Caries prevalence in adults seven years after previous exposure to fluoride in domestic salt

Summary

The aim of this study was to compare caries prevalence in three groups of adults aged 18 to 47 who had had different exposures to fluoride. The first group of adults (N = 205) had continuously lived in a town with 1.1 ppm natural fluoride in the drinking water, considered to be optimal in the Hungarian climate. The second group (N = 213) had been consuming fluoridated salt (200–350 ppm F) between 1966 and 1985. The third group (N = 258) had minimal exposure to fluorides. In 1991/92, examinations for caries were carried out according to WHO-guidelines. Caries prevalence was lowest in the subjects who had been using fluoridated water during their entire life whereas the subjects with minimal fluoride exposure had DMF-averages 1.5 to 2.5 times higher. In the subjects who had been using fluoridated salt from 1966 to 1985, caries prevalence was intermediate but consistently lower than that of the residents of the villages where the fluoride exposure was minimal. The results show that fluoridated salt provides a protective effect against caries up to the age of 38–47 years.

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Introduction

In 1966, a research group headed by K. Tóth started to investigate the caries preventive effect on human dental caries of fluoridated domestic salt in agricultural villages situated around the Hungarian city of Szeged. At that time, most of the inhabitants worked at the local agricultural co-operative as farmers. Children went to school locally, each village having an 8-year school curriculum which ended at the age of 14 years. Only few children went to high school or university; most of them stayed in the villages as farmers and in related professions. A bus connection to Szeged existed already, but the buses ran infrequently. The low mobility of the population was an advantage for carrying out the investigations, because the consumption of the fluoridated salt by the children suffered only few interruptions during summer holidays. At the time of the salt fluoridation project people had very few opportunities to travel, and the absence of the children was generally not more than one or two weeks a year. Similarly, it was almost impossible for the fluoridated salt, produced at the Szeged University Dental Institute, to spill over to the reference villages. The result of the studies, including food analyses and fluoride determinations in food and urine were published in a large number of papers, and the results were eventually put together in a monograph (TÓTH 1984).

Production and consumption of the fluoridated salt ended in 1985. At that time, examinations showed that the cariostatic effect of fluoride administered through salt was found to be as strong as that obtained through fluoridated water, i. e. in the range of 50 to 60 percent reduction of DMFT-experience in the age range of 5–14 years (TÓTH, a, 1984).

In 1991–92 there were still enough inhabitants with a history of permanent residence in the test and reference villages to provide a basis for a study of caries prevalence. It was therefore considered to be useful to check whether there was a measurable residual caries protective effect of the fluoride used previously during up to 19 years. The purpose of this paper is to present the results of dental examinations obtained in adults with and without earlier exposure to fluoridated salt and to compare

Table I Number of subjects examined according to residence, sex and age

AGE (years*)	BORN IN	CONSUMPTION OF FLUORIDE in water (all life)			in salt (1966-85)			LOW F LEVEL REFERENCE		
		men	women	total	men	women	total	men	women	total
18–27	1964–73	31	41	72	41	35	76	19	39	58
28–37	1954–63	20	47	67	29	30	59	37	41	78
38–47	1944–53	24	42	66	44	34	78	54	68	112
TOTAL		75	130	205	114	99	213	110	148	258

* Age in years at last birthday

a possible residual effect of fluoridated salt with that of long term water fluoridation.

