# Successes and Drawbacks in the Caries-Preventive Use of Fluorides – Lessons to be Learnt from History

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**Summary:** Water fluoridation was the first breakthrough in the practice of preventive cariology on a community level and has remained one of the cornerstones of prevention in dentistry. The concepts regarding the mechanisms of the caries-inhibitory effect, however, have changed in several respects. Today there is general agreement that topical effects on the erupted enamel are most important. The contention that there is no pre-eruptive effect whatsoever has created confusion; there is in fact evidence for a minor pre-eruptive protective effect. Around 1980 many experts believed that fluorides should not be used in high concentrations, for instance above those in dentifrices, because this could block remineralisation in the body of pre-cavity lesions. However, it is now known that such undesirable effects are negligible or non-existent.

In the fifties and sixties, fluoride tablets were widely used in Europe and helped to make the concept of caries prevention popular. From 1980 onwards, fluoride dentifrices were found to have a much greater impact and were recognized as being able to lead to a decline of caries prevalence in entire countries, and fluoride tablets gradually lost their importance. Antifluoridationists were unable to delay or hinder the widespread use of fluoride toothpastes but in many cases have successfully opposed public health measures such as fluoridation of water or of salt. The spread of these methods, beneficial for all social strata, might have been more rapid if some of the experts had not propounded the erroneous supposition that fluoride dentifrice will be sufficient for caries prevention.

Sale of fluoridated salt has been authorized in several countries on a nationwide scale. However, only Latin American countries have introduced salt fluoridation for entire populations. In Central and Eastern Europe where caries prevalence continues to be high and where the level of usage of topical fluorides including dentifrices will presumably remain at a low level for many years, salt fluoridation would be beneficial.

Key words: fluoride, fluoridation, caries prevention, historical aspects

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The paper "Recommendations for the Use of Fluoride in Caries prevention?" by Stefan Zimmer et al (2003) in the first Number of "Oral Health and Preventive Dentistry" provides an excellent overview of today's basic scientific concepts of the role of fluorides in preventing or controlling dental caries. The present review is focused on public health and political aspects regarding caries prevention by means of fluoride.

Regarding the implementation of caries prevention on the public health scale, interesting and sometimes unexpected developments took place in the second half of the 20th century. In many cases endeavors to introduce fluorides were unsuccess-

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ful, and the respective reasons were often difficult to identify. Most of the difficulties were due to antifluoride lobbies, which started to become active soon after water fluoridation was recommended. In spite of extensive material disproving their sometimes irrational claims, antifluoride activists have denied the benefits and the safety of fluorides as recommended in modern dentistry.

While scientific views on details of the effects of fluorides on teeth underwent a number of changes in the course of the second half of the twentieth century, the early findings regarding the safety of the recommended fluoride uses were confirmed by increasingly sophisticated research using updated methods and criteria. On the other hand, it emerged that the caries-preventive potential of fluoride is much greater than assumed in the early days of water fluoridation: Topical fluorides in various forms – most commonly when added to dentifrices – have caused much stronger declines of caries prevalence than was anticipated.

On the worldwide scene, only a minority – about one out of 10 children – benefits from the potential of fluorides in controlling caries. However, even in industrialized countries where prevention has been functioning for decades, much remains to be done. In Central and Eastern Europe, for instance, caries prevalence is high (Künzel, 2001) and the use of fluorides is still insufficient to provide a substantial protection against caries.

#### WATER FLUORIDATION – THE FIRST BREAK-THROUGH OF PREVENTIVE DENTISTRY

Several epidemiological studies, published mostly between 1939 and 1951, showed that children aged 13–14 who lived all their lives in the same city where the drinking water contained around 1 ppm (1 milligram of fluoride per liter), had on average approximately only half as many DMF-teeth as were found in children of comparable cities where fluoride contents were below 0.3 ppm.

Based on these findings, "artificial" fluoridation of the drinking water was introduced in 1945 in three cities, two of them in the USA, and one in Canada: Grand Rapids, (Michigan), Newburgh (New York) and Brantford (Canada). After 10 years it became evident that dental caries prevalence in the three fluoridated cities (1 ppm) was decreasing (Arnold, 1957). In addition, it was possible to predict that in due time the low caries levels documented in cities where the drinking water had always contained around 1 ppm fluoride should also be attained in these three cities. Numerous studies proved this prediction correct. It should be noted that up to the late fifties, which is before fluoride toothpastes began to become available and to play a role in public health, caries remained stable locally. Accordingly, the results of the early studies were not confounded by any secular decline of caries prevalence.

