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ORIGINAL COMMUNICATION

Effect of tamarind ingestion on fluoride excretion in humans

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Objective: To evaluate the effect of tamarind (*Tamarindus indicus*) ingestion on excretion of fluoride in school children.
Design: Randomized, diet-control study.
Subject: Twenty healthy boys were included and 18 of them completed the study.
Interventions: Each subject consumed 10 g tamarind daily with lunch for 18 days at the social welfare boys' hostel. The nutrient composition of the daily diet was constant throughout the experimental period.
Results: Tamarind intake led to significant increase ($P < 0.001$) in the excretion of fluoride in 24 h urine (4.8 ± 0.22 mg/day) as compared to excretion on control diet (3.5 ± 0.22 mg/day). However, excretion of magnesium and zinc decreased significantly (7.11 ± 1.48 mg of Mg and 252.88 ± 12.84 μg of Zn per day on tamarind diet as compared to 23.39 ± 3.68 mg of Mg and 331.78 ± 35.31 μg Zn per day on control diet). Excretion of calcium and phosphorous were not significantly different while creatinine excretion decreased with tamarind intake (225.66 ± 81 mg creatinine/day with tamarind and 294.5 ± 78.76 mg creatinine/day without tamarind).
Conclusion: Tamarind intake is likely to help in delaying progression of fluorosis by enhancing urinary excretion of fluoride.
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Introduction

Hydrofluorosis is a major public health problem in 17 out of the 32 constituent states of India. Around 62 million people including 6 million children suffer from fluorosis due to excessive consumption of fluoride through water (Susheela, 1999). Various techniques for the defluoridation of drinking water have been adopted by the government and nongovernmental agencies, but the problem remains unresolved as of today. Medical intervention is not possible for this disease due to unavailability of any specific drugs or medicines for treatment. Short-term studies on animals (Wagner & Muhler, 1960) and humans (Jowsey & Riggs, 1978) indicated that calcium salts interfere with fluoride absorption. Aluminium salts were also used in cattle to counter fluoride toxicity (Allcroft & Burns, 1969). Although fluoride accumulation in bone was delayed, complete prevention was not possible and toxic side effects of aluminium were not ruled out. Calcium and phosphorous supplementation did not enhance the beneficial effect of aluminium salts. Although serpentine (magnesium metasilicate) administration ameliorated clinical symptoms to some extent (Reddy *et al*, 1985), long-term toxicological studies were not undertaken. Borate was found to offer some protection in long-term animal studies (Elsar *et al*, 1979). The effect of cereals on fluoride retention was studied in normal humans by Lakshmaiah and Srikantia (1977). Fluoride excretion in urine was found to be significantly greater on rice-based diets as compared to jowar-based diets. Similar experiments on rats using sorghun-, wheat- and rice-based diets showed increased retention of fluoride in femur bone on sorghum-based diets as compared to wheat- and rice-based diets (Lakshmi & Lakshmaiah, 1999). However, further studies on the effect of various components of diets on fluoride retention in the body are not available. Our earlier studies on dogs suggested beneficial effect of tamarind ingestion on fluoride toxicity by way of increased

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urinary excretion and decreased retention in bone (Khandare *et al*, 2000). The present study has been undertaken in humans to explore the possibility of similar benefits from tamarind intake.

Methods

Five social welfare hostels for boys from Nalgonda and RR districts of Andhra Pradesh, India, were selected and water samples from six bore wells located in these hostels were analyzed for fluoride content. Fluoride content was 3.7 ppm in the Nelapatla village (Nalgonda) water sample and 3.9 ppm in the Batasingaram village (RR district) water sample. In others, the fluoride content was less than 2 ppm. The students from Nelapatla and Batasingaram hostels were screened for dental fluorosis and various grades of dental fluorosis ranging from grade I to III were found among the students. The prevalence rate of dental fluorosis was as follows: none, 15; grade I, 23; grade II, 11; grade III, 4, among 53 students screened randomly at Batasingaram; and none, 0; grade I, 11; grade II, 9; grade III, 2, out of 22 students at Nelapatla hostel. Ten students from each hostel having grade I–III (grade I, 11, grade II, 5, grade III, 4) dental fluorosis were randomly selected and recruited for the study with informed consent. The study was conducted at two different time points because the subjects belonged to two different villages 40 km apart. The characteristics of all the 18 subjects are given in Table 1. During the experiment, two students from Nelapatla hostel dropped out due to personal reasons. The experiment was conducted in two stages each of 18 days' duration. The study was approved by the human ethics committee of the Institute.

