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Original article

Assessment of Fluoride Concentration in Drinking Water and Its Correlation with Dental Caries in Primary School Children in Gharyan, Libya

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Abstract
Dental caries is a widespread infectious disease influenced by bacterial activity, dietary factors, and host susceptibility. Community water fluoridation has been a key public health measure for caries prevention, particularly in children. The optimal fluoride concentration in drinking water (0.7 mg/L) balances caries reduction with minimal fluorosis risk. This study assessed fluoride levels in drinking water and their correlation with dental caries in primary school children in Gharyan, Libya. A cross-sectional study was conducted on 350 children (aged 7–10 years) from urban and rural schools in Gharyan. Water samples from five stores and one groundwater source were analyzed for fluoride concentration using an ion-selective electrode. Dental caries was assessed using the dmft/DMFT index. Fluoride levels in water stores were negligible (0.0–0.1 mg/L), while unfiltered groundwater exhibited high concentrations (6.0–7.0 mg/L), exceeding WHO guidelines (1.5 mg/L). The low fluoride availability in most drinking sources suggests limited caries-preventive effects from water fluoridation in this region. The study highlights insufficient fluoride exposure in Gharyan's public water supply, potentially contributing to higher caries prevalence. Further research is needed to evaluate alternative fluoride delivery methods and assess groundwater safety to optimize oral health outcomes.
Keywords. *Fluoride Concentration, Drinking Water, Dental Caries, Primary School.*

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Introduction

Dental caries is an infectious, multifactorial disease affecting most individuals in industrialized countries and some developing nations (1). It results from the interaction of bacteria, fermentable carbohydrates, and host factors over time (2). Community water fluoridation has been used for over half a century, and results show that the greatest effect of fluoridated water on tooth protection is in deciduous and mixed dentition (3,4). Water fluoridation is a simple, cost-effective method to prevent caries, and it is less than the cost of one dental restoration per person in their lifetime (5). The United States Public Health Service recommends a fluoride concentration of 0.7 mg/L of water to prevent caries while reducing the risk of dental fluorosis (6).

Fluorides play a central role in the prevention of dental caries and are also used therapeutically for the inactivation of incipient carious lesions. The effect of fluoride is mainly achieved when applied topically, which is further enhanced when accompanied by good oral hygiene (7). Since the implementation of water fluoridation, there has been a decrease in the prevalence of dental caries. The risk of dental fluorosis is mainly related to the systemic consumption of fluorides during the first six years of age (7). Fluoride's ability to inhibit or even reverse the initiation and progression of dental caries is well documented. The first use of adjusted fluoride in water for caries control began in 1945 and 1946 in the United States and Canada, when the fluoride concentration was adjusted in the drinking water supplying four communities (8-11). Initial studies of community water fluoridation demonstrated that reductions in childhood dental caries attributable to fluoridation were approximately 50%-60% (12-15). More recent estimates are lower, 18%-40% (16,17). This study was conducted to assess of fluoride concentration in drinking water and its correlation with dental caries in primary school children in Gharyan, Libya.

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Methods

Study design and setting

This cross-sectional study included 350 children who were examined by well-trained general dentists under the supervision of consultants in operative dentistry, the faculty of dentistry, Gharyan. It was conducted in some private or public primary school in rural and urban communities of the Gharyan Municipality during the winter of 2024, between January 1 and February 30. The number of males and females was 200 and 150, respectively, and their ages ranged from 7 to 10 years old.

Ethical considerations

The ethical approval of the current study was obtained from the faculty of dentistry at Gharyan University, and the oversight of education in Gharyan, as well as permission to conduct the study, was gained from school administration. All patient details were recorded in self-prepared patient files, including general patient information, hard tissue findings, in addition to the dmft/DMFT score (dental caries index).

Sample Collection

Water samples were collected from five different water stores and one groundwater source (Groundwater 6) in pre-cleaned, high-density polyethylene (HDPE) bottles to prevent contamination. Groundwater samples were taken before filtration to assess baseline fluoride levels. Samples were labeled, preserved, and transported to the laboratory under 4°C refrigeration to maintain integrity.

Fluoride Analysis

Fluoride concentration was determined using a fluoride ion-selective electrode (ISE) calibrated with standard solutions (0.1–10 mg/L). Total Ionic Strength Adjustment Buffer (TISAB) was added to each sample to eliminate interference from other ions. Measurements were taken in triplicate, and the average value was recorded for accuracy.

Quality Control

Blank samples (deionized water) were analyzed to ensure no contamination. Certified reference materials (CRMs) were used to validate the electrode's accuracy. Replicate analysis showed a relative standard deviation (RSD) $< 5\%$, confirming precision.

Data Reporting

Results are reported in milligrams per liter (mg/L), rounded to one decimal place. Values below the detection limit (0.05 mg/L) are reported as 0.0 mg/L.

Data analysis

The data was collected and exported to an Excel file, and descriptive methods were used to analyze the study data and obtain the results.