With a heretofore unknown energy, the dental profession and academia, first in the USA and Canada, and soon in other English speaking countries, made concerted efforts to introduce water fluoridation wherever it was considered technically feasible. For more than two decades, fluoridated drinking water has been provided to the majority of the population in the USA, Canada, Ireland and Australia and reaches all inhabitants of Hong Kong and Singapore.

Up to about 1985, initiatives for water fluoridation were successful in more than 8,000 communities in the USA and more than 1,000 other communities scattered around the world. This number is evident from the chapter "Community fluoridation schemes throughout the world" (Murray, Rugg-Gunn and Jenkins, 1991). Water fluoridation will remain the first historical breakthrough in preventive dentistry.

More recently, water fluoridation was introduced in large cities like Los Angeles and San Antonio, Texas. In the Basque Province of Spain, the drinking water of most of the large cities is now fluoridated. In the United Kingdom, the policy is to use fluoridation of water - or of milk as an alternative - in those regions where caries prevalence continues to remain high. On the other hand, water fluoridation was abolished after the political changes of 1989-1990 in Central and Eastern European countries. Of the approximately 100 schemes in Eastern Germany and the former Czechoslovakia, none has survived the fall of communism in 1989. Colombia and Mexico have switched from water to salt fluoridation policies on a nationwide scale in order to increase the proportion of their population covered by fluoridation.

#### CHANGING CONCEPTS REGARDING THE CARIO-STATIC FLUORIDE MECHANISMS: PREDOMI-NANCE OF TOPICAL EFFECTS DEFINITELY DEM-ONSTRATED

The original idea was that fluoride provides the teeth with a kind of "constitutional caries resis-

either 7, 5 or 2 years of age. 'Peri.eff.' is short for peri-eruptive effect, 'Pre.eff' is short for pre-eruptive effect. Fluoridation began in early 1945										
	Age 9 years at examination				Age 13 years at examination					
Year of examination	1947	1949	Peri.eff.	1952	Pre.eff.	1951	1953	Peri.eff.	1956	Pre.eff.
Age when fluorida- tion began	7	5		2		7	5		2	
Number of children examined	465	519		720		497	557		265	
DMFT and its change	3,12	2,48	-0,64	2,02	-0,46	6,60	5,12	-1,48	4,47	-0,65
The DMFT data were published in three papers: Arnold et al 1956, 1957, 1962										

Table 1 Average DMFT in children at age 9 and 13 when the use of fluoridated water began when they were

tance": enamel formed in children consuming fluorides since birth - or even before birth - would be more resistant against the attacks by acids produced by microorganisms in the microbial dental plaque after sugar consumption. In fact, just one year before water fluoridation was introduced in the three pioneering North American cities, that is in 1944, Stephan had demonstrated that the dental microbial plaque becomes acid - below pH 5.0 within 4 to 10 minutes after sugar came into contact with the undisturbed plaque. The predominant hypothesis was that part of the hydroxyapatite, the main crystal of dental enamel, will be transformed to fluorapatite, which is more resistant to dissolution in acids. The paper by Zimmer et al (2003) summarized the evidence that conversion of hydroxyapatite (and other apatites) to fluorapatite can only play a minor role, if any, in the effectiveness of fluorides against caries.

Already in the early stages, a few dental researchers wondered whether fluoride applied topically in high concentrations or when added to dentifrices would also act cariostatically. This avenue of research was initially disregarded by many proponents of water fluoridation. Based on extensive laboratory research and hundreds of clinical studies, mostly carried out with children and adolescents, topical fluorides have continued to gain ground. Today, they are by far the most successful measures in the control of dental caries.