Material and methods

Study population: Group 1 (fluoride in drinking water): In the last 25 years the population number in Kunszentmárton (natural 1.1 ppm fluoride in water) has been around ten thousand. Group 2 (fluoridated salt): According to the 1965 Statistical Yearbook of Csongrád county, the population figures were 2909 in Deszk (250 ppm fluoride in salt beginning in 1966), 3860 in Röszke (200 ppm beginning in 1968) and 643 in Gyálarét (350 ppm since 1972). From 1981 till November 1985 (when production of fluoridated salt at the University of Szeged ended) the fluoridated salt supplied to the 3 villages contained 350 ppm F (Tóth, b, 1984). In part of the families, fluoridated salt may have been used until early 1986. This delay of a few months is negligible when compared to the long period of consumption of fluoridated salt. Group 3 (reference villages) Szőreg, Tápé and Dorozsma, the total population was 19,301. Since the beginning of Tóth's investigations until 1992 the number of inhabitants in these settlements had not changed substantially.
Fluoridated salt: The fluoridated salt used in the experiment was produced in the laboratories of the University Dental School in Szeged, Hungary. In the shops of the experimental villages only this type of salt was sold, and the kitchens of the kindergartens and the schools used it, too. In Hungary children received 3 or 4 meals daily in kindergarten and generally 3 meals at school, because they stayed there for 8–9 hours, while their mothers were working. The salt for bakeries was not fluoridated, whereas communal kitchens used the fluoridated salt. The inhabitants of the three villages were informed about the project and were asked not to use other methods of caries prevention, with the exception of toothbrushing. There was no organized caries prevention in the schools of the villages studied nor was there a dental prevention program for the entire country. (Fluoridated toothpastes have been available since the early eighties but did not immediately become popular, particularly in the villages.) The drinking water in all villages contained 0.2 ppm fluoride or less.
Dental examinations: Dental examinations of the adults were carried out in 1991/92. Group 1 consisted of the inhabitants of Kunszentmárton, where the average fluoride content of the drinking water has been 1.09 mg/l for the last 50 years (Tóth 1984). The second group comprised subjects from Deszk, Röszke and Gyálarét who had been consuming fluoridated domestic salt between 1966 and 1985. In these two groups only those persons were examined who were born and had lived continuously in these villages. The subjects were asked before the examination whether they had always lived at the same place. Those who had moved to Kunszentmárton, Deszk, Röszke or Gyálarét as adults were not included in the study. The third group consisted of subjects from the 3 reference villages where the fluoride exposure was minimal. The fluoride content of the drinking water was 0.15 ppm in Szőreg and 0.2 ppm in Dorozsma and Tápé (Tóth, c, 1984).
The examinations were carried out by one of the authors (M. R.) in conjunction with a lung screening program which was compulsory for everybody in 1991. Generally, the standards recommended by the WHO (WHO 1987) were adopted. Subjects older than 47 were not included because in this age group extractions due to periodontal disease are more frequent than for dental caries, and the DMF index is therefore not a reliable measure of caries prevalence (Fermin & Carranza 1979). The number of the examined persons by age is shown in Table I. Explorers, plane mouth mirrors and natural daylight were used for the examinations. All comparisons were based on 28 teeth, the third molars being excluded. Teeth with primary, secondary and root caries were considered as decayed teeth. Caries was diagnosed at the cavity level; pre-cavity lesions were not considered. Teeth with crowns (CrT) were recorded separately from teeth with fillings (FiT) and were included in the DMFT-count.
Student's t-test was used for testing the statistical significance between DMFT averages.

Results

Table II shows the data of the DMFT indices in the three groups. DMFT-averages were consistently lowest in the first group, with lifelong exposure to optimal levels of fluoride in the drinking water. At the age of 18–27, the averages were 5.45, 7.68 and 13.82 DMFT in the first, second and third group, respectively. The same pattern was observed in the subjects aged 28–37 and

Table II Average number of DMFT teeth in 1991/92 according to the level of fluoride consumption

AGE (years)	BORN IN	CONSUMPTION OF FLUORIDE in water (all life)		in salt (1966–85)		LOW F LEVEL REFERENCE	
		mean	SD	mean	SD	mean	SD
18–27	1964–73	**5.45***	4.85	**7.68*****	6.41	**13.82**	10.47
28–37	1954–63	**9.69*****	5.85	**13.39****	5.74	**16.53**	6.11
38–47	1944–53	**12.66***	7.61	**15.10*****	6.71	**19.23**	6.43

Statistical significance when contrasted to next average on the right: *p < 0.05, **p < 0.01, ***p < 0.001

38–47, group 2 having intermediate means between the low DMFT-averages in the water fluoride and the high ones in the reference group. Within each age bracket, the statistical significances between the first and second group were at $p < 0.05$ or < 0.001 while between the second and the third group they were at $p < 0.01$ or < 0.001 (Table II).

