Scientific Research Report

Dental Fluorosis and Its Associated Factors Amongst Libyan Schoolchildren

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ABSTRACT

Background: Little is known about dental fluorosis (DF) in Benghazi, Libya, where the public water supply is naturally fluoridated.

Objective: The study aims to investigate the distribution of DF and its related risk factors and impact on oral health-related quality of life (OHRQoL) and the association between DF and caries amongst Libyan school children.

Methods: A cross-sectional survey was carried out amongst 12-year-old schoolchildren in the city of Benghazi. Dean’s and decayed, missing, and filled surfaces (DMF) indices were used to assess the severity of DF and dental caries. In addition, a self-administered questionnaire was used to collect sociodemographic and behavioural information and OHRQoL using the Child Oral Health Impact Profile—Short Version 19 (COHIP-SF19).

Results: Out of 1125 children who participated in the study, 15%, 7.8%, 2.2%, and 0.4% of participants were coded as having questionable, mild, moderate, and severe DF, respectively. Children enrolled in private schools were less likely to have DF (odds ratio, 0.55; 95% confidence interval, 0.35–0.83; P = .007). Moderate-severe DF was associated with more decayed surfaces and DMF scores and low scores for COHIP-SF19 and its socioemotional well-being subscale.

Conclusions: The data demonstrate that rates of DF are relatively low in naturally fluoridated areas in Libya. DF amongst Libyan schoolchildren was associated with social disparities, higher caries rates, and negative impacts on OHRQoL.

Introduction

The US Centers for Disease Control and Prevention named water fluoridation amongst the 10 most important public health measures of the 20th century. The fluoridation of drinking water has been considered one of the measures that resulted in declining dental caries levels in developed countries, but this comes at the cost of increased levels of dental fluorosis (DF), which is a developmental disturbance of enamel caused by excess intake of fluoride during tooth formation. Therefore, drinking fluoridated water and exposure to fluorides in supplements, toothpaste, and infant formulas amongst preschool children increase the risk of DF. Moderate and severe forms of DF are linked to increased caries risk and negative impacts on dental aesthetics and quality of life.

The prevalence of DF varies broadly across and within countries, which is ascribed to regional variations in fluoride exposure. The optimum daily consumption of fluoride from different sources, with minimum DF, has been empirically determined for children to be in the range of 0.5 to 0.7 mg/kg of body weight. However, fluoridated water continues to be the primary equitable and efficient vehicle to deliver fluoride to the population. Therefore, in order to prevent harmful effects of fluoride, the World Health Organisation (WHO) recommended that fluoride in drinking water should not exceed 1.5 mg/L.

Libya is a Mediterranean country located on Africa’s north coast with a naturally fluoridated water supply (0.66 mg/L).
mg/L) that reaches people living in the central coastal cities (Tripoli and Benghazi) through the tremendous artificial river. In recent years, several kinds of toothpaste have been increasingly promoted in school settings, which might increase the risk of DF due to inappropriate use by young children. So far, to the authors’ best knowledge, little is known about DF in the Libyan context. Therefore, it is timely to investigate the distribution of DF and its related risk factors and impacts on oral health—related quality of life (OHRQoL) and dental caries amongst Libyan schoolchildren.

Methods

Study design

A cross-sectional survey using self-administered questionnaires and clinical examination was used. Before commencing the study, ethical approval and permissions were obtained from the faculty of Dentistry, University of Benghazi (REF: LR/1/0016).

Setting and participants

The study was carried out in Benghazi, the second-largest city in Libya, which is located on the eastern Libyan coast and benefits from a naturally fluoridated water supply. Since 1996, the primary water resource has been groundwater pumped through pipelines from the desert in the south of Libya to the north where most Libyan citizens reside. The concentration of fluoride is 0.66 mg/L according to investigations carried out at the University of Newcastle. The study population comprised 12-year-old schoolchildren registered in the sixth grade in both private and state-run schools, distributed over the 8 districts of Benghazi. A multistage clustering random sampling technique was used to select study participants. The clustering unit was the schools. At the first stage, a proportional sample of schools was randomly selected from each district according to the numbers of state-run and private schools. At the second stage, children were randomly selected from each school. A computer system was applied for the random selection of schools and participants. A total of 1200 school children were invited to participate in the survey. The study packs, which included a questionnaire, informed consent forms, and information sheets, were handed to the children. Participation was voluntary, and no informed consent forms, and clinical examination was used. Before commencing the study, ethical approval and permissions were obtained from the faculty of Dentistry, University of Benghazi (REF: LR/1/0016).

