Prevention of Dental Caries by Salt Fluoridation

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ABSTRACT

At present, fluoridation of drinking water is regarded as an efficient and safe public health measure by competent national and international organizations. In view of the success with iodized salt, fluoridation of domestic salt was started in 1956. Data collected in surveys and published in 1961 and 1962 suggested a cariostatic effect of fluoride supplemented by domestic salt. The benefit was fairly low which was to be expected in view of the low dosage of 90 mgF/kg salt. This type of salt made at the Vereinigte Schweizerische Rheinsalinen, Schweizerhalle BL, Switzerland, has become the most frequently used type of salt as far as packages for domestic usage are considered. On the basis of salt consumption data, a higher fluoride dosage, 200 mgF/kg, was already envisaged in 1962. This discussion was intensified in the later sixties. Studies in Switzerland with salt at 250 mgF/kg have been under way since 1970. The expected caries preventive effect has been confirmed. Studies on the cariostatic effectiveness were started 1963 in Colombia and 1966 in Hungary. In Colombia 200 mgF were added to 1 kg of salt, while in Hungary, 350 mgF/kg were used. Research on salt fluoridation has so far produced the following results: findings regarding dental caries, and urinary fluoride levels provide substantial evidence that salt as used in households and bakeries may be a valuable and safe vehicle for fluoride in mass prevention of dental caries. Questions of physiology and safety of fluoride as provided through salt are intensely studied.

INTRODUCTION

Water containing fluoride at a level of 1 to 2 mg per liter or more has been drunk for centuries by millions of people. At this concentration, no harmful effects have been observed but the number of carious teeth was found to be very low in such populations. Based on these findings, artificial water fluoridation has been used since more than 30 years for mass prevention of dental caries (WHO, 1970).

The first publications suggesting salt as a vehicle for fluoride appeared in 1948 and 1950. Their author, Wespi, had been active in the prevention of goiter by promoting the introduction of iodized salt in all cantons of Switzerland. Results of a clinical study initiated in 1956 were in favor of a cariostatic effect of fluoride added to salt (Marthaler and Schenardi, 1962). This conclusion was supported by data from a survey which had been published a year earlier (Marthaler, 1961).

Carefully planned studies with fluoride added to salt were started in Colombia and in Spain in 1965, and in Hungary in 1966. These studies are most important because concentrations of fluoride in salt in the range of 200 to 350 mg F/kg salt were used whereas in Switzerland only 90 mg F/kg were added until 1970.

RESULTS OF STUDIES IN FOUR COUNTRIES

Switzerland. Endemic goiter due to insufficient levels of dietary iodide had been a serious problem in Switzerland. In 1917, iodization of salt began, leading to the gradual disappearance of endemic goiter in the following decades. This success facilitated the introduction of fluoridated salt which

began in 1955. By 1967 three-quarters of the 1-kg-packages of salt sold for domestic use by a population of 5.5 million were fluoridated to 90 ppm F (Table 1). In several cantons, with a total of approximately two million inhabitants, only fluoridated salt has been available for up to 10 years. The fluoride content was indicated on the package, yet there was practically no antifluoridationist opposition.

Production of salt with 250 ppm F was started in 1970 for the canton of Vaud (VD, population 500,000), and in 1975 for the canton of Glarus (GL, population 40,000). In the latter canton a press conference was held to inform the public.

Results of early surveys of caries prevalence associated with the use of domestic salt at the low level of 90 ppm F are given in the upper part of Table 2. The data obtained from children up to nine years of age support the hypothesis of a cariostatic effect of fluoride added to domestic salt. At ages above 12, DMF counts were similar whether or not fluoridated salt had been used; this was to be expected in view of the fact that the fluoride content was substantially below the optimum level and that fluoridation had been in effect for only four to five years. Caries prevalence in the children of the cantons of Freiburg (FR) and Neuenburg (NE) decreased from 1970 to 1974 (lower part of Table 2). This decrease was due to the introduction of fluoride tablet distribution at school in the late sixties. In 1970, caries