## IS THERE EVIDENCE FOR PROTECTIVE EF-FECTS OF "SYSTEMIC" FLUORIDE?

The DMFT-data from Grand Rapids (1 ppm fluoride in the drinking water since early 1945) and Muskegon (1 ppm F since 1951) can be used to illustrate the point, because yearly examinations were made over a period of 15 years. The left part of Table 1 presents DMFT-averages of nine-year-old children examined in 1947, 1949 and 1952:

- Those examined in 1947 had started to consume fluoridated water at age 7 (plus/minus 1 year), i.e. after the eruption of those permanent teeth with any risk to become carious before the age of 10 (these are the first molars and very rarely incisors; these teeth may have had a limited posteruptive benefit from topical fluoride contained in the drinking water).
- Those examined in 1949 had started to use fluoridated water at the age of 5 (plus/minus 1 year), which means that their first molars were subject to fluoridation approximately one year before and one year after their eruption.
- Those examined in 1952 began to consume fluoridated water at the age of 2 years (plus/minus 1 year), that is 3 to 4 years before eruption of their first molars.

The children examined in 1949 had 0.64 DMFT less than those examined in 1947 (see Table 1). This reduction by 0.64 DMFT may be called "peri-eruptive effect", occurring mainly in fissures and pits of the first molars because other sites rarely show decay before the age of nine. The children

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**Fig 1** Pre-eruptive and perieruptive effects, in 8 to 16-year-old children, of fluoride in the drinking water in terms of DMFT reduction as explained in Table 1.

examined on 1952 had 0.46 less DMFT teeth than those examined in 1949, who had benefited from peri-eruptive effects. This finding suggests a strictly pre-eruptive effect. The same set of comparisons was applied to the DMFT data of 13-year-old children (see right part of Table 1). Again, the DMFT averages seem to have been reduced as a consequence of peri-eruptive and pre-eruptive effects.

The age groups 9 and 13 were chosen for Table 1 because of the large numbers of children examined. The same calculations were applied to all age groups from 8 to 16. The results are depicted in Figure 1. Obviously, there were reductions in all nine age groups. The average reduction was 1.04 DMFT for the pre-eruptive effect; the fact that exposure to high fluoride concentration starts immediately with eruption is thought to be most important. The reduction due to the pre-eruptive effect was 1.02 DMFT on average. While it is true that part of the DMFT averages were based on small sample sizes (3 of the 27 averages involved had n<100, but 16 had n>200), all differences pointed in the same direction. In the sign test, the probability of 9 reductions occurring by mere chance is 1/2to the ninth or <0.002. The data thus strongly suggest that both a genuine pre-eruptive and a peri-eruptive cariostatic effect had resulted from fluoride at 1 ppm in the drinking water. As might be expected, no increase of the pre-eruptive effects seemed to occur. This is not surprising because the benefit is likely to be exerted solely during the pre-eruptive and peri-eruptive periods, whereas the topical effect is the decisive factor throughout life once the eruption has taken place.

An analysis of DMFT-data available prior to 1977 showed that pre-eruptive effects as revealed by overall DMFT-counts are in fact due to a protective effect in fissures and pits (Marthaler, 1979). A recent multivariate study indicates that the pre-eruptive cariostatic effect might even be more important than generally assumed (Singh et al, 2003). Therefore, statements like "there is no systemic protective fluoride effect at all" seem to overlook a weak pre-eruptive effect. On the other hand, no doubt remains that topical fluorides will retain their overwhelming importance throughout life. When topical fluorides are used extensively, their combined effect may mask the weak systemic effect.

## FLUORIDE CONCENTRATION PEAKS VERSUS SUSTAINED LOW CONCENTRATIONS OF FLUO-RIDE IN THE ORAL CAVITY

The first sentence of the Introduction to the WHO Technical Report Nr. 846 (1994) reads as follows:

"Laboratory research suggests that fluoride is most effective in caries prevention when a low level of fluoride is constantly maintained in the oral cavity". Someone not familiar with the necessity of bringing fluoride to the teeth is automatically led to think that fluoride toothpastes should be banned. For after their use, fluoride concentrations in the oral fluid will reach a peak in a few seconds and then fall back to the initial value within an hour. In fact, the aim of a "constantly maintained low level of fluoride" could best be reached if fluoride-containing oral care products are not used.

How is it possible that publishers do not recognize the misleading potential of such statements before they are printed? (The present author was in fact a member of the expert committee but the misleading wording escaped his attention). One of the likely reasons for such statements was that results from laboratory research carried out around 1980. Experimenting with artificial caries lesions under stable conditions in vitro, immersion in high-fluoride remineralisation solutions were shown to result in rapid remineralisation of superficial enamel layers, thereby blocking diffusion of fluoride into the underlying body of the lesion - or rather the demineralized enamel. Several scientists concluded that the rapid "repair" of this surface enamel was a hindrance to the remineralisation of this deeper layers of enamel. Some experts went as far as to discourage the use of high concentration oral care products such as gels or topical fluoride solutions.

