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EFFECT OF FLUORIDE IN DRINKING WATER ON DENTAL CARIES AND IQ IN CHILDREN

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ABSTRACT: The aim of this work was to evaluate the impact of fluoride exposure on the prevalence of dental caries and the intellectual ability of children. Method: In this cross-sectional study, 161 children from 9 to 10 years of age were evaluated. The concentration of fluoride in drinking water and urine was analyzed individually. Oral health status regarding dental caries and dental fluorosis was assessed. The intellectual ability of children was evaluated through the Raven's Colored Progressive Matrices. In addition, variables such as diet, oral hygiene, body mass index, and socioeconomic status were included. Results: There was a negative relationship between the DMFT index and the level of dental fluorosis. In the logistic regression analysis, a water fluoride exposure above 1.0 mg/L showed less risk of dental caries (OR = 0.41; p=0.025). Parental education level lower than high school raised significantly the risk of dental caries (OR = 2.81; p=0.036). No relationship was found between intellectual ability and fluoride exposure variables such as, dental fluorosis, levels of fluoride in drinking water and urine, and exposure dose. Conclusion: The results suggest that exposure to fluoride reduces the prevalence of dental caries, but no association was found to the intelligence of children.

Keywords: Dental caries; Dental fluorosis; Fluoride; IQ; Intelligence tests;

INTRODUCTION

Dental caries remains one of the most prevalent chronic diseases and represents a major public health concern across the globe.[1] Three main inter-related factors have been involved in the etiology of caries: carbohydrates, microorganisms (dental plaque), and the host.[2] Since the late 1960s, the World Health Organization (WHO) has supported the use of fluoride for the population-based prevention of dental caries.[3] The opportune use of fluoride, including fluoride delivered in drinking water, milk or salt, intra-oral topical fluoride application, and fluoridated toothpaste, has been widely recommended as a safe, simple and cost effective public health strategy to reduce the incidence of dental caries.[4] However, some considerable health disadvantages have been associated with chronic fluoride exposure, including skeletal fluorosis, dental fluorosis, teratogenicity, genotoxicity, immunotoxicity, carcinogenicity, renal toxicity, and gastrointestinal tract toxicity.[5,6]

Several studies have found a significant relationship between high levels of fluoride exposure and low intelligence in children.[7-9] Furthermore, a recent meta-analysis of 26 observational studies confirmed that exposure to high levels of fluoride in drinking water was associated with lower intelligence levels.[10] Nevertheless, the information on these outcomes is limited and inconclusive. Since the effects of long-term exposure to fluoride from drinking water are of great concern to human health,

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the aim of this study was to evaluate the effect of fluoride exposure on the intellectual ability of children and the relationship between fluoride exposure and dental caries prevalence, while considering potential confounding variables in the design of the study.

MATERIAL AND METHODS

Study population: In this cross-sectional study, a total of 245 children were examined between May and December 2017 in Chihuahua, Mexico. Subjects were enrolled by multistage cluster sampling. In the first stage, 13 public elementary schools of the city were randomly included from an initial pool of 73 schools, according to a cluster sample design. Secondly, fourth grade students, 9 to 10 years of age, were selected in order to keep the same grade level and to perform a more equal intellectual evaluation. Moreover, only children whose parents or guardians attended and responded directly to the survey were included in the study. The clinical and ethics research committee of the Faculty of Dentistry at the Autonomous University of Chihuahua approved the study (reference number: FOIP-004-17). Informed and voluntary written consent from the parents or guardians and children's assent were obtained from each eligible participant. According to the statement of ethical principles of Helsinki 2008, the risks and benefits were explained before the clinical examination. Individuals receiving a topical fluoride application in the last six months, having a different residence since the time of pregnancy, or having any diagnosis of mental illness or systemic disorder were excluded from the study. Thus, the final sample comprised 161 children who fulfilled the selection criteria.