The average numbers of decayed, missing and filled teeth (those with crowns separately recorded from those with mere fillings) are shown in Table III. On average, there were between 0.91 and 2.41 DT, with no obvious connection to age or fluoride exposure. MT increased strongly with age to averages of 7.57 (first group, age 38–47), 7.17 (second group) and 10.26 (third group, reference). The average number of teeth with fillings (FiT) was consistently lowest in the optimal water fluoride (first) group. Above the age of 37 it decreased in all groups whereas the number of crowned teeth exceeded the number of teeth with filling. At all ages, the subjects of the reference group had more crowned teeth than those in the other groups. The number of the crowned teeth increased parallel with the increasing number of the MT, because the crowns were made mostly to anchor bridges or removable partial dentures replacing the extracted teeth.

Although no specific fluorosis index has been used, the examiner, familiar with the appearance of fluorosis, did not see such cases.

Table III Average number of DT, MT, FiT, CrT* and DMFT in different age groups according to the level of fluoride consumption*

	DT	MT	FiT	CrT	DMFT
Group Nr. (type)					
18–27 years					
1 (F-water)	1.66	1.13	2.48	0.18	5.45
2 (F-salt)	2.17	1.11	4.10	0.30	7.68
3 (Reference)	1.80	2.99	8.12	0.91	13.82
28–37 years					
1 (F-water)	1.86	4.38	2.25	1.20	9.69
2 (F-salt)	2.41	4.98	4.46	1.54	13.39
3 (Reference)	1.65	5.76	6.28	2.84	16.53
38–47 years					
1 (F-water)	0.91	7.57	1.54	2.64	12.66
2 (F-salt)	2.02	7.17	2.47	3.44	15.10
3 (Reference)	1.44	10.26	2.92	4.62	19.23

* FiT: teeth with fillings, CrT: crowned teeth, FiT+CrT=FT

Discussion

In accordance with well-known world-wide observations (NEWBURN 1989, MURRAY et al. 1991), the DMFT experience of permanent residents of Kunszentmárton, where the drinking water has contained fluoride at the optimum level for decades, was about half of that in the reference villages. The main result of this survey is that adults who had been exposed earlier to fluoridated salt for up to 19 years still benefitted from a residual protective effect of the fluoride. For the majority of the subjects, the exposure had begun when they were 3 to 23 years old and lasted for 19 years (200 or 250 ppm between 1966 and 1981, and 350 ppm from 1981 to 1985). In the age group 18 to 27 only those born in 1964, 1965 and 1966 had been exposed to fluoridated salt during 19 years while the youngest adults among them, born in 1973, used fluoridated salt only during 12 years. The subjects from Gyálarét consumed fluoridated domestic salt with 350 ppm F during 13 years, from 1972 to 1985.

At all ages, the components of the DMFT were lower in the fluoridated groups (1 and 2) than in the reference group (3), except for the DT counts in group 2. These high DT averages were due to the absence of a local dental service in one of these villages (Gyálarét), and part of the adults there did not make the effort to seek dental treatment outside their village. This disadvantage did not exist for these subjects when they still were at school age, because the children's dental service transported them to neighboring villages for dental care.