Eventually, this extreme position was abandoned. First of all, many clinical studies carried out in the last 50 years demonstrated the cariostatic benefit of two to six applications per year of highly concentrated fluoride via solutions and gels. The obvious cariostatic benefits of fluoride varnishes in recent years have accelerated this process.

A recent study using preformed enamel lesions in enamel specimens mounted on partial dentures and kept in the mouth for four weeks illustrates the point. The dentures were taken out of the mouth only for the treatments: brushing twice a day with a fluoride toothpaste (1450 ppm) in one group, whereas the subjects of the other group additionally placed an excess of a high fluoride gel (12500 ppm) on the enamel specimen for four minutes once a day. Unequivocal remineralisation occurred under both treatments. The high concentration gel resulted in a higher mineral uptake from the saliva of the experimental subjects. Remineralisation was demonstrable throughout the depth of the lesions in both treatment groups (Lagerweij and ten Cate, 2002). The experiment shows that high fluoride concentrations do not have negative but in fact positive effects on remineralisation under natural in vivo conditions.

"Static" in vitro experiments, used 20 years ago for remineralisation studies, must obviously give way to studies mimicking the rapid changes of conditions in the oral cavity. "In the oral environment there is a continual cycling of pH resulting from acid challenge and subsequent neutralization by saliva and other factors. Therefore, de- and remineralisation will only occur for relatively short periods and are intimately connected." (ten Cate and Featherstone, 1996). The principle "fluoride as frequently as possible but in (relatively) low concentrations" is misleading even as a rule of thumb. In reality, short peaks of fluoride concentration occur in connection with all topical fluorides, and then they fall back to normal levels within approximately one hour, whether dentifrices, rinses, gels or other oral care products are used to bring fluoride onto the teeth. Water and universal salt fluoridation may result in three or more contacts of fluoride with the teeth per day. In this respect, more or less "permanent" maintenance of increased fluoride in plague seems to be dependent on the simultaneous calcium concentration in the plaque (Whitford et al, 2002).

A recent review by Featherstone (2000) used a precise wording: "Fluoride incorporated during tooth development is insufficient to play a significant role in caries prevention. Fluoride is needed regularly throughout life to protect teeth against caries". This is an excellent statement for two reasons:

1. It does not completely dismiss the possibility of some systemic protective effect. In this way, it may mitigate heated debates on whether a (weak) systemic effect of fluoride exists or not.

2. It stresses the necessity of making fluoride available to the erupted teeth throughout life. In many old individuals the capacity and the discipline to use a fluoride toothpaste twice a day tends to disappear, and fluoridation of water or salt, or other means must be sought to maintain the daily oral fluoride concentration peaks.

# VANISHING ROLE OF FLUORIDE TABLETS IN PRACTICAL CARIES PREVENTION

Fluoride tablets were tested for their cariostatic action soon after the first European tests with fluoridated water were begun in North America. One of the first clinical studies suggesting their cariostatic effect was published by Held and Piguet (1956). Favorable results were also reported from Germany and Austria. The number of children who were given tablets – on 200 days per year at school or at home daily (or rather 4 to 6 times a week) – amounted to several millions when considering the period 1955–1970 in Germany, Austria and Switzerland. Due to the existence of school dental services within which many dentists experienced a substantial decrease in the burden of caries treatments, the dental profession regarded the cariostatic effect of tablets as remarkable – even excellent in these early days.

The early success of fluoride tablets had resulted in a generally favorable attitude towards fluoride:

1. Many preventive-minded dentists of the older generation were or still are anxious to continue with fluoride tablets that had been a cornerstone of their successful preventive care.

2. While fluoride tablets may have had a public dental health impact aided by the tighter discipline in well-organized countries decades ago, their public health impact today is negligible when compared to the public health value of adding fluoride to water or salt.

3. In the European countries where fluoride tablets were successfully administered at school, the negative propaganda of antifluoridationists met with little response in those millions of families who had given their children fluoride tablets for years and saw their children develop normally.