General and medical information: The parents or guardians of the children completed a multiple-choice question type survey administered by an examiner (KY E-V). Detailed data were obtained regarding children's medical history, nutritional status, source of drinking water, oral hygiene, and sociodemographic characteristics. Socioeconomic status was determined accordingly to a survey of region-specific and household based variables developed by the Mexican Association of Marketing Research and Public Opinion Agencies.[11] Weight and height were measured using a calibrated standard balance scale and a stadiometer, respectively. The corresponding body mass index (BMI) was calculated based on the Centers for Disease Control growth charts, and children were grouped according to age and gender specific criteria as: underweight—less than the 5th percentile, normal—between the 5th and 85th percentiles, overweight—between the 85th and 95th percentiles, and obese—at levels greater than the 95th percentile.

Clinical oral examination: A single calibrated examiner (B H-L) carried out the dental examinations in all the individuals assisted by a collaborator as a recorder. The examinations were held in their classrooms, using a portable dental unit and an artificial light under standardized conditions. The caries experience was estimated as the number of decayed, missing due to caries, and filled teeth in the primary dentition (dmft) and in the permanent dentition (DMFT) in accordance with the WHO guidelines.[12] Dental fluorosis was assessed on the vestibular, occlusal, and lingual surfaces in accordance with the Thylstrup-Fejerskov (TF) Index. Tooth surfaces were dried by using sterile gauze and cotton wool. The examination was accomplished employing sterile dental mirrors and a sterile explorer to confirm the dental caries findings. The inter-examiner and intra-examiner reliability with regard to the diagnosis of dental caries and dental fluorosis was analyzed by intraclass correlation coefficient, obtaining scores above 0.85.

Intellectual ability assessment: The intellectual ability was evaluated through the Raven's Colored Progressive Matrices (RCPM) by an independent examiner. The RCPM test was administered in accordance with the instructions for group administration in the classroom by a researcher and the regular school teacher of the children was present during testing. Standard instructions corresponding to the official established guidelines were given.[13] The test consisted of 36 items in three sets of 12: A, AB, and B. The RCPM test is indicated for five to 11 year-old-children with minimal cultural bias, and it has been useful to determine the interrelation between environment, nutrition, and mental development in a school population.[14] There was no time limit imposed and completion of the test took approximately 30 min. The results obtained were converted into a percentile according to the age, and then the overall score in the individual assessment was graded as described in Table 1.

Table 1. Grades of intellectual ability in agreement with the RCPM[13]

Grade	Description
I	"Intellectually superior" (score ≥ 95th percentile)
II	"Definitely above the average in intellectual capacity" (score ≥ 75th and < 95th percentile)
III	"Intellectually average" (score > 25th percentile and < 75th percentile)
IV	"Definitely below average in intellectual capacity" (score > 5th and ≤ 25th percentile)
V	"Intellectually impaired" (score ≤ 5th percentile)

Sample collection, analysis, and fluoride exposure dose: A blind analysis of the fluoride concentration in the drinking water and in the urine of the children was performed. First morning void urine samples were collected in acid-washed 50 mL ultra-cleaned polyethylene bottles containing 0.2 g EDTA and kept at –20ºC until used for analysis, based on the NIOSH standard method.[15] Also, water samples were collected from each participant by asking them to deliver the drinking water they consumed most. The water samples were kept at 4ºC until used for analysis. Five working standards in the range 0.01 to 100 µg F^-/mL were prepared by appropriate dilutions of the calibration stock solution with distilled water. In the analysis procedure, 10 mL of the samples were mixed on a magnetic stirrer at room temperature with 10 mL total ionic strength adjustment buffer (TISAB). The fluoride ion selective electrode (Orion 9609BNWP, Ionplus Sure-Flow Fluoride Electrode, Thermo Scientific, USA) was employed to measure the fluoride concentration of samples. Standardization was maintained by running the standard solutions with every 10 specimens. All the samples were analyzed by triplicate and the working standards, the samples, and the blanks were analyzed under the same conditions. The assessment of the daily exposure dose to fluoride (mg/kg bw.day) was based on the water fluoride concentration, the amount of the drinking water consumption, and the body weight. The water intake was calculated by asking the children and the parents the following question; "How many glasses of water do you consume per day?" and then a generic glass of 8-ounce size was shown for the estimation.

