

History of water fluoridation

Betul Kargul* / Esber Caglar** / Ilknur Tanboga***

Fluoride, the milestone element of pediatric dentistry, as well as modern dentistry, has been utilized for the last six decades in practice. Researchers all over the world have used fluoride in several forms in the prevention of tooth decay. Today, we are aware that most of this work has involved clinical research with children. It is particularly pertinent that the subject be adequately presented in the field of pediatric dentistry. In 1940's and 1950's were the years of ten-year studies, where caries reductions were first described. The industry of systemic fluoridation, public campaigns and advertisements became popular mostly in western world in 1960's and 1970's. The fluoridated dentifrices and changes of dentifrice formulations were established in 1980's. Many stated that children should receive one form of systemic fluoride and appropriate forms of topical fluoride in 1990's. Analyses showed that maximum protection against caries is obtained when teeth erupt into an environment with low concentrations of ionic fluoride. The similarity in caries reductions obtained in water fluoridation studies and long-term studies with topically administered fluoride regimens, including fluoride-containing dentifrices, indicates that the pre-eruptive effect of fluoride is of borderline significance relative to the more significant post-eruptive effect. It has taken a long time to show that water fluoridation and topical fluoride programs were thus important measures for the control of caries at the community level. Today, we are aware of the fact that the trio of diet, dentifrice and supplementation should exceed the optimal levels.

J Clin Pediatr Dent 27(3): 213-218, 2003

INTRODUCTION

Fluoride has been utilized for the last six decades. Researchers all over the world used fluoride in several forms in the prevention from tooth decay. We absolutely know that there are numerous sources of fluoride that contribute to human fluoride consumption. Food and drinking water are major sources, the latter being particularly important where the water is fluoridated.

There is recent data about fluoride and water fluoridation.¹⁻¹⁴ Based on extensive research, the United

States Public Health Service (USPHS) established the optimum concentration for fluoride in the water in the range of 0.7 to 1.2 parts per million. This range effectively reduces tooth decay, while minimizing the occurrence of dental fluorosis.¹⁵

Foods and carbonated beverages processed with fluoridated water are sources of dietary fluoride, regardless of where they are consumed. For infants and young children, baby cereals as well as powdered and concentrated liquid infant formulas, when mixed with optimally fluoridated water, may represent a particularly important source of fluoride consumption.¹⁶ The fluoride absorption rate from fluoride-containing drinking water, beverages, and supplements is typically around 95%.¹⁷

Today, we are aware of the fact that most of this work has involved clinical experimentation with children. Since many of these techniques are directly involved with the cure of dental caries in the young age groups, it is particularly pertinent that the subject be adequately presented in the field of pediatric dentistry field. Although the current results are of more importance compared to the discovery, the first attempts in water fluoridation should be noted and respected.

1800'S FLUORIDE

Occurrence of fluoride in calcified tissues was already known at the beginning of the nineteenth century. Magitot demonstrated the earliest reference relating

* Betul Kargul, DDS, PhD is Associate Professor, Department of Pedodontics, Faculty of Dentistry, Marmara University, Istanbul, 80200 Turkey.

** Esber Caglar, DDS is Research Assistant, Department of Pedodontics, Faculty of Dentistry, Marmara University, Istanbul, 80200 Turkey.

Ilknur Tanboga, DDS, PhD is Professor, Head of the Department, Department of Pedodontics, Faculty of Dentistry, Marmara University, Istanbul, 80200 Turkey.

Send all correspondence to Dr. Esber Caglar, Marmara University Faculty of Dentistry, Department of Pedodontics, Buyukciftlik sok No. 6, Nisantasi, Istanbul, 80200 Turkey.

Tel: 00902122319120

Fax: 00902122465742

E-mail: caglares@yahoo.com

fluoride to dental caries in 1878. While he was studying the action of various organic acids on extracted teeth, he noted that a solution of 1:1000 acetic acid was "without action upon the enamel, but vigorously attacks both the cement and the ivory".¹⁷

1900'S REPORTS ALERTED RESEARCHERS

In the intervening years, a series of events focused attention on the possible toxic effects of fluoride on the dentition. The occurrence of disfigured teeth was reported among people residing in the vicinity of Naples, Italy. This was believed to be due to a substance in the water that altered the calcification process. In the United States, it was also common to see the same among residents living in certain sections of Colorado, Arizona, New Mexico and Texas.¹⁷

1930'S FLUORIDE, SOMETHING WEIRD IN WATER?