These observations illustrate that fluoride tablets played an important role in awaking interest in the use of fluoride for caries control, at least in Europe. In part, they received too much attention because the proposed dosage schemes were discussed by professionals at length, though the various schemes did not differ essentially. The number of pages in the WHO Technical Report 846 of 1994 may illustrate the attention given to fluoride tablets until recently:

Fluoride in drinking water	4	pages
Fluoridated salt	3	pages
Fluoridated milk	1	page
Fluoride supplements		
(tablets and drops)	3	pages
Fluoride toothpastes	3	pages plus a
		few lines

In summary, fluoride tablets or supplements helped to spread the idea that fluoride can prevent caries, a message that was still difficult to disseminate in the fifties, sixties and seventies. A careful analysis lead to the conclusion that nowadays the use of fluoride tablets (or other daily supplements) "increases the risk of fluorosis while contributing little to caries prevention" (Burt, 1999).

#### LONG-TERM EFFECTS OF ANTIFLUORIDATION-ISTS' CLAIMS

Antifluoridationists had considerable influence on decisions regarding fluoridation. Their main aim was to reject or abolish water fluoridation. Their activities were minor regarding salt fluoridation. They tend to reject fluorides in toothpastes generally, but due to the fact that the individual is free to buy the product of his choice their opposition is not consistent in the case of dentifrices.

Most antifluoridatists have claimed that fluoride is ineffective against caries and that it threatens general health. These claims were maintained for decades and have been heard by billions of people for 40 years; nowadays they can be found in the Internet. The increasing success of preventive dentistry was not only disregarded by these groups; instead, these activists have used or rather exploited scientific discussions on details of the biological action of fluorides by stating for example that "even scientists do not agree on the effects and benefits of fluorides".

Unfortunately, antifluoride statements resulted in a widespread anxiety in the population, which is mild in most cases. However, when preventive dentists try to improve or intensify the use of fluorides, unexpected reaction may surface in people not sufficiently familiar with the matter. Examples are presented in Table 2. As an illustration to the lower part of the Table 2, a recent paper confirming the beneficial effects of water fluoridation may be cited. It is written therein that "antifluoridationists have stated that, with the virtual universal availability of fluoridated dentifrice, there is no need for water fluoridation in Scotland" (Stephen et al, 2002). It may come as a surprise that similar opinions are frequently heard from preventive dentists in Western Europe stating for example: "For Central and Eastern Europe, the introduction of fluoridated toothpastes will be sufficient and salt fluoridation is not needed". It is deplorable that caries prevalence in Central and Eastern Europe is still high, and there is little evidence of a decline in the near future.

#### WHAT CAN BE EXPECTED FROM SALT FLUORI-DATION?

The results of early research documenting the cariostatic effectiveness of salt fluoridation were summarized by Burt and Marthaler (1996). It was evident that salt fluoridation, if appropriately implemented to reach all consumers, is essentially equivalent to water fluoridation. In the meantime, new results have been obtained in Jamaica, where salt fluoridation, universal in the sense of covering all salt used for human consumption for the entire population, was introduced in 1987. In the initial survey of 1984, adolescents at age 15 had 9.6 DMFT on average (Warpeha et al, 2001). For the same age group, Estupinan (2001) reported 3.0 DMFT for 1995, and in a later local survey in 2000, the average DMFT was 3.8 (Meyer-Lueckel et al, 2002). Both reductions were above 50% when compared with the 1984 average.

In the State of Mexico surrounding the Federal District of Mexico (the City of Mexico), large samples of children were examined for caries in 1988, when salt fluoridation was introduced, and again in 1997. In 1988, the average DMFT was 4.39 (DM-FS: 6.93), and 2.47 (DMFS: 3.84) in the follow-up survey. This represents a reduction of 44% (DMFS: 45%). Part of the reduction may be due to a secular decline, but it is to be mentioned that fluoridated toothpastes had been on sale long before 1988 (Irigoyen et al, 1999). The cariostatic benefit from salt fluoridation was confirmed in Hungarian adults (Radnai and Fazekas, 1999).

