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Ten years domestic salt fluoridation in Hungary

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Results are presented regarding the caries reduction achieved over a 10 yr period using 250 mg F per kg of domestic salt, and compared with data from a fluoridated water area and from a control group. The frequency of caries-free children in the 4 to 6, 7 to 11 and 12 to 14 age range in the experimental group rose from 8.06%, 4.74% and 1.43% to 46.75%, 43.98% and 7.92% respectively, and dmft and DMFT indices dropped from 5.35, 3.62 and 6.60 to 2.80, 1.45 and 3.65. There was no significant change in the percentage of caries-free children or in the indices of the control group. The ratio of dmft and DMFT to teeth and the differences in the extent of caries among specified teeth are also presented. The data support the assumption that fluroidated salt prevents dental caries both in deciduous and permanent dentitions. The results were similar as those obtained in a water fluoride area. The optimum and tolerated F intake, water and salt ingestion, F intake from foods and the urinary F levels are also discussed.

Salt was first suggested as a vehicle for fluoride by Wespi [28] and in Switzerland fluoridated salt was put on sale with a F concentration of 90 mg/kg from 1955 [29]. Production of salt containing 250 mg F/kg commenced in one canton during 1970 and in another in 1975 [8]. Initial results were worthy of attention, as they clearly showed a caries-inhibiting effect of fluoridated salt [4, 6]. Further studies with salt have been carried out in Colombia [7, 10] and Spain [7, 26].

In Hungary, a preliminary experiment was started in 1965 to solve the technical problems. Since 1966, a clinical trial has been conducted under realistic field conditions using different F-concentrations. In 1966, salt containing 250 mg F (552 mg NaF); in 1968, 200 mg F (442 mg NaF); and in 1972, 350 mg F (773 mg NaF) per kg was put on sale, and some of the results obtained have already been published [13, 14, 15, 17, 18]. By 1976, after 10 years experience with the 250 mg F/kg salt dosage, the data justify a detailed report on the practicability of the method.

Method

The salt which was fluoridated was that used by housewives for cooking [12, 20]; it is therefore termed "domestic salt" rather than "table salt". Restaurants, common kitchens, student canteens, nursery and school kitchens employ the same preparation (visible salt). The salt used by bakeries and the food industry (hidden salt) was not fluoridated. Fluoride is added to the salt by spraying concentrated NaF solution over a layer of NaCl running on a conveyor belt.

F concentration of salt, water, urine, vegetables, fruits, cereals, egg, meats, meat tissues, soups, cooked vegetables and dishes of meat served with cereals or vegetables was determined by the Orion ion-specific electrode method. Meat tissues were separated from bone, fat, tendons and membranes. All foods, raw or cooked, were cut into small pieces, then spread in a thin layer and dried under infrared light to constant weight. The dry material content was calculated, and the material then burnt to ash. From these, basic solutions were made and aliquots were adjusted to pH 5.5 with acetate buffer and the F content determined using the direct potentiometric method. Evaluation of data was done by the help of a calibration curve. It was essential to know the F content of the above foods and fluids to evaluate the effectiveness of salt fluoridation.

The fluoridated salt is marketed in villages where no other salt is available. By this "compulsory" measure a similar situation is created as with the fluoridation of drinking water. The F content of drinking water in both the experimental and control villages was 0.2 ppm.

Dental examinations were performed each year during the last 2 weeks of May, when the subjects were examined by two teams, each consisting of a dentist and chairside assistant; neither team was informed of the other's findings. Results were computerized, the caries data being expressed as dmft and DMFT indices (average number of decayed, missing and filled deciduous and permanent teeth per child; dmft symbolizing deciduous and DMFT permanent teeth).

Children

Table 1 shows the number and age of participating children. Initially there was only one control village but later two more were included. The examined children in the experimental group are representative of the village as around 500 normally reside there with only small yearly fluctuations. To obtain a more accurate comparison of the cariostatic effect of salt, a further group was examined in 1977 from an area where the water contained at least 1 ppm F for 27 years [1, 22].

Results

Caries-free children. As shown in Table II, the number of caries-free children in all three fuoridated age groups rose significantly, although there was no change in the control group.

The dmft and DMFT indices. The average number of decayed, missing and filled deciduous and permanent teeth per child is shown in Table III. When the experiment started in 1966, the dmft index for the experimental group aged 4 to 6 was 5.35, and ten years later this had dropped to 2.80, corresponding to a decrease of 48%. The differences between experimental and control village indices in 1976 was 3.18, a difference of 53%. In the 7 to 11 year age-range, the experimental DMFT index was 3.62 in 1966, and ten years later it had been reduced to 1.45, a decrease of

TABLE I

Number and age of children examined

Age* range		Fluoridated salt 250 mg/kg		Water fluoride 1 ppm	Control	
		**1966	**1976	**1977	**1967	**1976
4— 6	M	4.06	4.6	4.09	4.06	4.06
	N	62	77	55	78	311
7—11	M	8.05	8.07	8.09	8.09	8.06
	N	190	158	340	236	1041
12—14	M	12.06	12.08	12.06	12.03	12.06
	N	140	82	250	212	606
Total	N	392	317	645	526	1958
Exact data for	M	3.10	3.05		4.01	4.00
2— 6	N	82	137	—	92	424