American and French investigators working independently showed that minimal quantities of fluoride were responsible for the abnormality. Churchill developed a method for determining concentrations of fluoride in drinking water. He showed that below 0.9 ppm fluoride in water, there was no toxicity and no mottled enamel.¹⁸

The immediate reaction to these observations was replacing water supplies containing levels of fluoride that produced mottling with those that were fluoride free. In certain instances this was not economically feasible. Possible benefits of fluoride in caries control were largely forgotten due to researchers attempts to develop methods removing excess fluoride from the water. Although mottling of the enamel focused attention on the toxicity of fluorides, it played a major role in pinpointing the relationship of the element to caries prevention.

Black and McKay observed that teeth so affected from fluoride had a limited susceptibility to dental caries. In the late 19th century, caries levels reached a maximum in Europe and North America after refined sugar became a cheap staple food.¹⁹ Clinical examinations for dental caries by Dean and his associates and accompanying water analysis by Elvove not only clearly illustrated the epidemiology of dental fluorosis, but carefully documented the reduction in dental caries liability that accompanied such a state.¹⁷

In 1938, early inventions of Churchill gave Dean and his associates the opportunity to study the epidemiological relationship between natural water fluoride concentrations and the related community caries experience in children, as well as the associated prevalence and severity of enamel fluorosis.¹⁶ This large-scale field study was classic in concept and definitive in execution determining the relationship of the fluoride content of the water and dental caries in 12 to 14 years old children in four cities of Illinois, USA. These cities were Galesburg, Monmouth, Macomb and Quincy. The results of this study are shown in Table 1.¹⁷

As a result of the epidemiological surveys of Dean, Cox suggested that optimal amounts of fluorides be added to public water supplies that were low in or free of fluorides.²⁰⁻²²

Table 1. Dental caries in children and the fluoride content of the domestic water. It was noted that all subjects were 12-14 years old and had a history of continuous residence in their respective communities.¹⁷

City	F ppm in water	No. of children	% with no dental experience	DMF permanent teeth per 100 children
Galesburg	1.8	243	36.2	194
Monmouth	1.7	99	36.4	208
Macomb	0.2	63	14.3	368
Quincy	0.1	291	4.1	628

1940'S BEGINNING OF WATER FLUORIDATION

Once the United States Public Health Service teams had accumulated the initial evidence that certain minimal levels of fluoride in the drinking water could inhibit dental caries in children without producing disfiguring mottling, researchers expanded the subject, studying new areas and re-evaluating information accumulated in the earlier investigations.

Scientists had confirmed the hypothesis in studies involving 21 cities selected on the basis of varying concentrations of fluoride in the public water supplies (Table 2). It had been noted that 12 to 14 year old children with a history of continuous residency in a city having less than 0.5 ppm of fluoride in the domestic water had on an average more than 7 decayed, missing and filled permanent teeth.

In 1942, Hutton proposed an experiment which consisted of studying the effects of artificially fluoridated water on residents of Brantford, Ontario.²³ In 1943, Ast²³ proposed an experiment nearly the same as Hutton in New York. The caries-preventive effect of 1 ppm F had been sufficiently well-established epidemiologically to permit the launching of three major community trials of controlled water fluoridation. In 1945, three important clinical studies were undertaken. These were at Brantford, Ontario, another at Newburgh, New York and the third at Grand Rapids, Michigan. In each instance the fluoride level of the water was supplemented to approximately 1.0 ppm. Studies were under the direction of City Health Departments. For these three studies, three control cities Sarnia, Kingston and Muskegon were utilized respectively.¹⁷ Each control city was a neighboring city with repeated water analyses indicating that fluorides were either absent or present in negligible amounts.