Data collection

Three outcome variables were assessed in the present study. These were 2 clinical indicators (caries and DF) and OHRQoL as a sociodental indicator. The clinical indicators were assessed according to WHO diagnostic criteria described in “basic oral health survey” methods. Decayed, missing, and filled surfaces (DMF) index was used for assessing dental caries. Dean’s index was used to examine the presence and assessment of the severity of DF. The score of DF was based on the 2 most affected teeth as “0 = normal,” “1 = questionable,” “2 = very mild,” “3 = mild,” “4 = moderate,” or “5 = severe.” All examinations were conducted in natural daylight whilst children seated on an ordinary chair in their classroom. The permanent upper teeth were dried with gauze before being visually inspected, using a disposable mouth mirror and explorer. Three trained and calibrated dentists carried out all clinical examinations. The training sessions were provided at the University of Benghazi. They involved one session of discussing DMF and Dean’s indices and its categories using photographs, followed by 2 sessions of clinical examinations on a separate group of 20 children, performed at a 3-week interval. Kappa coefficients ranged from 0.90 and 0.96 were reached for inter-examiner and intra-examiner reliability.

OHRQoL was measured using a validated Arabic version of Child Oral Health Impact Profile - Short Version 19 (COHIP-SF19), which the children completed in their classrooms. It comprises 3 domains: oral health well-being, functional well-being, and socioemotional well-being. The overall score of COHIP-SF19 ranges between 0 and 76. A lower score means a negative impact on the quality of life. Explanatory variables including sociodemographic and oral health—related behaviours were collected using a self-administered questionnaire that was pretested for clarity and relevance. The questionnaire was designed to be completed by the children and their parents at home. It covered the following information: children’s date of birth, gender, nationality, level of parental educational attainment (university or higher and less than university level), and whether they study in private or public school. The children were also asked to report their oral behaviours as part of the oral health questionnaire. For example, the source of drinking water (tap vs bottled), how frequently they consume sugary drinks and snacks, how often they brush their teeth regularly using fluoridated toothpaste, and how often they use fluoridated mouthwash (irregularly vs regularly). Behaviours were deemed regular if the respondent replied by selecting once or twice per day and considered irregular if the respondent selected never/seldom or sometimes as an answer.

Data analysis

The Statistical Package for Social Sciences (SPSS), version 25, was used for data management and analysis. Descriptive statistics were used for sample characteristics and distribution of DF. Logistic regression models were constructed and adjusted for potential predictors (Drinking water: tap vs bottle, fluoride toothpaste: regular vs irregular, fluoridated mouthwash) and covariates (gender, parent education and
school type as a proxy for family income). Kruskal–Wallis test was used to compare the average scores for COHIP-SF19 and its subscales and average decayed surfaces and DMF score according to the severity of DF (no DF, mild DF, and moderate-severe DF). The statistical significance for all statistical procedures was set at ≤0.05.

Results

Out of 1200 participants invited to participate in the study, 1125 returned completed questionnaires suitable for data analysis, giving a total response rate of 95%. The study sample’s sociodemographic and behavioural characteristics are summarised in Table 1.

The study sample comprised a slightly higher proportion of girls (51.4%) than boys. The majority of children studied in public schools (74.5%), and regularly brushed their teeth (58.4%). Less than half of children reported drinking tap water (60%), and their fathers (44.5%) and mothers (42%) attained university education. The use of mouthwash was reported by less than a quarter of participants (20%). The proportion of participants who experienced dental caries (DMF score ≥1) was 42.8%, with an average DMF score of 1.55 (SD, 2.77) and an average number of decayed surfaces of 1.23 (SD, 2.22).

The Figure displays the summary statistics for the prevalence of fluorosis and its severity. Questionable DF was observed in 15% of children. The mild form was reported in 7.8% of participants. Moderate and severe forms were observed in 2.2% and 0.4% of the participants, respectively, giving a DF prevalence of 11.1%. Table 2 shows DF’s unadjusted and adjusted logistic regression analysis as an outcome variable. The unadjusted analysis demonstrated that children who enrolled in private schools (odds ratio [OR], 0.54; 95% CI, 0.35–0.81; P = 0.003) were less likely to have DF. This difference remained significant in the fully adjusted model (OR, 0.55; 95% CI, 0.35–0.83; P = 0.007). Children who regularly brush their teeth, use fluoridated mouthwash, and drink tap water appear to be more likely to have DF. However, these differences were not statistically significant.