Several Latin American countries, notably Costa Rica and Colombia, have introduced salt fluoridation schemes similar to the one in Jamaica. The public health impact will hopefully be further assessed in the years to come. In the late nineties, the number of consumers of fluoridated salt in France and Germany was some 60 million, which is close to half of the total population of the two countries. While the sheer number may seem impressive, it must be suspected that the families using fluoridated salt are those who are generally interested in dental (and general) health and have lower than average decay levels. By contrast, the non-users predominantly belong to lower socio-economic



strata where caries prevalence is highest. Accordingly, the public health effect of fluoride in salt is minor or even negligible in countries including Austria, Belgium, the Czech and Slovak Republics, Hungary and Spain where fluoridated salt is used by a minority or only a small fraction of the population. In Germany, the market share of the fluoridated salt (among all domestic salt) was 54% in 2002; this may be beneficial to some extent while in Switzerland the 84% are certain to be effective on the public health level.

There has been some interest in salt fluoridation in several countries of Central and Eastern Europe. Traveling in Eastern Europe, I have seen technical installations for fluoridation of salt in White Russia and Ukraine in the years 1989 to 1993. Labeled packages of fluoridated salt from Poland were available for some time in White Russia. Apparently, salt refineries were ready to invest in the production of fluoridated salt. Whether the obtained fluoride concentration would live up to Western standards is another question. But health politics, ideally formulated by both politicians and dental health advisors, failed to follow up the initiatives already taken by the industry, which learned from Western colleagues about the beneficial effect on dental health. Prices of fluoridated salt are often two or three times higher than those of unfluoridated, sometimes iodized, salt. Only the Czech Republic has a functioning market distribution. After a short period when imported fluoridated salt was available, they started their own production and promoted its use.

In Central and Eastern Europe, salt fluoridation could easily cover a total population of more than one hundred million. It would be by far the cheapest method for improving dental health there. In addition, everybody could be reached within a few months, that is as soon as the unfluoridated stocks of salt are consumed.

#### COMBINING TOPICAL AND SYSTEMIC FLUO-RIDE FOR MAXIMUM BENEFIT IN PUBLIC DEN-TAL HEALTH

In the Westernized countries in which fluoride is added to the water, toothpastes are also fluoridated. In spite of the double source of fluoride in small children who initially ingest up to 50% of the dentifrice (less at ages 4–6 years), preventive dentistry was successful in keeping levels of fluorosis low. This statement is based on decades of experience in Ireland and the United Kingdom and was recently confirmed by Stephen et al (2002). The slight fluorosis seen in approximately every fourth or third child has largely gone unnoticed by the public at large (Zimmer et al, 2003). In fact, little opposition was raised against fluoride uses on this ground.

The majority of Western European experts favor the introduction of fluoride toothpastes as the key measure for improving public dental health in Central and Eastern Europe. On the other hand, salt fluoridation, now under consideration in several of these countries, is hardly mentioned. In the light of the high caries prevalence there it would obviously be reasonable to use both systemic and topical fluorides in order to obtain an enhanced cariostatic effect. The use of fluoridated toothpastes has long been shown to provide an added benefit to children living in water fluoridated regions; the numerous studies carried out until 1980 were summarized by Mellberg and Ripa (1983). Accordingly, the reverse - an added benefit of "systemic" fluoride in water or salt in children already using fluoride dentifrices - is necessarily true as well.

What is cheaper: public fluoridation by water or salt; or topical fluorides in dentifrices? In the highly industrialized, affluent countries, toothbrushing with toothpaste has become a habit of most long-term residents decades ago. Once cariostatic fluoride dentifrices were available, the task was simple: obtain the highest possible market share for fluoride dentifrices at the expense of the unfluoridated ones. Dental academia and professional organizations obtained full cooperation of the toothpaste manufacturers to promote the use of fluoride toothpastes. The result is that in most of these "rich" countries, more than 90% of the toothpastes chosen by the public are fluoridated.

In the less industrialized world, and even in Central and Eastern European countries, conditions are different. For the majority of adults and children, daily toothbrushing is either still not habitual, often not considered worthwhile, and/or hardly affordable. In a Hungarian town I noticed that the price of toothpastes, whether fluoridated or not, is 2 to 5 times higher when compared to the income levels there. The cost of toothbrushes was similarly high; nevertheless, one Hungarian brand, hardly visible in the shelves, was half as expensive as the imported ones. Like Spain and Portugal 17 years ago, the EU candidates will be flooded with high-quality Western products at Western prices, and local enterprises, which possibly could produce at lower cost, have little chance of survival. The commercial or financial obstacles are summarized in the upper part of Table 3. Outside the industrialized world, another factor is fatalism, as shown in the lower part of Table 3. It will be very difficult to make people there believe that the decay of their teeth can be controlled. The limited success of anti-AIDS campaigns in some African countries exemplifies the seriousness of this additional obstacle.