Researchers in those days were aware that fluorides added to the communal water supply, presumably must have been incorporated into the calcifying tooth before they are maximally effective in limiting tooth decay. Since formation of the primary and permanent teeth had covered a span of ten or more years, a total fluoride effect on tooth decay could be determined only after a decade of water fluoridation.

Soon after these studies, a quadro study in Southbury, Connecticut; Sheboygan, Wisconsin; Marshall, Texas; Ottawa, Kansas was done.²³ According to Grossman, while fluoridation of a community water supply is both practical and economical, the value of such fluoridation for inhibiting dental decay would not be known for nearly another decade. Most of the scientists thought that the bulk of the population was concentrated in rural areas not the cities and towns.²⁵

Table 2. Dental caries in children and fluoride concentration in the public water supply.¹⁷

No. cities studied	No. of children examined	Permanent DMF teeth Per 100 children	Fluoride concentration of public water supply in ppm
11	3867	More than 7	Less than 0.5
3	1140	4	0.5 to 0.9
4	1403	3	1.0 to 1.4
3	847	2.5	More than 1.4

1950'S IT WORKS

With the excitement of the early results, water fluoridation started in the US in the states of Florida and Illinois. The state of California started in 1952, Ohio in 1955 and finally Missouri in 1957.²⁴ However, the literature did not accept the new concepts. The 10 year findings of the studies that started in 1945 were first demonstrated in JADA, volume 52, 1956.

Table 3 summarizes the 10 year findings relative to dental caries in Newbrugh children.¹⁷ Selected findings from the Brantford study are presented in Tables 4 and 5. Water fluoridation had begun in 1945 and the summary data were taken from the years 1948, 1951 and 1954. Researchers had an opportunity to support the belief that the addition of 1 ppm of fluoride to the drinking water would result in a maximal reduction in the permanent tooth caries experience of 6 to 8 year old children of continuous residency within ten years after fluoridation. With similar conditions, a significant, but not a complete reduction in the permanent tooth dental caries experience had been achieved in 12 to 14 years old.

In some regions of Canada, Chile, Brazil, New Zealand water fluoridation had begun in relative years. Based on experience of overseas countries, this type of

prevention of dental caries was started also in European countries. In the Netherlands and Czech Republic, fluoridation of drinking water introduced in 1958.^{26,27} In 1959, Knutson reported that approximately 35,000 residents in USA were drinking fluoride treated water as of August, 1959. Another 7 million had natural fluoride in the drinking water.²³

Table 3. Dental caries in children drinking domestic water with additions of 1.0 to 1.2 ppm fluoride.* Newbrugh children in these groups exposed to fluoridated water since birth.¹⁷

Age	City	ppm of F added	DMF teeth Per 100 children with permanent teeth	% reduction
6-9*	Newbrugh	1.0 to	98.4	57.9
	Kingston	0	233.7	-
10-12	Newbrugh	1.0 to	328.1	53.0
	Kingston	0	698.6	-

Table 4. Mean primary DMF teeth Per child of continuous residency in selected Canadian cities in 1948, 1951 and 1954.* Brantford added approximately 1.2 ppm F to water in 1946.** Stratford had approximately 1.2 ppm in water naturally.*** Sarnia had no F in water.¹⁷

Year	1948		1951		1954	
Age groups	6-8	9-11	6-8	9-11	6-8	9-11
Brantford*	4.95	2.37	3.58	2.25	2.76	1.93
Stratford**	2.20	1.66	2.62	1.76	2.63	1.58
Sarnia***	4.89	2.50	4.89	2.41	5.21	2.11

Table 5. Mean permanent DMF teeth Per child of continuous residency in selected Canadian cities in 1948, 1951 and 1954.* Brantford added approximately 1.2 ppm F to water in 1946.** Stratford had approximately 1.2 ppm in water naturally.*** Sarnia had no F in water.¹⁷

Year	1948			1951			1954		
Age groups	6-8	9-11	12-14	6-8	9-11	12-14	6-8	9-11	12-14
Brantford*	1.41	4.07	7.68	0.93	2.85	6.10	0.44	2.27	4.89
Stratford**	0.41	1.13	2.55	0.75	1.76	3.12	0.47	1.46	3.02
Sarnia***	1.60	4.21	7.94	1.99	4.48	8.55	1.69	4.67	8.84