Caries experience of adults from Deszk had been investigated by Tóth (TÓTH, d, 1984) in 1966, 1971 and 1979. In the age group 21–25, the average DMFT declined from 17.0 in 1966 to 11.2 in 1979, while in 1991 subjects of largely the same age (18–27) had only 7.7 DMFT (Table IV). The Deszk subjects examined in 1979 had consumed salt containing 250 ppm during 13 years (1966–1979, consumption starting between age 8 and 12) whereas the subjects examined in 1991 had profited from fluoridated salt during 19 years (from 1966–1985, consumption starting between age 0 and 8); in addition, the fluoride concentration was increased to 350 ppm for all of them during the last 4 years prior to the cessation of the program. In the absence of changes of other factors this prolonged and enhanced fluoride exposure would seem to be the most likely reason for the lower DMF in 1991 as compared to 1979. The overall decline from 17.0 DMFT (1966) to 7.7 (1991) corresponds to a 55% reduction. In the age group 31–35 (28–37 in 1991), a similar albeit smaller decline of 32% (from 19.7 to 13.4 DMFT, Table IV) was observed.

Table IV Average DMFT in adults of Deszk and other communities using fluoridated domestic salt (250 ppm F from 1966–1972, then 350 ppm until 1985)

		Age Groups					
Year	**(subjects)**	**15–20**	**21–25**	**26–30**	**31–35**	**36–40**	**41–45**
1966*	**(70–119)**	10.7	17.0	18.8	19.7	21.4	22.6
1971*	**(54–93)**	11.8	15.3	17.5	18.7	19.7	20.6
1979*	**(28–55)**	7.6	11.2	15.8	16.4	16.7	22.4
			18–27		**28–37**		**38–47**
1991**			7.7		13.4		15.1

* Data from Deszk 1966–1979: Tóth (1984), Table 93

** Data from Deszk, Gyálarét and Röszke 1991: Table II (numbers in Table I)

In the age group 41–45, the average DMFT ranged between 20.6 and 22.6 from 1966 to 1979, without evidence of a decline during these 13 years (Table IV). In fact, the subjects examined in 1979 were already 28–32 years old when they started to use fluoridated salt, which was obviously too late for a measurable protective effect. By contrast, the same age group (38–47) had only 15.1 DMFT in 1991; these subjects were 13–22 years old when they started to consume fluoridated salt for a period of 19 years. Similarly, O'MULLANE et al. (1996) documented a beneficial topical effect in subjects who started to use fluoridated water when they were already young adults.

In 1966, prior to fluoridation, the average DMFT of subjects aged 15–20 had been 10.7 (TÓTH, d, 1984; Table IV). In the absence of protective fluoride effects, the DMFT for the oldest adult group increased from 10.7 at age 15–20 (Table IV) to around 22 DMFT at age 41–45 (22.6, 20.6, 22.4 DMFT in 1966, 1971, 1979 respectively). Under conditions of salt fluoridation, the corresponding increase was from 10.7 to only 15.1 DMFT, as documented for 1991. Accordingly, an average DMFT increment of 11.3 (from 10.7 to 22) may be estimated as compared to 4.4

(from 10.7 to 15.1), corresponding to a reduction due to fluoridated salt of 61%.
The substantial protective effect of the fluoridated salt must be seen in the light of frequent use of domestic salt under Hungarian life conditions, at least until the late eighties. Prepackaged spices containing salt added during industrial process were virtually non-existent up to the eighties. On the contrary, domestic salt was used in the individual households for curing meat, making preserves, pickles etc., tasks rarely done at home in highly industrialized countries. Accordingly, average ingestion of domestic salt was 3.3 grams per person and day (TÓTH, e, 1984), whereas in Western Europe it is typically between 1.5 and 2 grams (BURT & MARTHALER 1996). The noteworthy cariostatic effectiveness was due to the increased number of meals and foods prepared with fluoridated salt and to the increased concentration of 350 ppm in the later stages rather than the higher intake per se.
Previously, evidence for a cariostatic effect of fluoridated salt in adults was obtained from a study with 20-year-old Swiss military recruits (MENGHINI et al. 1991). Fluoridated salt had been used by 56 of them since the age of 5. Their average DMFT was 7.1 which was 30% lower than the DMFT of 10.2 of 153 recruits from the same region (Western, French speaking Switzerland), who had consumed unfluoridated domestic salt or salt containing only 90 ppm fluoride (less than 50% of them). The average DFS-count and radiological DF of approximal surfaces were 33 and 38% lower, respectively, in the recruits who had consumed fluoridated salt as compared to the reference group. Since the fluoridated salt program started when they were already 5 years old, the effect was mainly topical. Similarly, in the present study, the adults aged 30 and older in 1991 had received supplemental fluoride, via salt, at the earliest after completion of their first 5 years of life.
In conclusion, this paper presents evidence of a caries-protective effect of fluoridated salt extending up to the age of 45 years. In view of consumption of fluoridated salt starting as late as in adolescence for part of the subjects and not continued during the last 6 years prior to the caries examinations, the protection can be considered substantial. On the other hand, it is not surprising that life-long use of fluoride at the optimum level in drinking water provided a superior protection.
In the present study, dental fluorosis was not assessed systematically. Nevertheless, the fact that no cases of obvious fluorosis was observed is in agreement with a recent paper on 49 subjects from the Csongrád County who had been consuming the 350 ppm fluoridated salt from birth to 2.3–3.8 years (STEPHEN et al. 1999). Evidence of significant anterior tooth fluorosis and a difference to 59 subjects who had not been consuming fluoridated salt were not observed upon clinical examinations nor on standardized photographs.