During the first stage students received normal rice- and pulse-based diet without tamarind. During the second stage they received tamarind paste (10 g tamarind/day/student) in addition to the rice- and pulse-based diet. The tamarind used was a ready-to-eat commercial preparation (Priya tamarind paste) with 60% moisture content. During the last 3 days on each regimen, 24 h urine samples were collected for biochemical analysis. Fluoride content of water and urine samples was estimated with Orion Ion specific electrode (Tusl, 1970) using an Orion expanded ion analyzer (EA 940, Boston MA). Urinary phosphorous was estimated by the micro method (Chem *et al*, 1956). Calcium, magnesium and zinc in urine as well as in the diet were estimated by atomic absorption spectrophotometer. Creatinine was estimated according to Hippocrates, (1974) method.

Table 1 Characteristics of the 18 boys included in data analysis

Characteristic	*Mean ± s.e.*
Age (y)	10.7 ± 0.32
Weight (kg)	27.2 ± 1.33
Height (cm)	135.0 ± 9.46
Water intake (ml/24 h)	1133.0 ± 56
Urine output (ml/24 h)	1108 ± 438.1
Urinary pH	6.734 ± 1.01
Dental fluorosis grade	1 to 3
Nutrient intake per day	
Protein (g)	35.75 ± 1.55
Fat (g)	9.05 ± 0.41
Carbohydrate (g)	60.05 ± 3.48
Energy (kcal)	1641.91 ± 79.99
Calcium (mg)	232 ± 8.62
Magnesium (mg)	348 ± 15.55
Phosphorous (mg)	501.02 ± 27.64
Zinc (mg)	4.31 ± 0.2

Statistical analysis

Data were analysed to see the effect of tamarind on different parameters (urinary fluoride, calcium, magnesium, phosphorous, zinc and pH); paired *t*-tests, parametric and non-parametric, were applied. The levels of significance are also given.

Results

The data obtained from diet analysis indicate that the protein and energy intake of the subjects were less than RDA by 33.8 and 25%, respectively. There was a significant increase in 24 h urinary excretion of fluoride ($P < 0.001$) during the period of tamarind ingestion. The fluoride excretion was 4.8 ± 0.22 mg/day with tamarind supplements and 3.5 ± 0.22 mg/day during the control period (Table 2). Excretion of zinc and magnesium decreased significantly (Table 2) during tamarind intake (7.11 ± 1.48 mg Mg/day and 252.88 ± 12.84 μg Zn/day). Due to low calcium intake (232 ± 8.62/24 h, Table 1), the calcium excretion of the children was quite low (10–30 mg/day in 12 children and 90–400 mg/day in the remaining six). The differences in the 24 h excretion of calcium with and without tamarind supplement were not statistically significant (Table 2). Phosphorous excretion was also not significantly different (189.04 ± 22.12 mg/24 h with and 195.8 ± 21.20 mg/24 h without tamarind, Table 2), while creatinine excretion decreased ($P < 0.05$) significantly during tamarind ingestion (225.66 ± 81.0 mg/24 h with and 294.5 ± 78.86 mg/24 h without tamarind, Table 2). The urinary pH increased significantly ($P < 0.001$) with tamarind ingestion (pH 7.57 ± 0.31 with and pH 6.73 ± 2.45 without tamarind). Urine volume did not show any difference with or without tamarind.