1960'S W.H.O. ENDORSES THE PRACTICE OF WATER FLUORIDATION

The World Health Organization (WHO) and the Pan American Health Organization endorsed the practice of water fluoridation in 1964.²⁸

University of Illinois College of Medicine and Dentistry started a survey by sending letters to the all recognized pediatric dentists listed in 1965 American Dental Directory. All the letters answered by the specialists demonstrated the fact that pediatric patients who previously suffered from the dental disease decreased up to 65% within the last ten years in the states where water fluoridation was established 10 to 16 years ago.²⁴

1970'S FAR BEHIND THE EXPECTATIONS

Over 150 million people in about 30 countries live in areas where water supplies are fluoridated, and a further 40 million live in areas naturally rich in fluoride. In U.K only about 3 million drink fluoridated water (6 percent of the population), but over 100 million people (60 percent of the population) in the USA.²⁹

1980'S AROUND THE WORLD

Brazil covered 60 million people with fluoridated water. Latin American countries were looking forward to enjoy the system because of the negative factor of high sugar production and consumption in South America.²² In USA, Philadelphia became the first city with a population over 1 million to fluoridate its water supply.²⁹ During the 80's, Germany, Spain, Yugoslavia, USSR, China, and Japan were far away from water fluoridation.²² The concept of the anti-caries mechanisms of fluoride has undergone a paradigmatic shift during the late 1980's deriving the systemic effect of fluorides downgrade.³⁰

1990'S WATER FLUORIDATION, EFFICIENT?

Water fluoridation was accepted in U.S., Australia, Brazil, Canada, Hong Kong, Malaysia, United Kingdom, Singapore, Chile, New Zealand, Israel, Columbia, Costa Rica and Ireland in the 1990's.³¹⁻³⁴ The most recent countywide decision for fluoridated drinking water occurred in South Africa.³⁵ Some of the most thorough investigations of fluoridation have been conducted in Britain and Australia. These investigations have resulted in a significant amount of published documentation, which supports the safety and effectiveness of water fluoridation.^{36,37} Despite these data, Kuopio, the only town artificially water fluoridated in Finland and in Scandinavia, stopped water fluoridation in 1992.³⁸

2000'S FUTURE, NOW?

In contrast to the anticipated increase in dental caries following the cessation of water fluoridation in the former East Germany, Cuba and Finland, significant fall in caries prevalence was observed. This trend corresponded to the national caries decline and appeared to be a new population-wide phenomenon. The causes for the changed caries trend were seen on the one hand in improvements in attitudes towards oral health behavior and, on the other hand, to the broader availability and application of preventive measures (F-salt, F-toothpastes, fissure

sealants etc.). There is, however, still no definitive explanation for the current pattern and further analysis of future caries trends in the formerly fluoridated towns would therefore seem to be necessary.³⁹⁻⁴¹ In the Czechoslovakia Republic, there is a claim that cessation of water fluoridation caused high incidence of caries.²⁷ Political actions contrary to the recommendations of health authorities should not be interpreted as a negative response to water fluoridation, e.g. although fluoridation is not done in Sweden and the Netherlands, preventive health measures, in addition to the use of fluoride toothpastes include; mouthrinses and dietary fluoride supplements.^{28,42} Sweden has been reconsidering the water fluoridation.

Austria, Belgium, Denmark, France and Norway are convinced that fluoridation is a good health measure, but no decision regarding fluoridation has been made.

The reunification of Germany in 1990 has resulted in a complete change in medical and dental care. Water fluoridation in 35 towns, reaching 18% of the citizens, was stopped in 1990. Prior to this date there were technical problems of the fluoridation process that caused ineffective fluoride levels from 1964 to 1985. This has been stated as the most important reason for the lack of decline of dental decay in East Germany. The stopping of fluoridation was not a result of banning, but a change in political, economic and social structures. For example, Germany currently benefits from fluoridated salt and fluoride supplement programs.⁴³

In Switzerland, currently Basel is fluoridating at 1.0 ppm.⁴⁴ Many fluoridation systems that used to operate in Eastern and Central Europe did not function properly and, when the Iron Curtain fell in 1989-90, shut down because of obsolete technical equipment and lack of knowledge as to the benefits of fluoridated water.

