ABSTRACT: Monitoring urinary fluoride ion (F) excretion, which directly reflects the intake of F, during tooth development has been used in different countries in systemic fluoridation programs. The objective of the present study was to analyze the effect of malnutrition on urinary fluoride excretion in 3–5-year-old children. Twenty-four hour urine samples were analyzed in 56, 3–5-year-old, children recruited in a rural community, with and without malnourishment, as assessed by their age-related weight. No significant difference (p>0.05) was found in the daily total F urinary excretion between those with a normal weight (323±156 µg F/24 hr) and those with either mild (290±117 µg F/24 hr) or moderate (303±126 µg F/24 hr) malnutrition. We concluded that malnutrition did not affect the urinary F fluoride excretion.

Key words: Children; Malnutrition; Mexico; Urinary fluoride excretion.

INTRODUCTION

The urinary excretion of the fluoride ion (F) is one of the F exposure biomarkers and it has been used during odontogenesis in community fluoridation programs, which use the paradigm that the systemic ingestion of F is beneficial for reducing dental caries, to assess the total F intake and the associated benefits and risks. In children, “safe and adequate daily dietary intakes of F” were estimated in 2006, by a Committee on Fluoride in Drinking Water of the National Research Council (NRC)\(^1\) based on the recommended dietary allowances of the NRC,\(^2\) ranging from 0.017–0.083 mg F/kg body weight/day at ages 0–0.5 yr to 0.054–0.089 mg F/kg body weight/day at ages 7–10 yr. The NRC Committee noted that the use of the term “safe and adequate daily dietary intake” should not be taken to imply that the present committee considered these intakes to be safe or adequate.\(^1\) The Subcommittee on the Tenth Edition of the Recommended Dietary Allowances of the NRC noted that the status of fluorine as an essential nutrient had been debated and the contradictory results did not justify a classification of fluorine as an essential element.\(^2\)

Two paradigms have been proposed for the mode of action of fluoride on teeth. Aoba and Ferjerskov commented, in 2009, that in the middle of the previous century, the paradigm was that, to exert its maximum cariostatic effect, F had to become incorporated into dental enamel during development, and hence it was inevitable to have a certain prevalence and severity of fluorosis in a population to minimize the prevalence and severity of caries among children.\(^3\) They noted that by 1981, it was possible to propose a paradigm shift concerning the cariostatic mechanisms of fluorides in which it was argued that the predominant, if not the entire, explanation for how fluoride controls caries lesion development lay in its
topical effect on demand remineralization processes taking place at the interface between the tooth surface and the oral fluids. They observed that this concept had gained wide acceptance. In 1999, the Centers for Disease Control and Prevention considered that any action that F has in preventing dental caries occurs predominately after the eruption of the teeth into the mouth and that it is primarily topical, for both adults and children, via inhibiting demineralization, enhancing remineralization, and inhibiting bacterial action in dental plaque. Similarly in 2011, the Scientific Committee on Health and Environmental Risks (SCHER) of the European Commission found that while the evidence that topical fluoride has a protective effect against dental caries is considered to be strong, the scientific evidence that the systemic application of fluoride via drinking water is beneficial is less convincing.

In a 2009 review, Ozsvath commented that while most scientists believed that small amounts of F in the diet could help prevent dental caries and strengthen bones, there were a number of adverse effects that chronic ingestion of F at high doses could have on human health, including dental fluorosis, skeletal fluorosis, increased rates of bone fractures, decreased birth rates, increased rates of urolithiasis (kidney stones), impaired thyroid function, and lower intelligence in children. F uptake, and hence its excretion, have been shown to be affected by factors such as gastrointestinal, respiratory, and nutritional disease. In the setting of calcium deficiency, F uptake and the risk of fluorosis increase.

Daily urinary F excretion (DUFE) allows the inference of the total daily F intake (TDFI). Analytical studies in children, aged 1.8–6 yr, reported that 30 to 51% of ingested F was excreted in the urine. In Mexico, there are few reports on urinary excretion of F. The present study took place in a rural community in which childhood malnutrition is a health problem. Currently, 12.5% of Mexican children have some degree of malnutrition that negatively affects growth and general health with consequences on work performance and in the development of capabilities, all with subsequent repercussions on social development. A previous study on urinary F excretion reported an excretion between 355 and 367 µg/F/day. Using the paradigm that the systemic ingestion of F is beneficial for reducing dental decay, the purpose of the present study was to compare urinary F excretion in children with and without malnutrition, in a rural community, in order to infer whether the F intake was at optimal levels for caries prevention or a risk factor for dental fluorosis, and to investigate if nutritional status was associated with F retention.