Table 3 compares the average number of decayed surfaces, DMF score, and scores on COHIP-SF19 and its subscales.

| Variables                  | Gender Male | Gender Female | Gender total (%) | School type Public | School type Private | School type total (%) | Mother’s education Less than university | Mother’s education University or higher | Mother’s education total (%) | Father’s education Less than university | Father’s education University or higher | Father’s education total (%) | Tap water Yes | Tap water No | Tap water total (%) | Fluoride mouthwash Yes | Fluoride mouthwash No | Fluoride mouthwash total (%) | Frequency of toothbrushing Regular | Frequency of toothbrushing Not regular | Frequency of toothbrushing total (%) |
|----------------------------|-------------|---------------|------------------|-------------------|-------------------|----------------------|----------------------------------------|--------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|----------------------------|-------------|-------------|-------------------|-------------------|-----------------|---------------------|---------------------|----------------------|----------------------|
|                            | 547 (48.6)  | 578 (51.4)    | 1125 (100)       | 838 (74.5)        | 297 (25.5)        | 1125 (100)          | 653 (58)                              | 472 (42)                            | 1125 (100)                         | 624 (55.5)                         | 501 (44.5)                          | 1125 (100)            | 450 (40)    | 675 (60)     | 1125 (100)       | 900 (80)          | 225 (20)         | 1125 (100)         | 468 (41.6)          | 567 (58.4)          | 1125 (100)         |

Higher mean numbers of decayed surfaces (P = .002) and DMF score (P = .003) were observed amongst children who have moderate-severe DF. The overall score of COHIP-SF19 ranged between 4 and 76, with an average of 62.12 ± 12.47. Significantly lower scores for COHIP-SF19 (P = .028) and the socio-emotional well-being subscale (P = .03) were seen amongst children with moderate-severe DF. Lower oral health well-being subscale scores were observed amongst those with severe DF, but this difference was not statistically significant (0.230).

Discussion

The present study set out to assess the prevalence of DF amongst 12-year-old schoolchildren in Benghazi, Libya, where the public water supply is naturally fluoridated. The current study’s data show that 11.1% of the participants had some form of DF, ranging from very mild (7.8%) to severely affected teeth (0.4%). These rates of DF are comparable to those reported in areas with low natural fluoride levels, such as central Nigeria and Germany. The concentrations of fluoride in the city of Benghazi were estimated to be 0.66 mg/L in tap and 0.24 mg/L in bottled water, and daily intake of fluoride is estimated to be less than 0.4 mg/L. Previous systematic reviews and meta-analysis have demonstrated a 12% chance of having DF in optimally fluoridated areas and a dose-response relationship between the severity of DF and levels of fluoride in drinking water. Therefore, the prevalence and severity of DF observed in our study are not unexpected. A possible explanation of this is that fluoride is ingested from different sources in quantities sufficient to cause DF even when the concentration in the drinking water is within the optimum levels. In the present study, DMF scores were positively associated with the severity of DF. This finding corroborates the findings of previous studies conducted in areas with high levels of natural fluoride in drinking water. However, mixed findings have been reported in the dental literature, with many studies finding negative or no association. DF is associated with subsurface porosity that is easily demineralised. In addition, a severe form of DF is characterised by enamel pitting, which can create a suitable niche for bacterial accumulation. Therefore, it is likely for DF-affected teeth to become carious. However, DF and caries may have common risk factors.

Interestingly, children from public schools and less-educated families were more likely to have DF. Although this finding is inconsistent with previous studies reporting a higher risk of DF amongst children of higher-income families and more-educated parents, the association between caries and lower social class is well documented. It could be the case that less-educated parents are less likely to supervise their children during toothbrushing, and hence these children are more likely to ingest toothpaste which is a well-known risk factor for DF. Further research is required to understand the association between caries and DF fully.