* = Next birthday
** = Year of examination
M = Mean age: years and month
N = Number

TABLE II

Caries-free children, per cent

Age range	Fluoridated salt		Water fluoride	Control	
	1966	1976	1977	1967	1976
4— 6*	8.06	46.75	60.08	11.54	13.82
7—11**	4.74	43.98	52.65	12.71	17.91
12—14**	1.43	7.92	23.60	0	0.82

* = Deciduous dentition
** = Permanent dentition

TABLE III

Average number of decayed, missing and filled deciduous and permanent teeth per child

Age range	Fluoridated salt		Water fluoride	Control	
	1966	1976	1977	1967	1976
4— 6 dmf	5.35	2.80	1.37	5.94	5.98
7—11 DMF	3.62	1.45	1.06	3.35	2.80
12—14	6.60	3.65	2.58	7.33	7.20
Exact date for 2 — 6 dmf	4.18	1.43	—	5.19	4.56

dmf = Decayed, missing or extractions indicated and filled

60%. Comparing the 1976 indices from experimental and control villages, a difference of 1.35 (48%) was evident. In the 12 to 14 year age-range the experimental DMFT index was 6.60, and ten years later this had dropped by 45% to 3.65. Comparison of the 1976 data shows a difference of 3.55 (49%).

The ratio of dmft and DMFT to the number of teeth examined is shown in Table IV. In the experimental group the ratio dropped significantly when compared to that of 1966. In the control group no change could be seen.

The cariostatic effect of fluoridated salt could also be demonstrated by differences in caries among the various

TABLE IV

Ratio of decayed, missing and filled deciduous and permanent teeth to the teeth examined, per cent

Age range	Fluoridated salt		Water fluoride	Control	
	1966	1976	1977	1967	1976
4—6*	26.77	11.30	7.41	29.68	30.37
7—11**	27.53	12.59	8.59	26.86	22.90
12—14**	25.61	14.77	10.34	29.68	28.42

* = Deciduous dentition
** = Permanent dentition

TABLE V

Differences in the extent of caries among the different types of permanent teeth per 100 children, aged 12 to 14 years

Tooth		Water fluoride	Fluoridated salt	Control
M_2	Upper jaw	12.2	12.1	33.9
M_1		71.6	126.2	166.5
PM_2		5.8	7.9	36.4
PM_1		6.6	7.9	41.9
C		0.2	0	5.7
LI		7.0	10.3	67.6
CI		4.2	12.1	78.0
CI	Lower jaw	0.2	0	6.2
LI		0.2	0	4.5
C		0.2	0	0.7
PM_1		1.2	6.1	5.9
PM_2		6.2	8.5	18.9
M_1		112.6	151.8	183.6
M_2		30.4	32.3	76.7

CI = Central incisor; LI = Lateral incisor; C = Canine; PM = Premolar; M = Molar permanent tooth types in 12 to 14 year old children. In Table V, the data relate to scores per 100 children. After ten years, no caries was found on the upper canines or the lower incisors and canines. All other specified teeth had a lower caries attack in the experimental group as compared to the controls.

Discussion

The caries inhibiting effect of fluoridated domestic salt was obvious not only in the permanent but also in the deciduous dentition. The original age-range of the experimental and control groups was 2 to 6 years but for comparison with those exposed to F in drinking water for a lifetime the age was reduced to 4 years. The original data are shown in Tables I and III.

As seen in Table I, there was a difference in the mean age of children aged 2 to 6 years between the experimental and control groups in 1976, the children in the experimental group being 7 months younger. No significant age difference could be observed in the 7 to 14 age group. The number of children examined in all groups varied, as in 1976 more control subjects were examined. Statistical analysis of the experimental and control data for 1976 yielded for the age group 2–6 years: $t = 7.39$ ($P < 0.05\%$); for the age group of 7–11: $t = 2.51$ ($P < 1\%$); and for the age group of 12–14 years: $t = 8.24$ ($P < 0.05\%$). Thus the differences between indices was significant in all the three age groups.

After ten years, in the fluoridated salt group the percentage of caries-free children increased while the dmft and DMFT indices decreased significantly. The level of caries reduction observed in naturally fluorided areas could not be reached although the variations were small (Tables II, III, IV and V). This may have been due to two factors, i.e. either that salt fluoridation commenced only ten years previously, or because the F concentration was not adjusted to a level high enough to ensure ingestion of the optimum amount.