TABLE 1

Data on Production of Fluoridated Salt in Switzerland

1955	F-salt at 90 ppm F (by addition of NaF) first produced by VSR.
1958	127 tons produced, used in 9 Cantons (of 25).
1960	313 tons produced, used in 20 Cantons.
1964	598 tons produced.
1967	746 tons produced. In 13 Cantons, 80% to 100% of all salt in 1-kg-packages are fluoridated. VSR produced 9.83 millions of 1-kg-packages, and 76% of them contained 90 ppm F. The situation of the 90-ppm-salt has changed very little since then.
1969	F-salt at 100 ppm F for the Canton of Vaud (population 500'000, by addition of KF first produced by SB.
1970	F-salt at 250 ppm F produced by SB. 1-kg-packages as well as 50-kg-sacs for bakeries are fluoridated.
1974	Small scale production of 250 ppm F-salt by VSR for the canton of Glarus (40'000 inhabitants). 1-kg-packages as well as 25-kg-packages for bakeries, canteens.

VSR: Vereinigte Schweizerische Rheinsalinen A.G., producer of salt for 24 Cantons with 5.5 million inhabitants. SB: Saline de Bex, producer of salt for the Canton of Vaud with 0.5 millions inhabitants. VSR and SB are the only Swiss producers of salt for human consumption.

TABLE 2

Average numbers of carious (DMF) surfaces according to the use of domestic salt in control and fluoride children examined at common locations where they were brought together and examined under blind conditions (Switzerland).

Zurich, May 1960	**Age 8–9**	**Age 12–14**
No F-salt or sometimes	8.1	26.0
F-salt (90 ppm) for 4–5 years	6.1	25.4
Total number of children	266	122
Wädenswil, May 1961	**Age 7–9**	**Age 12–14**
No F-salt or sometimes	4.7	22.2
F-salt (90 ppm) regularly since 1956	3.2	22.7
Total number of children	436	395

Cantons FR, NE, VD, April 1970 and 1974	**Age 10**	**Age 12**	**Age 14**
FR, NE 1970, no organized prevention	7.43	15.41	20.24
1974 F tablets irregularly since 1969	5.98	11.17	17.84
Total number of children	339	208	30
VD 1970 F tablets from 1953 to 1969	5.36	10.37	16.22
1974 F salt (250 ppm) since 1970	3.72	7.33	12.62
Total number of children	266	221	213

Zurich: Marthaler, 1961.
Wädenswil: Marthaler and Schenardi, 1962 (unweighted means of 3-year age groups).
Cantons FR and NE: 3 communities (Romont, St-Aubin, Châtel-St-Denis).
Canton VD: 3 communities (Moudon, Grandson, Vevey), Marthaler et al. 1975.

levels in the canton of VD were already as low as those found in the three communities of FR and NE in 1974. In the canton of VD, DMF levels fell further when daily tablet distribution was abandoned in 1970 in favor of salt fluoridation at 250 ppm.

Colombia. With the cooperation of the Pan American Sanitary Bureau, and with a Grant by the National Institute of Dental Research of the USA, an investigation was started in four Colombian towns. The papers describing the project and the results obtained during the period 1964–1972 have been compiled in a special volume (WHO, AMRO, 1976).

The four Colombian communities selected for study were Armenia, Montebello, San Pedro and Don Matías. The four communities, each with stable populations in the range of 8,000 to 12,000, are not adjacent to one another. Don Matías served as control community. In San Pedro fluoride was added to the drinking water. In Montebello and Armenia either NaF or CaF_2 were added to the domestic salt. The first DMF survey was made in 1964. From 1966 through 1972, surveys were made every year by the same group of examiners who conducted the initial 1964 survey. The examiners were regularly checked, with the result that inter-examiner margins of error were brought down to below three percent comparing repeated individual DMFT counts. The total number of examinations carried out in the four communities between 1964 and 1972 was 27,032.