Statistical analysis: Descriptive statistics were used to consider the frequency and proportion for the categorical variables and the mean and standard deviation for the quantitative variables. The Kolmogorov-Smirnov test was used to determine the variable distribution. The Kruskal Wallis test was used for the comparison among groups and the Dunn's test was applied for the post-hoc analysis of the quantitative variables. The Chi-square test was used for the comparison between the qualitative variables. A binary logistic regression model was used to analyze the effects of each independent variable. The dependent variable was the presence of dental caries. The potential risk factors included sex, parental education level, consumption of sweet snacks, tooth brushing frequency, dental fluorosis, and fluoride concentration in drinking water and urine. Statistical significance was set as $p<0.05$. All analyses performed by using the SPSS for Windows software package (version 23.0; SPSS Inc, Chicago, IL, USA).

RESULTS

A total of 161 eligible children, aged 9 to 10 years, were evaluated in this study. The sample was contained a marginally higher proportion of male children. About 34% of children were at the 85th percentile or above (overweight or obese)—according to sex and age. Most of children (79.5%) had parents whose highest level of education was high school or lower, and 73.5% of the sample was composed of individuals from middle socioeconomic status. Moreover, 47.2% of children reported drinking public tap water and 44.1% had a fluoride concentration in their drinking water greater than 1.0 (mg/L).

The levels of fluoride exposure and dental caries were compared according to the level of dental fluorosis (Table 2).

Table 2. Fluoride exposure and dental caries according to dental fluorosis

Variable	TF 0 n=32	TF 1–2 n=45	TF 3–4 n=60	TF > 5 n=24	p*
Water fluoride (mg/L)	$0.75±0.95^{A}$	$0.67±0.15^{A}$	$1.22±1.09^{AB}$	$1.66±0.93^{B}$	0.008
Urinary fluoride (mg/L)	0.48±0.23	0.51±0.38	0.62±0.32	0.67±0.41	0.088
EDI (mg/kg bw/day)	$0.016±0.02^{AB}$	$0.017±0.02^{A}$	$0.035±0.03^{BC}$	$0.047±0.03^{C}$	0.001
DMFT	$2.46±1.68^{A}$	$1.39±1.67^{B}$	$1.29±1.48^{B}$	$0.77±1.19^{B}$	0.002
dmft	2.29±2.62	1.65±2.02	1.76±1.78	1.72±2.09	0.696

Abbreviations: EDI= exposure dose to fluoride; DMFT= decayed, missing and filled teeth in the permanent dentition; dmft= decayed, missing and filled teeth in the primary dentition; TF= Thylstrup-Fejerskov. Data are expressed as mean±standard deviation. *Different letters indicate significant differences between groups ($p<0.05$).

The fluoride content in the drinking water and the exposure dose were significantly higher in the moderate-to-severe fluorosis cases. The urinary fluoride level increased as the level of the severity of the dental fluorosis increased but no statistically significant difference was present. Also, a significant decrease in the DMFT score was found in children with dental fluorosis (p=0.002) compared to children without dental fluorosis. Table 3 shows a binary logistic regression analysis of the potential explanatory variables associated with dental caries in both the temporary and the permanent teeth of children.

Table 3. Logistic regression analysis of the children's caries experience (n = 161) and the individual risk indicators

Covariate	Coefficient	SE	OR	95% CI	p
Constant	2.08	1.29			
Sex					
Female	Reference				
Male	0.24	0.39	1.27	0.59 – 2.75	0.545
Parental education level					
College graduate or higher	Reference				
< High school	0.99	0.51	2.69	0.99 – 7.27	0.050
High school graduate	1.03	0.49	2.81	1.07 – 7.37	0.036
Sweets consumption					
Rarely or never	Reference				
Sometimes	–0.17	1.23	0.84	0.08 – 9.40	0.890
Frequently	0.109	1.25	1.11	0.09 – 13.0	0.931
Tooth brushing					
Twice or more per day	Reference				
Once a day or less	–0.15	0.41	0.86	0.39 - 1.89	0.704
Dental fluorosis					
TF score = 0	Reference				
TF score = ≥ 1	–0.80	0.56	0.45	0.15 – 1.34	0.152
Water fluoride					
≤ 1.0 (mg/L)	Reference				
> 1.0 (mg/L)	–0.90	0.40	0.41	0.19 – 0.89	0.025
Urinary fluoride	0.57	0.61	1.77	0.54 – 5.83	0.545

