$) was found between the F level (0.5–2.8 ppm) in the drinking water and the severity of fluorosis, but not on caries experience (Akpata et al., 1997). Another study found that 75% of the public water supplied in the Central Province cities of Riyadh and Qassim had fluoride levels between nil and 6.2 ppm (Aldosari et al., 2003). Moreover, Manji et al. (1986) examined children aged 11–15 years from low F zones (<0.5 ppm in drinking water) residing at three altitudes: sea level, 1500 m, and 2400 m above sea level. They compared the findings to those from two higher fluoride zones (0.5–1.0 ppm in drinking water) of the same altitudes. Their study showed the prevalence of dental fluorosis at the three altitudes was 36.4%, 78.0%, and 100.0%, respectively. Additionally, in a Tanzanian study, Yoder et al. reported that 98% of participants living at a high altitude, where the water fluoride concentration was very low (0.18 ± 0.32 ppm), had dental fluorosis.

The higher DMFT score of Ruwaished participants, compared to the Kuraymah group (3.81 versus 3.18), could be partly related to higher consumption of sugar-sweetened beverages for caloric need in the relatively cold climate. The oral hygiene in participants of both towns was poor. More than half of the participants did not brush their teeth at all; overall, females were more concerned and motivated about their oral health.

Although excess F in drinking water was the principal factor for the occurrence of dental fluorosis, other parameters are involved. For example, tea is rich in F and Jordanians are heavy tea drinkers, which significantly contributes to their total daily F intake. A previous study showed that the F concentration in 26 brands of dried tea leaves ranged from 82 to 371 mg/kg body weight. When infused in deionized water, the F concentration ranged from 0.80 to 3.5 ppm, with an

average of 1.48 ppm (Hattab and Wei, 1988). The intake of 250 mL (~1 teacup) of tea leaves infused in tap water, containing 1.1 ppm F in Kuraymah and 1.38 ppm F Ruwaished, exposes the body to 0.61 mg F and 0.76 mg F, respectively. This amount of ingested F accounts for about half of the optimum daily F intake (0.05–0.07 mg F/kg body weight).

Another important source of excessive F intake is gaseous airborne F emitted from phosphate fertilizer plants, the largest industry in Jordan. Workers at these sites exhibited dental fluorosis and signs of osteofluorosis (Amin et al., 2001). The lack of safety and protection measures is a causative factor of health deterioration among workers. People living in areas with high F levels in the drinking water should be aware of the ill effects of this mineral, as boiling the water does not remove F. The intake of dairy foods reduces the amount of absorbed F, while deficient intake of nutrient items worsens the problem (Wei and Hattab, 1988, Ekstrand et al., 1988).

This study has several limitations. For instance, due to time constraints, the effects of fluorosis on the general health in older age groups were not investigated. Future studies are being planned to assess these effects. However, the present study provides information on the correlation of F levels in drinking water with caries experience, dental fluorosis, and altitude, in appropriate age groups.

5. Conclusions

The present study showed the following: (1) high F concentrations in drinking water were found in the wells of two tested towns, (2) severe dental fluorosis was evident among examined students, (3) higher fluorosis incidence and severity was found in high-altitude locations, (4) a correlation was found between the severity of dental fluorosis and increased DMFT scores, (5) poor oral hygiene was significantly associated with higher DMFT scores, (6) moderate and severe fluorosis are esthetically objectionable and require treatment because of their significant effect on psychosocial development, social interaction, and general well-being, and (7) the preventive management of dental fluorosis should be directed to de-fluoridation of the drinking water in endemic areas.

Ethical statement

The necessary ethical approval for this study was obtained from the Ethical Committee of the University of Jordan. Procedures on human subjects were conducted in accordance with the ethical standards of the Institutional and National Research Committee and the Helsinki Declaration of 1964 and its later amendments. Informed consent was signed by all the individuals who participated in the study.

CRediT authorship contribution statement

Salah A. Al-Omoush: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **Sandra Al-Tarawneh:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing - original draft, Writ-

ing - review & editing. **Motaz Abu-Awwad:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. **Samiha Sartawi:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. **Wijdan Elmanaseer:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. **Firas Alsoleihat:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare no potential conflicts of interest in the present study.

Acknowledgements

We would like to express our deepest appreciation and sincere gratitude to Professor Faiez N. Hattab for his invaluable suggestions and for reviewing the paper. We thank all participants for their cooperation and understanding. This research was conducted at the School of Dentistry at the University of Jordan.

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