In Japan, currently less than 1% has community water fluoridation.^{42,43}

The benefits from water fluoridation are considerably less today than when the method was introduced, mainly because of the increased exposure of fluoride from other sources. The differences in caries prevalence between fluoridated and non-fluoridated areas have decreased.³⁰ It should be concluded that water fluoridation needs be targeted on high caries areas, which are normally also areas of social and material deprivation.⁴⁵

Every community, region or country with a high or rising prevalence of dental caries should implement a caries-preventive program that automatically brings the benefits of systemic and topically applied fluoride to the entire population. The fluoridation of community water supplies the requirements of providing safe, effective protection from dental caries at reasonable cost. The use of dietary fluoride supplements, salt or fluoridated milk does not meet the requirements of a comprehensive national or community program because compliance is poor or only selected age groups are targeted. Water fluoridation is ideal for countries,

regions or communities with central water supplies or where salt production or distribution is not centralized or easy to control.⁴⁶

REFERENCES

1. Scott DB. The dawn of a new era. *J Public Health Dent* 56: 235-238 1996.
2. Arnold FA Jr, Likins RC, Russell AL, Scott DB. Fifteenth year of the Grand Rapids fluoridation study. *JADA* 65: 780-785 1962.
3. Ast DB, Fitzgerald B. Effectiveness of water fluoridation. *JADA* 65: 581-587 1962.
4. Blayney JR, Hill IN. Fluorine and dental caries: findings by age group. *JADA (Spec Iss)* 74: 246-52, 1967.
5. Jackson D, James PM, Thomas FD. Fluoridation in Anglesey 1983: a clinical study of dental caries. *Br Dent J* 158: 45-9, 1985.
6. Stephen KW, McCall DR, Tullis JI. Caries prevalence in northern Scotland before, and 5 years after, water defluoridation. *Br Dent J* 163: 324-6, 1987.
7. Brunelle JA, Carlos JP. Recent trends in dental caries in U.S. children and the effect of water fluoridation. *J Dent Res*, 69 (Spec Iss): 723-7, 1990.
8. Horowitz HS. The future of water fluoridation and other systemic fluorides. *J Dent Res* 69 (Spec Iss): 760-4, 1990.
9. Newbrun E. Fluorides and dental caries, 3rd ed. Springfield, Illinois: Charles C. Thomas, publisher, 1986.
10. Lambrou D, Larsen MJ, Fejerskov O, Tachos B. The effect of fluoride in saliva on remineralization of dental enamel in humans. *Caries Res* 15: 341-5, 1981.
11. Mellberg JR, Ripa LW. Fluoride in preventive dentistry: theory and clinical applications. Chicago, Quintessence pp 41-80, 1983.
12. Backer-Dirks O, Kunzel W, Carlos JP. Caries-preventive water fluoridation. In: Progress in caries prevention. Ericsson Y, ed. *Caries Res* 12 (Suppl 1): 7-14, 1978.
13. Fejerskov O, Thylstrup A, Larsen MJ. Rational use of fluorides in caries prevention. *Acta Odontol Scan* 39: 241-9, 1981.
14. Ripa LW. A half-century of community water fluoridation in the United States: review and commentary. *J Public Health Dent* 53: 17-44, 1993.
15. US Department of Health and Human Services, Centers for Disease Control, Dental Disease Prevention Activity. Water fluoridation: a manual for engineers and technicians. Atlanta, September 1986.
16. Workshop Group I, *J Dent Res* 71: 1218-1235, 1992.
17. Finn SB. Clinical pedodontics, 2nd ed, Philadelphia, Saunders, 1965.
18. Gottlieb B. Dental caries, Philadelphia, Lea and Febiger, 1947.
19. Marthaler TM. Dentistry between pathology and cosmetics. *Community Dent Oral Epidemiol* 30: 3-15, 2002.