The number of teeth attacked by dental decay is usually denoted as the number of DMF-teeth (decayed, missing and filled teeth). Average numbers of DMF-teeth remained constant in the control community (Table 3). By contrast, DMF teeth averages fell strongly in the fluoride communities. The preventive effectiveness of fluoridated water (San Pedro) and of calcium fluoride (Armenia) and sodium fluoride (Montebello) was very similar. In the younger children for whom fluoride supplementation had begun at age of one to three years, DMF teeth averages were reduced by more than 50 percent. For the children 11 to 13 years of age for whom fluoride supplementation started at age four to six the benefit was slightly less than 50 percent. The reduction of DMF averages obtained in the 3 fluoridated communities was comparable to that obtained by water fluoridation when considering the age at which the children started to consume fluoridated water (Marthaler, 1967).

TABLE 3

Average number of carious teeth (DMF permanent teeth, unweighted means of the averages at ages 8, 9–13 as given by Mejía et al., 1976) per child in 4 communities with either no supplemental fluoride or fluoride added to water or salt from 1965 to 1972 (Colombia).

Year of Examination, (age in years)	No Added Fluoride	F in Water	NaF in Salt	CaF_2 in Salt
1964 8–10 yrs	5.53	4.87	4.33	4.89
1972, 8–10 yrs	5.27	1.78	1.71	1.98
1964, 11–13 yrs	11.24	9.44	8.74	10.49
1972, 11–13 yrs	11.81	4.74	4.50	5.42

Spain. A study of salt fluoridation was started in Pamplona in 1965. Cooperation of a salt production plant was obtained for providing fluoridated salt. A closed institution with some 200 children was chosen for the clinical trial. A study of dietary habits showed that an average of 10 grams of salt was used per person and day. Five grams were needed in the bakery for bread. Based on these figures, a concentration of 112 ppm F (250 ppm NaF) was considered adequate and has been added to the salt used in this institution since the end of 1965. At that time, examinations for DMF counts were made. The second examination was carried out in June 1969. At all ages, DMF averages were substantially lower in 1969 than in 1965 (Vines, 1971).

Hungary. After preliminary studies in 1965, a clinical trial was begun in 1966, using a 250 ppm F domestic salt. In 1968, domestic salt with 200 ppm F and in 1972, salt with 350 ppm F (by adding NaF in all cases) were introduced in two further experimental villages. The salt for bakeries and other industrial processing was not fluoridated.

Results from the study with 250 ppm F in salt are shown in Table 4. The numbers of carious teeth (*def* deciduous or DMF permanent teeth) remained fairly constant in the control villages. By contrast, caries experience fell by more

TABLE 4

Average number of carious teeth (*dmf* deciduous teeth at age 2 to 6 and DMF permanent teeth at ages above 7) on average per child. Fluoridation of domestic salt started in 1966 (Hungary).

Year of Examination	Carious Teeth Per Child Control	Fluoride
Age group 2–6, *dmf* teeth		
1966/67	5.19	4.18
1976	4.56	1.43
Numbers*	516	219
Age group 7–11, DMF teeth		
1966/67	3.85	3.62
1976	2.80	1.45
Numbers	1277	348
Age group 12–14, DMF teeth		
1966/67	7.33	6.60
1976	7.20	3.65
Numbers	818	222

*Numbers of children examined in the control community (examinations 1967 and 1976) and fluoride community (examinations in 1966 and 1976).

than 50 percent in the age groups 2–6 and 7–11, and by slightly less than 50 percent in the children aged 12 to 14. With respect to the deciduous dentition the data suggest that fluoride added to salt is as effective as fluoride added to water.

SOME PROBLEMS OF SALT FLUORIDATION

Production of fluoride-containing salt. In Switzerland and Hungary, fluoride is added to salt by spraying concentrated solutions of NaF or KF on salt on a conveyor belt. In the Colombian experiments, NaF and CaF_2 were first mixed with suitable phosphate carrier salts in the USA. The premixed granulates were then added to the salt produced in Colombia and subsequently shipped to the respective communities.

Twenty years of experience of large-scale production of fluoridated salt in Switzerland showed that batch production of fluoride-containing salt is preferable to continuous production. Conditions necessary for obtaining a homogeneous and stable product ready for use have been given by Rutishauser (1977).