The WHO Technical Report (1994) states that "since the use of fluoridated toothpastes is a public health measure, it would be in the ultimate interest of countries to exempt them from the duties and taxation applied to cosmetics". While this recommendation is justified, dentifrices will still be expensive for the many millions of poor families, in rural areas outside the booming cities, and in the poorer section of the rapidly growing cities. Under these circumstances, even after price reductions of 10–20%, one cannot expect substantial increases in the use of toothbrushes and – fluoridated – dentifrices.

used twice a day in Central and Eastern Europe								
	Children,	Adu						
	adolescents	20-40y	41+					
Commercial obstacles High price of toothbrush High price of fluoride toothpaste	strong strong	strong strong	strong strong					
Behavioral obstacles Lack of faith in prevention Insufficient brushing discipline	minor minor	minor strong	strong strong					

Table 3 Obstacles to the effective use of fluoride toothpastes to be

It is evident that under these conditions, fluoridation of water, and particularly of salt, is by far the cheapest means of reducing caries. In the light of numerous abandoned water fluoridation schemes in Central and Eastern European countries, fluoridation of salt will for many years remain the only feasible method for reducing dental caries in all strata of the population. One finding is most pertinent: a study in England showed that the lower the social stratum, the higher was the benefit afforded to the primary teeth (Jones et al, 1997). The traditional body of knowledge, occasionally questioned by a few outsiders, has recently been re-examined in a paper with the title "Why we have not changed our minds about the safety and efficacy of water fluoridation" (Newbrun and Horowitz, 1999). Hopcraft and Morgan (2003) recently confirmed in recruits (average age 22 years) that those who had lifetime exposure to fluoridated water had 23% lower DMFS experience than those who had not benefited from water-borne fluoride. However, the socio-economic stratum had a greater influence: The 12% of subjects from the highest SES-stratum had 90% less caries than the 7% in the lowest one.

Statements and recommendations of the most affluent countries are keenly watched by dentists and governments in Central and Eastern Europe as well as in the Third World. If prevention of caries is boiled down to the recommendation "use fluoride toothpastes", the chances of effective action to be taken will be dim and oral conditions will hardly improve except for minorities living in high socio-economic strata.

#### OBSERVATIONS REGARDING IMPLEMENTA-TION OF FLUORIDE IN PUBLIC HEALTH: 3 EX-AMPLES

It is evident that in dental academia, the vast majority of the experts have adopted the idea that fluorides act mainly or exclusively by their topical effects on erupted teeth. As discussed above, certain groups are still reluctant to accept this well-grounded hypothesis. The question here is how to proceed in specific situations.

#### **Disagreements in Germany**

In the last three years, several German experts thought that the time had come to state that the protective effect of fluorides is exclusively due to their topical action. Such categorical statements met with considerable opposition. In fact, many pediatricians and dentists had been successful in preventing dental caries by prescribing daily intake of fluoride tablets. They adopted the recommendation that their patients – mostly children – keep the tablets in their mouths as long as possible to enhance the topical effect; however, they were not entirely ready to dismiss the idea that fluoride tablets have a systemic cariostatic effect. Recommendations based exclusively and explicitly on the topical effect met with considerable resistance and have resulted in confusion among professionals that could have been avoided by using a more careful wording such as cited above from Featherstone (2000).

#### The Case of Switzerland

In April 1983, the concentration in all of the fluoridated domestic salt sold in Switzerland was increased to 250 ppm, labeled on the packages as 0.025% fluoride. From 1955 until 1983, the concentration had been a mere 90 ppm; but 250 ppm had been used since 1970 in the Canton of Vaud and 1974 in the Canton of Glarus, with a total population of 550,000. It was thought that along with the new concentration of 250 ppm, pediatricians must be informed that fluoride tablets should not be used any more. However, the prestige of the tablets was still high, and after many discussions it was decided to retain fluoride tablets as an alternative to salt fluoridation. Decisions to continue with fluoride tablets were thus left to the parents who were supposed to consult their family dentist or pediatrician. The dosage schedule of tablets was not changed; it had been lower anyway than in most other European countries (Marthaler, 1990).