Discussion

Fluoride absorption and bioavailability are influenced by several factors. Metal ions such as Ca^{2+}, Mg^{2+} and Al^{3+} form insoluble complexes with fluoride in the gut and reduce absorption (Wagner & Muhler, 1960). However, Spencer *et al* (1978) reported that high magnesium intake was not associated with any significant change of fluoride balance even with additional higher intake of calcium, magnesium

Table 2 Excretion of urinary constituents (mean ± s.e.) before and after tamarind supplementation

	Fluoride (mg/24 h)	*Zinc (μg/24 h)*	*Magnesium (mg/24 h)*	*Calcium (mg/24 h)*	*Phosphorus (mg/24 h)*	*Creatinine (mg/24 h)*
Before	3.46	331.78**	23.39*	82.24	195.80	294.5**
	± 0.22	± 35.31	± 3.68	± 78.86	± 21.20	± 78.76
After	4.77*	252.88	7.11	48.33	189.04	225.66
	± 0.22	± 12.84	± 1.48	± 81.00	± 22.12	± 81.00

*$P < 0.001$; **$P < 0.05$.

and fluoride. Anions like phosphate, sulphate and molybdate are reported to enhance fluoride absorption (Ruzicka *et al*, 1976; Spencer *et al*, 1975; Stookey *et al*, 1964). Iron and zinc could also form insoluble complexes with fluoride but the concentration of these chemicals in water and foods is too low to exert significant effect on absorption of fluoride (Feldman *et al*, 1957; Brudevold *et al*, 1972). Physiological factors such as age, calcium and parathormone status, renal function etc also influence absorption and retention of fluoride in the body (Rao, 1984). Kidney damage markedly affected the toxicokinetics of fluoride and decreased its elimination in rats (Tomotaro *et al*, 2000). Earlier experiments in humans have shown that sorghum-based diets promote greater retention of fluoride in the body as compared to rice-based diets (Lakshmaiah & Srikantia, 1977). A similar experiment conducted recently in rats showed increased retention of fluoride in femur bone on sorghum-based diets as compared to wheat- and rice-based diets (Lakshmi and Lakshmaiah, 1999). However, there was a statistically insignificant trend towards higher excretion of fluoride in urine on sorghum-based diets as compared to wheat- and rice-based diets. It was speculated that the trace element profile of the diets could be responsible for these differences in retention.

The present study on humans substantiates our previous observations in dogs given tamarind supplements (Khandare *et al*, 2000). Increased urinary excretion of fluoride may reflect changes in reabsorption of fluoride at the level of renal tubules. Although fluoride binding by tamarind *in vitro* has been reported (Sriramachari, 1983; Maruthamuthu & Venkatanarayana, 1987), the extent and avidity of the binding are not strong enough and hence this low affinity binding is unlikely to reduce the absorption of fluoride from the gut. Change in the pH of urine towards alkaline range with tamarind ingestion may have some bearing on renal clearance of fluoride. Renal clearance of fluoride showed large day-to-day variations depending on renal flow but extra renal clearance representing mainly clearance to bone pool and the fraction of intake remaining in pool bone pool showed remarkable consistency. In a subsequent study, the renal clearance of fluoride has been reported to be always lower with acid urine than with alkaline urine (Ekstrand *et al*, 1978, 1980). The extra-renal clearance of fluoride to the bone pool of fluoride was also found to be significantly lower during the production of alkaline urine. The higher pH of urine with tamarind supplementation suggests such a possibility for increased urinary fluoride excretion.

Higher protein intake has also been reported to reduce fluoride retention in bones (Carald & Floriant, 1987), but such a possibility is unlikely with tamarind intake in view of its low protein content and limited amount used for supplementation. The calcium, zinc and phosphorus intake of the children included in this study was very poor judging from diet analysis. The urinary excretion of zinc decreased significantly with tamarind intake. Zinc deficiency is associated with skeletal growth impairment (Oner *et al*, 1984). It is reported to be a contributory factor in osteoporosis observed in postmenopausal women (Herzberg *et al*, 1990). Decrease in zinc excretion with tamarind supplementation may have a beneficial effect on the skeletal health of children from fluorotic areas.

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