Zusammenfassung

Ziel dieser Erhebung war der Vergleich der Kariesprävalenz in 3 Gruppen von 18- bis 47-jährigen Erwachsenen mit unterschiedlicher Fluoridversorgung. Die erste Gruppe (N = 205) lebte in einer ungarischen Stadt, in der das Trinkwasser natürlicherweise Fluorid im optimalen Bereich von 1,09 ppm enthielt. Die zweite Gruppe (N = 213) hatte zwischen 1966 und 1985 fluoridiertes Kochsalz (200 bzw. 350 ppm) benützt. Die dritte Gruppe (N = 258) hatte nur minimalen Zugang zu systemischen Fluoriden. 1991/92 wurden Kariesbefunde gemäss den WHO-Richtlinien erhoben. Die Kariesprävalenz war am niedrigsten in der Gruppe, welche zeitlebens das optimal fluoridhaltige Trinkwasser benützt hatte. In der dritten Gruppe, mit minimaler Fluoridexposition, waren die DMF-Durchschnitte 1,5 bis 2,5-mal höher. Bei den Personen, die zwischen 1966 und 1985 fluoridiertes Salz benützt hatten, lag der Kariesbefall zwischen den beiden anderen Gruppen, jedoch regelmässig niedriger als in der dritten Gruppe mit minimaler Fluoridexposition. Die Resultate zeigen, dass fluoridiertes Salz einen Kariesschutz weit ins Erwachsenenalter gewährleistet.

Résumé

Le but de cette étude était de comparer la prévalence de carie chez trois groupes d'adultes, âgés de 18 à 47 ans, préalablement exposés à des doses différentes de fluorures. Le premier groupe (N = 205) avait vécu sans interruption dans une ville avec une eau potable à 1,1 ppm de fluorures naturelles, une concentration considérée comme optimale pour le climat hongrois. Le deuxième groupe (N = 213) avait consommé du sel fluoré (200–350 ppm F) entre 1966 et 1985. Le troisième groupe (N = 258) n'avait été exposé qu'à des doses minimes de fluorures.
Dans les années 1991/92, les examens effectués selon les directives de l'OMS ont montré que la prévalence de carie était la plus faible chez les sujets ayant utilisé l'eau fluorée durant leur vie entière. En revanche, les individus exposés à des doses minimes de fluorures, présentaient des taux DMF moyens 1,5 à 2,5 fois plus élevés. Quant aux sujets ayant utilisé le sel fluoré leur prévalence de carie s'est révélée être intermédiaire, mais toujours inférieure à celle des habitants de villages en l'absence quasi totale de fluorures. Les résultats montrent que le sel fluoré fournit un effet de protection contre la carie jusqu'à l'âge de 38 à 47 ans.

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