Accordingly, the official pediatric and dental recommendations in the late eighties favored the use of fluoridated salt. The usage of fluoride tablets decreased gradually after the introduction of salt with 250 ppm. Hardly any paper published in the "Swiss Dental Journal" (Schweiz Monatsschr Zahnmed) after 1990 mentioned fluoride tablets. In the mid-nineties, fluoride tablets finally disappeared from the pediatric recommendations. In fact, they are by now largely "forgotten". For those families who absolutely wish to continue with tablets, a simple recommendation is to take one tablet of 0.25 mg every day independent of age and use of fluoridated (domestic) salt. A limited caries-preventive effect is certain and enamel fluorosis will not be caused.

No disadvantage has resulted from the slow switching from tablets to fluoridated salt. Press releases on the new situation were published only once or twice, and antifluoridationists had little opportunity to raise their voice against the preventive uses of fluorides. The market share of the fluoridated domestic salt, sold at the same price as both the iodized and unionized salt, increased from 66% in 1984 to 75% at the end of the eighties. It has remained at 83% since 1998 and may thus be regarded as a public health measure. In children 14 years of age (Menghini et al, 2003), recruits (Menghini et al, 2001) and adults up to the age of 45 (Menghini et al, 2002) the decline of caries prevalence has continued until the late nineties.

#### **Observations in a Balkan Country**

The wars in former Yugoslavia have disrupted prevention schemes which prior to 1992 had been functioning well in many cities, towns, regions or provinces. After the war, many colleagues tried to reestablish preventive programs in the schools. The easiest, in fact the only feasible way, was to start with the reintroduction of fluoride tablet distribution in schools, since it was too difficult to revive the former tooth brushing exercises with concentrated fluoride preparations in the first years after the war.

When I tried to assess the situation with the prevention-minded local colleagues, they were somewhat afraid of objections against the fluoride tablet programs because "systemic" methods might be considered obsolete by some preventive dentists. At the same time, they feared that discontinuing the tablet distribution, which in spite of being called "systemic" has a strong topical effect, would mean another setback, a setback which could be overcome only with the greatest difficulties. We concluded that for reasons of feasibility, the fluoride tablet programs should not be stopped in any case before an adequate topical program - usually including several tooth brushing exercises per year with a fluoride preparation - would be firmly established. It was pointed out that overlaps of the tablet programs with tooth brushing exercises would not have any adverse effect, and fluoride tablet stocks in the schools should be used until no further supplies were available. In addition, this policy reminded the population that fluoride must be used regularly and continuously.

#### **CONCLUDING REMARKS**

There is no doubt that the cariostatic effectiveness of the various recommended uses of fluoride results essentially from local processes. On the other hand, it is unscientific to postulate once and for all that there is no systemic protective effect whatsoever of fluoride reaching the tooth before eruption. Attempts to convince experienced dentists or pediatricians of an exclusively topical action have in several cases created confusion and resistance. It is in fact difficult to understand the dynamic biological and crystallographical processes in the dental hard tissues. Debates concerning the specific arguments when carried to the fore may be exploited by antifluoridationists in order to interfere with broader and more effective uses of fluorides.

The latent opposition against fluorides was exemplified by the Belgian Ministry of Health in summer 2002 who attempted to ban the caries-preventive uses of fluorides, including fluoride toothpastes. The consequences of this ill-conceived ruling, withdrawn within weeks, were fortunately minor in Europe. In this case, the reaction was largely unanimous throughout Western Europe except for very few antifluoridationists who took advantage of the opportunity to try to intimidate the population. In fact, the agreement on safety and effectiveness of fluoride has become strong enough to resist "attacks" from antifluoridationists, even when the latter occupy important and powerful political positions.

Both the negligible cariostatic effect of systemic fluoride and the strong decline of caries prevalence in industrialized countries have entailed diminished interest in water and salt fluoridation programs. This in turn weakens endeavors to introduce "mass" fluoridation in the developing world, where such cheap methods would be most beneficial: except for the small well-situated socio-economic strata, the use of fluoride toothpastes and similar products is most likely to remain too expensive for decades. The real problems in connection with caries prevention by fluorides are not uncertainties in scientific bases, but the fact that only a small part of humanity is benefiting from them.

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