Optimum and tolerated intake of fluorine has been studied on the basis of body weight, and the calorie and fluid requirements of subjects belonging to different age groups [9, 16]. As the main F-source is normally the drinking water, that amount of F which is ingested daily with drinking water containing 1 ppm F should be considered optimal. This amounts to 0.045 mg per kg body weight in infants, and decreases with age to 0.026–0.020 mg in adults i.e. half that for infants on a mg/litre basis. When calculating an upper limit, excessive intake should also be borne in mind. During the first eight years of life, the excess intake per day cannot exceed 1.72 mg (in adults 5.8 mg), even if the water contained 1.5 ppm F. Salt fluroidation, as an alternative to water fluoridation, should be based on the knowledge of the maximum permissible individual dose of F per day and the maximum individual ingestion of salt [11].

Drinking water ingestion by children was critically reviewed by Marthaler [5]. He found that individual levels of ingestion were obliquely distributed with the bulk of the population ingesting less water, although a small percentage consumed a great amount. We found [25] the same in smelters during work (their ingestion of protective drinks being monitored summer and winter; Table VI). Here, 2.06% of the subjects ingested over 5 litres per day, i.e. with water containing 1 ppm F, about 2% consumed 5 mg F or more daily.

Similar results were obtained for the intake of domestic salt [20] per kg body weight/day, with 0.83% taking excessive quantities (Table VI).

The diet is mostly low in F [2, 24]. According to our data [24] the daily dietary intake in Hungary contains at most about 0.39 mg per kg of F (Table VII). The amount of F ingested with food is unpredictable [27]. Nevertheless, human urinary concentrations depend on, and in fact are nearly equivalent numerically to, the drinking water concentrations [3, 19, 21, 22]. Thus, the important role of water as a main source of F is supported by the urinary F level.

Studies of salt ingestion are difficult to undertake. The first question to be decided is the kind of salt that has to be fluoridated? We are fluoridating the domestic salt, but it was a surprise to find that considerable amounts of salt purchased for household use were not ingested, more than 60% of each purchase being discarded [20]. Furthermore the more industrial foods are consumed, the less the domestic salt ingestion. The decision as to which kind of salt should be fluoridated is really a question of philosophy and policy. If the salt used in bakeries and the food industry were fluoridated, this would amount to a compulsory measure. Consequently that problem must also be taken into consideration before the introduction of large scale production of a homogeneous and stable fluoridated salt [7].

The urinary concentration of F is a convenient and established method of estimating F intake by a population, group or individual [3, 7, 23]. Urinary F concentration can vary throughout the day because a single dose of fluoride is excreted in a few hours [3, 21]. Thus a spot sample of an individual will not reflect his F ingestion. It is more meaningful if two fractions (a.m. and p.m.) are obtained from the individual, and the F concentration of the pooled urine is determined. This technique is suitable for large-scale monitoring of F ingestion with salt. When salt containing 200 or 350 mg F per kg is ingested for months or years, the urinary F level also increases. Table VIII shows the results of our experiment. Here the 250 mg F (since 1966) and the 200 mg F (since 1968) groups had reached a steady state but in spite of the prolonged ingestion of the salt we do not see sufficient F concentrations in the urine. The

TABLE VI

Water and domestic salt ingestion per kg body weight

N	NN	Mean body weight kg	Mode	Median	Mean	SD	Mean + 3 SD
		water, ml					
97	291	69.0	22.9	30.2	35.2	16.0	83.2 = 2.06%
		domestic salt, gram					
242	581	55.6	0.020	0.060	0.066	0.037	0.177 = 0.83%

N = Number of persons observed
NN = Number of observations (days)

TABLE VII

F content of foods

	Mode	Median	Mean	SD
	mg/kg			
Foods without fish	0.12	0.16	0.28	0.14
with fish	0.12	0.17	0.39	1.02
Dishes of cooked food	0.14	0.20	0.21	0.09

350 mg F group, however, had been consuming that concentration since September 1972, and in the urine of adults the expected level of F has been obtained.

TABLE VIII

Urinary F levels after long term consumption of fluoridated salt (200, 250 and 350 mg F per kg salt), mg per litre

F in salt	Age range	F concentration mean ± SD
200 mg/kg	2–14	0.75 ± 0.32
	Adults	0.69 ± 0.31
250 mg/kg	2–14	0.86 ± 0.35
	Adults	0.85 ± 0.45
350 mg/kg	2–14	0.73 ± 0.20
	Adults	1.10 ± 0.49

CONCLUSION

Long term use of fluoridated domestic salt prevents dental caries not only in the permanent but also in the deciduous dentition. The effectiveness of fluoridated salt is similar to that which could be observed after drinking water with optimum F content. Unfortunately, to adjust salt to an adequate F concentration is difficult and may only be achieved by studying the dietary and nutritional habits of the group involved. In the case of fluoridated domestic salt, an approximate estimate of salt ingestion can be done from the quantity of salt sold, 60% of which is known to be discarded. Thus urinary tests for fluoride ingestion may be monitored accurately. However, the greater the consumption of industrial foods the more difficult it is to decide which salt was to be fluoridated and to estimate the daily ingestion. If salt other than that used in households is to be fluoridated, the decision is more or less a question of philosophy and policy.

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