Abbreviations: SE= standard error; OR= odds ratio; CI= confidence interval; TF= Thylstrup-Fejerskov.

The exposure to levels of drinking water greater than 1 mg/L was inversely related to dental caries (OR = 0.41, 95% CI = 0.19–0.89, p = 0.025). With respect to the level of parental education attained, the children with parents with an educational level of no higher than high school had a higher risk of dental caries (OR = 2.81, 95% CI = 1.07–7.37; p = 0.036) when compared to the children whose parents had attained college or higher education. No significant associations were found between the variables: sex, consumption of sweet snacks, tooth brushing frequency, dental fluorosis, and urinary fluoride.

For the total sample, 49% obtained intellectual grade III, followed by 27.3% in grade II, and 17.4% in grade IV. Only 3.7% and 2.5% were at intellectually superior and intellectually defective levels, respectively (Table 4).

Table 4. Comparison of the fluoride exposure and the general characteristics with the intellectual grades of the children

Variable	Intellectual grade					p
	Grade I n=6	Grade II n=44	Grade III n=79	Grade IV n=28	Grade V n=4	
Age (years)	9.16±0.41	9.04±0.26	9.27±0.44	9.29±0.66	9.5±0.57	0.060
Child's sex n (%)						
Male	4 (4.5)	25 (28.4)	43 (48.9)	14 (15.9)	2 (2.3)	0.950
Female	2 (2.7)	19 (26.0)	36 (49.3)	14 (19.2)	2 (2.7)	
Water fluoride (mg/L)	1.48±1.13	1.05±1.06	1.04±1.06	0.97±1.10	0.79±1.17	0.645
Urinary fluoride (mg/L)	0.45±0.34	0.54±0.29	0.61±0.38	0.56±0.33	0.35±0.19	0.559
Exposure dose	0.03±0.03	0.026±0.03	0.027±0.03	0.029±0.03	0.016±0.02	0.389
Fluorosis index (TF score)	2.67±1.51	2.57±1.87	2.56±1.81	2.68±1.83	3.0±1.83	0.851
Dental fluorosis n (%)						
Fluorosis	1 (3.1)	10 (31.3)	16 (50.0)	5 (15.6)	0 (0)	0.856
No fluorosis	5 (3.9)	34 (26.4)	63 (48.8)	23 (17.8)	4 (3.1)	
Parental education level n (%)						
< High school	2 (3.3)	18 (30.0)	23 (38.3)	14 (23.3)	3 (5.0)	
High school graduate	2 (2.9)	15 (22.1)	39 (57.4)	11 (16.2)	1 (1.5)	0.301
College graduate or higher	2 (6.1)	11 (33.3)	17 (51.5)	3 (9.1)	0 (0)	
Socioeconomic status n (%)						
High	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Medium	5 (6.1)	26 (31.7)	38 (46.3)	12 (14.6)	1 (1.2)	0.218
Low	1 (1.3)	18 (22.8)	41 (51.9)	16 (20.3)	3 (3.8)	

Grade I= intellectually superior; Grade II= above average; Grade III= average; Grade IV= below average; Grade V= intellectually defective. Observed frequency (n) and proportion (%) were used for categorical variables; mean and standard deviation for quantitative variables.

There were no statistically significant differences between the fluoride exposure variables and the intellectual ability of the children. In addition, no significant differences were found between the general characteristics, such as the child's sex, the parental education level, the socioeconomic status, and the BMI classification, and the level of intelligence evaluated in the children.