20. Dean HT. Endemic fluorosis and its relation to dental caries. *Public Health Reports* 53: 1443-52, 1938.
21. Dean HT, Arnold FA, Elvove E. Domestic water and dental caries. *Public Health Reports* 57: 1155-79, 1942.
22. Simonsen RJ. Dentistry in the 21st century: a global perspective, Chicago, Quintessence, 1989.
23. Nizel AE. Nutrition in clinical dentistry. Philadelphia, Saunders, 1964.
24. Douglas BL, Coppersmith SB. *J Ped Dent*. March, 128-134, 1966.
25. Grossman LI. Handbook of dental practice. Philadelphia, Lippincott, 1948.
26. Kalsbeek H, Kwant GW, Groeneveld A, Backer Dirks O, van Eck AA, Theuns HM. Cessation of fluoridation of drinking water; results of caries research in Tiel and Culemborg in the period of 1968-1988 *Ned Tijdschr Tandheelkd*. 99: 24-8, 1992.
27. Lekosova I. Fluorine in the prevention of dental caries *Cas Lek Cesk* 137: 201-6, 1998.
28. World Health Organization. Fluorides and oral health. Report of a WHO Expert Committee on Oral Health Status and Fluoride Use. WHO Technical Report Series 846. Geneva, 1994.
29. Andlaw RJ, Rock WP. A manual of Paedodontics, Churchill Livingstone 2nd ed. 1989.
30. Twetman S, Garcia Godoy F, Goepferd SJ. Infant oral health. *Dent Clin N Amer* 44: 499, 2000.
31. Majid ZA, Hussein NN, Bagramian RA. The prevalence of caries and enamel defects in 229 Malaysian children 16 years after water fluoridation (a pilot study). *Singapore Dent J* 21: 11-5, 1996.
32. Villa AE, Guerrero S, Icaza G, Villalobos J, Anabalia M. Dental fluorosis in Chilean children: evaluation of risk factors. *Community Dent Oral Epidemiol* 26: 310-5, 1998.
33. Heintze SD, Bastos JR, Bastos R. Urinary fluoride levels and prevalence of dental fluorosis in three Brazilian cities with different fluoride concentrations in the drinking water. *Community Dent Oral Epidemiol* 26: 316-23, 1998.
34. Federation Dentaire Internationale. World fluoridation status. Basic Facts 1990.
35. FDI World. South Africa to fluoridate. *FDI World* 6: 7, 1997.
36. Fluoride, teeth and health. Royal College of Physicians. Pitman Medical, London, 1976.
37. Knox EG. Fluoridation of water and cancer: a review of the epidemiological evidence. Report of the Working Party. London: Her Majesty's Stationary Office, 1985.
38. Seppa L. The future of preventive programs in countries with different systems for dental care. *Caries Res* 35(Suppl): 26-29, 2001.
39. Seppa L, Karkkainen S, Hausen H. Caries trends 1992-1998 in two low-fluoride Finnish towns formerly with and without fluoridation. *Caries Res*, 34: 462-8, 2000.
40. Kunzel W, Fischer T, Lorenz R, Brassmann S. Decline of caries prevalence after the cessation of water fluoridation in the former East Germany. *Community Dent Oral Epidemiol* 28: 382-9, 2000.
41. Kunzel W, Fischer T. Caries prevalence after cessation of water fluoridation in La Salud, Cuba. *Caries Res* 34: 20-5, 2000.
42. Roemer R. Legislation on fluoridation of water supplies. In: Experience on water fluoridation in Europe. Copenhagen: World Health Organization. pp 23-36. 1987.
43. Jones S. Water fluoridation in Europe. Paper presented to the British Association for the Study of Community Dentistry, Spring Scientific Meeting, Dundee, Scotland, 1996.
44. Marthaler TM. Water fluoridation results in Basel since 1962: health and political implications. *J Public Health Dent* 56: (5 Spec No), 265-70, 1996.
45. Craig GC. Fluorides and the prevention of dental decay: a statement from the Representative Board of the British Dental Association. *Br Dent J* 188: 654, 2000.
46. Horowitz HS. Decision-making for national programs of community fluoride use. *Community Dent Oral Epidemiol* 28: 321-9, 2000.