For optimal cariostatic effectiveness, ionized fluoride should be available in the food. Therefore, cations forming insoluble precipitates or stabilizers such as tricalcium phosphate should not be contained in the salt (Alanen and Pohto, 1977).

Determination of optimum fluoride levels in salt. Studies of salt intake are very difficult to conduct. Salt may reach the human consumer by the following ways: 1) domestic salt: purchased as such for the household (visible salt), 2) salt added in local production and preparation: small bakeries, butchers, canteens, restaurants, hospitals (partially hidden salt) and 3) salt added in industrial food production (hidden salt). This hidden salt consumption seems to increase since large-scale production of bread, sausages etc. and of ready-to-eat prepared meals is becoming more frequent.

In many salt consumption studies, it was overlooked that considerable amounts of salt purchased for individual households and used for cooking are not ingested. Only a very small part of the salt added to water used for boiling potatoes, spaghetti, noodles, and vegetables is ingested. Tóth and Sugar (1975) studied this problem on a large scale. They found the following averages (in grams) in Hungary:

Salt sold	10.97 g/day and person
Used in private households	8.25 g/day and person
Ingested with food	3.34 g/day and person

Regarding the distribution of fluoride in the body, considerable work has been done on blood samples, duct saliva samples, bone samples, dental hard tissue samples (WHO, 1970). In blood and duct saliva, concentrations between 0.01 to 0.04 mg/l are usually present. Older data indicating much higher contents have been shown to be incorrect. Since fluoride is trapped in deep enamel and in primary dentine, samples of hard dental tissues available from extracted teeth give valuable information regarding fluoride supply to the body at the age at which these tissues became mineralized. The increased fluoride intake obtained by salt fluoridation has been demonstrated in this way (Baumgartner et al., 1976).

The study of urinary fluoride levels is most important for determining optimum levels of fluoride in salt. Individual concentration in spot samples may be very high after a meal with high amounts of salt since up to 50 percent of a single dose of fluoride may be excreted in the urine within a few hours. In the age range of 20 to 50 years approximately 50 percent of all ingested fluoride are excreted. The average urinary F-concentration in regions with optimal fluoride content in drinking water is approximately 1 ppm. For large-scale monitoring of F-salt, it may be sufficient to choose 0.8 to 1.0 ppm F in pooled urine from groups as target concentrations. Some data obtained in salt fluoridation studies are given in Table 5.

TABLE 5

Some Data on Urinary Fluoride Concentrations, mg F/l

Source of Data	Age Range	Fluoride Concentration
USA		
1945, prior to water fluoridation	12–17	0.1 –0.3
1955 after 10 years of F water (Grand Rapids, Zipkin et al. 1956)	12–17	0.9 –1.1
Switzerland		
1970, 90 ppm F in salt (St-Aubin, Peters et al. 1975)	7–15	0.39
1974, 250 ppm F in salt	7–15	0.84–1.24
1974, 250 ppm F in salt (Peters et al. 1975)	Adults	1.11–1.24
Colombia, 1972, fluoridation since 1965		
Don Matías, control	12–14	0.23
San Pedro, F-water (1 ppm F)	12–14	0.90–1.20
Montebello, NaF in salt (200 ppm F)	12–14	0.74–0.87
Armenia, CaF_2 in salt (200 ppm F) (Mejía et al. 1976)	12–14	0.75–0.80
Hungary 1977, F since 1972 or earlier		
220 ppm F in salt	2–14	0.75
	Adults	0.69
250 ppm F in salt	2–14	0.86
	Adults	0.85
350 ppm F in salt	2–14	0.73
	Adults	1.10

CONCLUSIONS

Fluoride ingested via salt does prevent dental caries in man. The cariostatic effectiveness seems to be equal to the one provided by fluoride in water when the fluoride content of salt is adjusted so that it provides urinary fluoride excretion levels similar to those associated with optimal fluoride content of water.

It is possible to produce a homogeneous, stable salt containing fluoride in the order of magnitude of 250 ppm F. Batch mixing of NaCl and NaF granulates under conditions of controlled temperature and humidity now thoroughly investigated is preferable to continuous process production methods.

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