**MATERIAL AND METHODS**

The study was conducted in a sample of 3–5-year-old children, of both genders, who were residents of the rural communities of El Cerrito, Mina Vieja, and El Ocote in the Municipality of San Felipe del Progreso, State of Mexico. The project was approved by the Research Committee of the Facultad de Estudios Superiores Zaragoza.
Children with a diagnosis of mild or moderate malnutrition were invited to participate in the study through a national support program for children with nutritional deficit known as “Un Kilo de Ayuda” (One Kilo of Help). The control group was formed with preschoolers from kindergartens in the area. The nutritional status classification was established according to the children’s weight percentiles in relation to their age and sex.\textsuperscript{12}

A guideline for 24-hr urine collection was explained and provided to the children’s parents. They were given five plastic 500 mL containers with a screw top, labeled with the child’s name and numbered. The need to collect the entire urinary volume during each micturition was emphasized, as well as the need to register the time the child voided. Once each child’s total urine volume was measured and the excretion rate was calculated based on the time period between each micturition, cases with samples under 210 mL and/or an excretion rate below 9 µg F/hr, were excluded since they were considered incomplete.\textsuperscript{5} After the application of these criteria, four samples were excluded from the malnourished group, yielding a final sample of 56 participating preschoolers.

The F determination in water and urine was performed with the electrode specific method for the F ion with a potentiometer (720A-Orion) with a calibration curve with five reference values between 0.01 and 5 mg F/L. The F concentration in urine per child was obtained from the average of all submitted samples. The excretion rate was measured by multiplying the F concentration in each sample by the result of the division of the sample volume between the time lapses since the last micturition. DUFE was calculated with F concentration and the collected urinary volume.\textsuperscript{5}

The F intake was also calculated by assuming that 35% of the ingested F was excreted in the urine, as indicated in the following equations.\textsuperscript{13,16}

\[
\text{Fractional urinary fluoride excretion (FUFE)} = 0.35 \times \text{Fluoride intake}
\]

\[
\text{Fluoride intake} = \frac{\text{Fractional urinary fluoride excretion (FUFE)}}{0.35}
\]

The clinical examination of the children’s oral cavity was performed in sunlight, with dental mirrors with no amplification and rounded probes. The oral hygiene was evaluated with a dental biofilm revealing substance and the number of total pigmented surfaces in relation to the total number of surfaces present, except for those occluded, were recorded in accordance with O’Leary’s criteria.\textsuperscript{16,17} The dmf-d index was used to measure the caries in the temporary dentition, which refers to the teeth with caries in the primary dentition, and indicating those that had been extracted or obturated. The number of tooth surfaces affected by dental caries was also recorded with the dmf-s index. The index recordings were performed by a previously trained clinician using standardized Kappa statistical values: 0.90 for the dmf-d index, 0.82 for the dmf-s index, and 0.80 for the O’Leary index.
The frequencies, percentages, and averages of the obtained values were calculated. The comparisons between the groups were statistically analyzed with the two way ANOVA test, using the SPSS statistical package.

RESULTS

After applying the elimination criteria, the total sample included 56 children, 30 boys and 26 girls, with an average age of 3.8±0.92 yr. Table 1 shows the values for the urine volumes, F concentrations in ppm, excretion rate, total excreted F, and the estimated F intake based on a FUFE of 0.35.

Table 1. Urine volume, fluoride (F) concentration, excretion rate, and total excreted F in 3–5-year-old children, in a Mexican rural community, related to nutritional status. Data are expressed as mean±standard deviation, and the differences among groups were analyzed with two way ANOVA test

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Normal nutrition</th>
<th>Mild malnutrition</th>
<th>Moderate malnutrition</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine volume (mL/day)</td>
<td>455±171</td>
<td>405±125</td>
<td>349±120</td>
<td>0.11</td>
</tr>
<tr>
<td>Urinary F concentration (ppm)</td>
<td>0.76±0.3</td>
<td>0.79±0.3</td>
<td>0.88±0.2</td>
<td>0.56</td>
</tr>
<tr>
<td>Urinary F excretion rate (µg/hr)</td>
<td>18.4±7</td>
<td>16±5</td>
<td>15.9±5</td>
<td>0.34</td>
</tr>
<tr>
<td>Total F excreted (µg/day)</td>
<td>323.8±156</td>
<td>290±117</td>
<td>303±126</td>
<td>0.73</td>
</tr>
<tr>
<td>Total F intake (FUFE ÷ 0.35, µg/day)</td>
<td>925.2±447</td>
<td>830.2±336</td>
<td>867±360</td>
<td>0.73</td>
</tr>
<tr>
<td>Weight</td>
<td>16.01±3</td>
<td>13.5±1</td>
<td>12±1</td>
<td>0.02</td>
</tr>
</tbody>
</table>

The values for the urinary excretion rate, the total F excreted, and the total F intake were lower in the malnourished children but there were no statistically significant differences between the groups. The range for the estimated ingested F was 0.01–0.02 mg/kg body weight/24hr. The malnourished children had a caries experience of 5 teeth, slightly above that observed in the non-malnourished children, which was 4 (p>0.05). Table 2 shows the values for the caries indexes and plaque control according to the O’Leary index. The drinking water had an average F concentration of 0.02 mg/L.