The present study is believed to be one of a few studies that have reported children’s perception of DF’s impact on OHRQoL. A cross-culturally adapted and validated Arabic COHIP-SF19, suitable for children between 8 and 15 years of age.
The current study is the first of its kind amongst Libyan children, with a sizable sample which strengthens the study’s findings. However, some limitations should be addressed here. First, the study was conducted in an optimally fluorided area with low levels of natural fluoride. Therefore, its findings cannot be extrapolated to other areas in Libya with a different water supply and presumably different levels of fluoride, particularly in the southern and eastern parts of Libya. Second, the present study did not measure the daily exposure to fluoride amongst study participants. Although we recognise this as a limitation at the individual level, this is not the case at the population level. Therefore, epidemiologic studies have been endorsed as an appropriate method to study DF at the population level. Future research that investigates the prevalence of DF in areas with a different water supply and that

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**Table 2 – Binary logistic regression models for dental fluorosis and potential sociobehavioural risk factors (N = 1125).**

| Variables                  | Unadjusted model | Adjusted model |
|----------------------------|------------------|----------------|
| Gender                     |                  |                |
| Male                       | Reference        |                |
| Female                     | 0.92 (0.72–1.19) | 0.83 (0.64–1.09) |
| School type                |                  |                |
| Public                     | Reference        |                |
| Private                    | 0.54 (0.35–0.81) | 0.55 (0.35–0.83) |
| Mother’s education         |                  |                |
| Less than university       | Reference        |                |
| University or higher       | 0.79 (0.55–1.05) | 0.85 (0.58–1.21) |
| Father’s education         |                  |                |
| Less than university       | Reference        |                |
| University or higher       | 0.78 (0.60–1.01) | 0.92 (0.60–1.21) |
| Tap water                  |                  |                |
| No                         | Reference        |                |
| Yes                        | 0.82 (0.64–1.07) | 0.84 (0.64–1.09) |
| Fluoride mouthwash         |                  |                |
| No                         | Reference        |                |
| Yes                        | 1.14 (0.83–1.16) | 1.23 (0.89–1.70) |
| Frequency of toothbrushing |                  |                |
| Not regular                | Reference        |                |
| Regular                    | 1.12 (0.87–1.45) | 1.15 (0.88–1.49) |

Binary logistic regression models were applied.  
*P ≤ .05.  
**P ≤ .01.  
***P ≤ .001.
measures the daily exposure of fluoride from different sources is required to fully understand DF's occurrence and risk factors in Libyan schoolchildren.

In conclusion, our study has important implications for oral health services, planning, and education in Libya. The results indicated a relatively low level of DF associated with social inequalities and higher caries rates, and negative impacts on the socioemotional wellbeing of the affected children. However, further research that considers the actual exposure to fluoride and the time lag between exposure and effect and different fluoride levels in drinking water is needed to fully understand the distribution of DF and its associated factors in Libya.

Funding

The authors did not receive any material or financial support.

Conflict of interest

None disclosed.

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Table 3 – Comparison of DMF and COHIP-SF19 scores and its subscales by the presence of fluorosis (N = 1125).

|                     | Mean | SD  | P value |
|---------------------|------|-----|---------|
| **DMF score**       |      |     |         |
| No DF               | 1.48 | 2.66| .003**  |
| Mild DF             | 1.67 | 2.93|         |
| Moderate-severe DF  | 3.37 | 4.80|         |
| **DS**              |      |     |         |
| No DF               | 1.19 | 2.16| .002**  |
| Mild DF             | 1.29 | 2.32|         |
| Moderate-severe DF  | 2.50 | 3.29|         |
| **Oral health well-being subscale** | | | |
| No DF               | 15.03| 4.56| .230    |
| Mild DF             | 14.77| 4.33|         |
| Moderate-severe DF  | 13.90| 4.60|         |
| **Functional well-being subscale** | | | |
| No DF               | 14.42| 2.88| .786    |
| Mild DF             | 14.27| 2.96|         |
| Moderate-severe DF  | 14.57| 2.75|         |
| **Socioemotional well-being subscale** | | | |
| No DF               | 32.76| 8.29| .030*   |
| Mild DF             | 31.70| 7.64|         |
| Moderate-severe DF  | 31.04| 8.33|         |
| **COHIP-SF19**      |      |     |         |
| No DF               | 62.46| 12.50| .028*  |
| Mild DF             | 60.67| 12.46|         |
| Moderate-severe DF  | 58.38| 12.44|         |

Kruskal–Wallis U test was conducted to compare subgroups.

* P ≤ 0.05.
** P ≤ 0.01. ***P ≤ 0.001.

CODS, number of decayed surfaces; COHIP-SF19, Child Oral Health Impact Profile–Short Version 19; DF, dental fluorosis; DMF, decayed, missing, and filled surfaces; DS, decayed surfaces.
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