DISCUSSION

It is critical to know the relative cost effectiveness of fluoride exposure according to the prevention of dental caries and the reduction of the intellectual ability of children. The present study evaluates some effects of fluoride exposure in schoolchildren of Chihuahua, northern Mexico. A previous study reported chronic exposure to high levels fluoride in drinking water in the city of Chihuahua, and the surrounding small towns,[16] with 37.2% of the water samples having fluoride concentrations higher that the WHO maximum contaminant level of 1.5 mg/L. In this study, similar water fluoride level results were obtained, with 39% of the drinking water samples being above 1.5 mg/L. In addition, almost 50% of the study population referred to tap water as being their main source of consumption. The geological faults present in Chihuahua are believed to be the primary reason for the elevated fluoride level in the local groundwater supplies.[17]

The use of fluoridated water as a means of dental caries prevention has been subject of controversy worldwide. Some studies claim that dental fluorosis makes the tooth more susceptible to dental caries.[18-19] On the contrary, several studies have reported a lower risk of tooth decay at higher levels of dental fluorosis.[20,21] In the present study, we found a significantly higher DMFT index in teeth without dental fluorosis. The presence of fluorosis in the enamel is a marker of significant exposure to fluoride during tooth development and it is likely that a higher concentration of fluoride will provide resistance to acid attack and promote remineralization. However, the presence of enamel fluorosis in a child does not automatically mean that the exposure was continuous over all of the child's life. In this study, the logistic regression analysis showed a protective effect of fluoride against dental caries with the odds ratio for developing dental caries decreasing significantly in children exposed to water levels of fluoride higher than 1 mg/L. Evidence from a robust meta-analysis found an effectiveness for water fluoridation in reducing the levels of tooth decay in children.[22] Notwithstanding this however, these results were predominantly based on studies in which there were concerns about the methods used or about method of reporting the results. Therefore, the potential benefits and harms of adding fluoride to water are still questionable and are considered to be relatively unclear.

There has been growing interest in the effect of fluoride exposure on the intelligence of children but most of these reports are concentrated in Asian countries such as China, India, and Iran.[10,23,24] Despite the fluoride levels in the drinking water and urine having ranges of 0.05–2.93 mg/L and 0.11–2.10 mg/L, respectively, we did not find a relationship between any kind of fluoride exposure (fluoride concentration in drinking water, urinary fluoride, dental fluorosis, and exposure dose) and the intellectual capacity of the children we evaluated. Most of the studies have suggested a significant negative association of high fluoride exposure and the intelligence level of children.[10,24] However, different risks of bias have been identified and certain factors have to be considered. For instance, numerous studies have compared children by geographical region based on fluoride concentrations from wells in the study areas,[8,25-28] or based on previous reports at a community level.[29] Nevertheless, differences in the results of the intelligence evaluation between regions may not be limited to the fluoride concentrations of the well samples since other environmental or social characteristics could be involved. The present research was carried out in a single city, and variables, such as age, scholastic grade level, educational system, and settlement area, were controlled for by selection. In addition, the fluoride exposure was estimated at an individual level. However, due to the cross-sectional design of the study, it was not possible to evaluate fluoride exposure over time. Besides, by including only children whose parents responded to the survey, it could lead to selecting people more concerned about their health.

The lack of an association between fluoride and intelligence that was found in the present study may be partially explained by differences in the fluoride levels, population characteristics, or unidentified covariates. However, our results are consistent with the findings of a previous prospective study with a follow-up period for the cohort of more than 30 years, which did not find a relationship of fluoride exposure and IQ level.[30]

CONCLUSIONS

In conclusion, our results suggest that fluoride exposure above 1.0 mg/L in drinking water acts as a protective factor against dental caries. No evidence was found for fluoride-associated cognitive deficits. As the level of fluoride consumption remains a public health concern and its implications for health are still uncertain, further research is needed to clarify whether or not fluoride may possibly have adverse effects on brain development.

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CONFLICT OF INTEREST

Authors declare no conflict of interests from any relationships or the financial support received.

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