Table 2. Hygiene and caries indexes in 3–5-year-old children with and without malnutrition, in a Mexican rural community. Data are expressed as mean±standard deviation, and differences among groups were analyzed with two way ANOVA test

<table>
<thead>
<tr>
<th>Indexes</th>
<th>Normal</th>
<th>Mild malnutrition</th>
<th>Moderate malnutrition</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>O'Leary index</td>
<td>15±9</td>
<td>26±1</td>
<td>27±8</td>
<td>0.07</td>
</tr>
<tr>
<td>dmf-d</td>
<td>4.2±3</td>
<td>5±2</td>
<td>4.8±3</td>
<td>0.64</td>
</tr>
<tr>
<td>dmf-s</td>
<td>6.4±5</td>
<td>6.9±3</td>
<td>5.6±4</td>
<td>0.60</td>
</tr>
</tbody>
</table>
DISCUSSION

The total F excretion in 24 hr found in the present study was below the values reported in similarly aged children exposed to fluoridated water (0.30–0.39 mg F/L), fluoridated milk, fluoride supplements, and fluoridated salt, and below the range that the WHO considers an optimal F intake for caries prevention in children between the ages of 3 and 7 (360 to 600 µg/day). The F excretion in the children participating in the present study was similar to that found in British children, between the ages of 1.8 and 5 years old, whose F intake was 0.21 mg/day, as in other cases of sub-optimal F exposure reported in other European countries. By interviewing the mothers, we detected that 90% of the children in the study did not use tooth paste, had no access to dental services, and thus had never been exposed to topical F. There were no significant differences in the 24 hr F excretion values, in the present study, between the malnourished and non-malnourished children, consistent with previous data obtained in preschoolers in 2008 in Mexico City, although moderately malnourished children were included in the present study but not in the 2008 one. Both studies suggest that low body weight does not modify F excretion and that it is not associated with an increased F uptake. Villa et al. reported that F retention increases as F intake increases, and at TDFI values below 0.5 mg/F/day, a steep increase in fractional fluoride retention (FFR) is observed.

The results of the present study suggest that the metabolism of fluoride and the DUFE are not affected by the children’s nutritional status. We can only infer the F ingestion since the dietary habits were not evaluated. Further studies on F intake and urinary excretion would be required to understand its relation to nutritional status and to determine whether specific deficits in calcium and vitamin D intake in malnourished children affect fluoride retention. Nevertheless, we must underscore the fact that children residing in an urban area had greater F excretion values and optimal F exposure for caries prevention.

After inferring the F intake from the excretion values obtained in the present study, we found that the intake fraction ranged between 0.01 and 0.02 mg F/kg body weight/24 hr, a sub-optimal level for caries prevention. Systemic exposure to F at the levels found in the present study do not increase the risk of developing dental fluorosis, a complication that develops with exposures above 0.3 mg F/kg body weight/24 hr. However, another study conducted in Mexico, reported that 37% of 15–36-month-old children, ingesting a mean of 0.18–0.20 mg F/kg body weight/day were at risk of developing dental fluorosis. The mean fluoride ingested from the combination of foods and beverages was within the proposed safe threshold for fluoride intake of 0.05–0.07 mg F/kg body weight/day and most of the F intake by these children was derived from the ingestion of fluoridated toothpaste. When all sources of ingested F were added and total F intake was calculated, the children were ingesting amounts of F well above the upper limits of the proposed safe threshold for fluoride intake.

In the present study, the children in the studied rural communities had an average of 4 primary teeth affected by caries, and there were no significant differences in
caries prevalence between the malnourished and non-malnourished children. This suggests that malnutrition is not a determining factor in caries development, as pointed out in other research studies.\textsuperscript{31,32} The dmf-t was greater than that reported in children residing in other Mexican areas recorded by the Epidemiology National System (SIVEPAB), in children aged 2–5 yr.\textsuperscript{33} The children participating in the present study were from a low socioeconomic background and lacked health services. Social inequalities increase the risk of developing diseases of the oral cavity due to the inherent difficulties in accessing health services.\textsuperscript{34} Other investigators have associated calcium deficiencies and malnutrition with enamel abnormalities, such as fluorosis.\textsuperscript{31}

In order to decrease the prevalence and severity of caries in children with nutritional deficiencies, the prescription of nutritional supplements with vitamin D is recommended,\textsuperscript{35} as well as nutritional/dietary counseling and the control of the dental biofilm. It is also important to establish dental health programs that include the application of topical varnishes and sealants.

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