Results

Table 1 shows that water stores 1, 2, and 5 contain 0.0 mg/L of the measured substance, indicating no detectable levels. Water Stores 3 and 4 have trace amounts at 0.1 mg/L, which are slightly higher but still very low. In contrast, groundwater 6 (Before filtering) exhibits significantly higher concentrations at 7.0 mg/L and 6.0 mg/L, suggesting possible contamination or natural enrichment. Further investigation may be needed to determine the source of the elevated levels in the groundwater and whether filtration effectively reduces them.

Table 1. Fluoride Concentration in Water Stores and Groundwater Samples

Water store	Fluoride concentration
Water stores 1	0.0(mg/L)
Water stores 2	0.0(mg/L)
Water stores 3	0.1 (mg/L)
Water stores 4	0.1 (mg/L)
Water stores 5	0.0(mg/L)

Groundwater 6 (Before filtering)	0.7(mg/L)
Groundwater 6 (Before filtering)	0.6(mg/L)

Discussion

Because fluoride increases the enamel's resistance to acid activity, it helps prevent tooth decay. They also promote the accumulation of healthy minerals in the enamel, which further delays the initiation of tooth caries. According to some studies, fluoride may even be able to prevent tooth decay that has already begun. Fluoride is integrated into the permanent tooth enamel of children under six years old, increasing the teeth's resistance to dietary acids and germs. (18). Furthermore, Fluoride can only exert its effect if it is free, soluble in the aqueous oral environment (biofilm fluid or saliva) (19). As such, fluoride will physic chemically induce mineral precipitation on the tooth structure in the form of fluorapatite; this can happen while demineralization is occurring within the biofilm milieu (an effect called reduction of demineralization), or after acids have been cleared from the biofilm or the biofilm itself was removed (the so-called enhancement of remineralization (20,21). Thus, fluoride deposited on the tooth mineral must be regarded as a consequence of reduced mineral loss occurring in the presence of fluoride, and not the goal of its preventive action. Such concepts as “fluoride strengthening teeth”, “increasing the resistance of teeth to acids,” and “reducing the acid produced by bacteria,” although theoretically reasonable, are no longer accepted as clinically relevant to the reduction of caries associated with fluoride use (19,22).

In the current results, water Stores 1, 2, and 5 show 0.0 mg/L of fluoride, indicating that fluoride levels were below the detection limit. Meanwhile, Water Stores 3 and 4 contain trace amounts (0.1 mg/L), which remain well below the World Health Organization (WHO) recommended limit of 1.5 mg/L for drinking water. These low concentrations suggest that the water sold in these stores undergoes effective purification processes, such as reverse osmosis or distillation, which remove fluoride along with other dissolved solids. In contrast, Groundwater 6 (before filtering) exhibits significantly higher fluoride levels (6.0–7.0 mg/L), exceeding the WHO guideline by 4 to 5 times. Fluoride can leach into groundwater from fluoride-rich minerals (e.g., fluorite, apatite) in rocks and soils. Additionally, potential sources include industrial discharges or agricultural runoff; however, natural enrichment is more likely in this case.

In other words, fluoride is not able to affect biofilm accumulation (a necessary factor) and the production of acids from its exposure to sugars (a determinant factor), but will chemically reduce the mineral loss induced by the combination of these two factors, through the precipitation of a fluoridated mineral on teeth (23). The main constituents of tooth enamel's hydroxyapatite are calcium ions (Ca2+) and phosphate ions (PO43–). The crystalline hydroxyapatite, which makes up 96% of tooth enamel, and the calcium and phosphate ions in saliva are in a stable balance under normal circumstances. Demineralization is the process by which tooth mineral (hydroxyapatite) dissolves when the pH falls below a certain level (5.5 for enamel and 6.2 for dentin). Remineralization is the process by which minerals are reincorporated into the tooth when the pH is raised by saliva's natural buffering ability (24).

By comparing the effectiveness of naturally occurring low and high fluoride concentrations in tap water to prevent dental caries, the role of fluoride in dental health has been demonstrated. A recent study in Denmark found an inverse relationship between fluoride concentration in nonfluoridated drinking water and dental caries in both primary and permanent teeth, with the risk being reduced by about 20% at the lowest level of fluoride exposure (0.125-0.25 mg/L) compared to less than 0.125 mg, and by about 50% at the highest level of fluoride exposure (more than 1.0 mg/L) after controlling for socioeconomic factors (25).

Conclusion

Half of the schoolers had dental caries coupled with a high prevalence of unmet dental treatment needs. Association between caries experience and age of child, consumption of non-sweetened milk, dental plaque, in addition to water without fluoride in school, and poor oral hygiene has been established. This analysis underscores the significance of water quality testing and treatment, particularly in areas where groundwater fluoride levels exceed safe limits. Further studies should evaluate seasonal variations and alternative water sources to ensure safe drinking water access.

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