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Salt Fluoridation: A Review

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ABSTRACT Salt fluoridation is sometimes suggested as a prospect for communities that have a low water fluoride concentration and have no possibility of implementing community water fluoridation. School-based milk fluoridation programs also are practiced in some countries as an alternative. This paper reviews the evidence of effectiveness in dental caries prevention and risks of dental fluorosis in countries where salt or milk fluoridation is practiced.

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The world's population exceeds 7 billion, yet fewer than 1 billion have access to a proven community-based water or salt fluoridation program to reduce the prevalence and severity of tooth decay, the most common chronic disease of children, which may be untreated in as much as 95 percent of the population of some countries.[1] It is also anticipated that in light of changing living conditions and dietary habits, the global incidence of dental caries will increase, particularly as a result of growing consumption of sugars and inadequate exposure to fluoride.[2] Water fluoridation is practiced extensively in the United States, but not in communities that depend on nonpublic water supplies. In 2005, the Pan American Health Organization published a comprehensive book on salt fluoridation.[3] Information from the book has been used for this paper, in addition to other published sources prior to and since that time. Rather than being a systematic review, this is a selected review of published evidence on the current status of salt fluoridation. Meta-analyses of the caries preventive effect of salt fluoridation have demonstrated effectiveness in the permanent dentition,[4] while a systematic review with strict criteria (such as only including randomized control and clinical trials) has been unable to find studies of sufficient quality.[5] In 2009 the World Health Organization published a comprehensive book on milk fluoridation.[6] Milk fluoridation programs are relatively small in scale and scope but show promise for providing appropriate fluoride exposure for the prevention of dental caries during vulnerable preschool and school years for children.

Water Fluoridation

Water fluoridation is practiced in many countries throughout the world. As of 2012, more than 435 million people worldwide have access to either naturally fluoridated water (about 57 million) or water with

TABLE 1

The Extent of Water Fluoridation in the U.S. and Other Countries: Population Served by Optimally Fluoridated Water

Country	Fluoridated water
United States	204 million
Brazil	73 million
Malaysia	20 million
Australia	17 million
Canada	14 million
Chile	11 million
Hong Kong	7 million
Great Britain	5.8 million
Israel	5.3 million
Singapore	5 million
Spain	4.2 million
Vietnam	3.5 million
Ireland	3.2 million
Argentina	3 million
South Korea	2.8 million
New Zealand	2.3 million
Guatemala	1.8 million
Peru	0.5 million
Panama	0.5 million
Others	52 million
Total	435 million

TABLE 2

Countries Using Salt Fluoridation

Continent	Country
Europe	Switzerland, France, Germany, Spain, Finland, Poland, Serbia, Czech Republic, Slovakia, Belgium, Denmark, Austria, Romania
North America	Mexico, Jamaica, Belize, Costa Rica, Cuba, Dominican Republic
South America	Colombia, Peru, Bolivia, Ecuador, Uruguay, Venezuela

adjusted fluoride concentrations at or near optimal (about 378 million).[7] These countries include the United States (204 million), Brazil (73 million), Malaysia (20 million), Australia (17 million), Canada (14 million), Chile (11 million), Hong Kong (7 million), Great Britain (5.8 million), Israel (5.3 million), Singapore (5 million), Vietnam (3.5 million), Ireland (3.2 million), Spain (3.2 million), Argentina (3 million), South Korea (2.8 million), New Zealand (2.3 million), Guatemala (1.8 million), Peru (0.5 million) and Panama (0.5 million)[7] (TABLE 1).

Some countries, including China (more than 200 million), India (more than 60 million), Tanzania (12 million), Mexico (3 million), Sri Lanka (2.8 million), Zimbabwe (2.6 million) and several more, have fluoride levels in water significantly in excess of the optimum.[7]

Salt Fluoridation

Salt fluoridation is practiced as a community-based alternative to water fluoridation in many countries where there are few central water systems, water infrastructure is otherwise not appropriate or where other factors preclude the use of water fluoridation. It is recommended that a national fluoride program use only one of these approaches.[8] It has been estimated that between 40 million and 280 million people worldwide use salt fluoridation, mainly in European, South American and Central American countries.[9,10,11] Some Asian countries, including Cambodia and Laos have recently adopted salt fluoridation.[12] In Africa, Madagascar has also implemented salt fluoridation.[13]

If salt fluoridation is identified as the preventive method to use in a country, it is necessary to do a thorough assessment of drinking water sources to identify communities or regions where fluoridated salt should not be distributed. For example, in Mexico, which has a national salt fluoridation program, fluoridated salt is not distributed in four Mexican states that tend to have appreciable concentrations of fluoride in their drinking water sources.[14]

Fluoride Concentration in Salt

For salt fluoridation, potassium fluoride and sodium fluoride are used at a concentration of 250-300 mg F per kg of salt (250-300 ppm).[15] At this concentration, the level of fluoride in saliva was very similar to that found in the saliva of individuals exposed to water fluoridation at 1 mg/l.[15] The concentration of 200 mg/kg of fluoride is regarded as the minimal acceptable level of fluoride in salt to achieve a meaningful effect on caries control. Most of the studies designed for monitoring salt fluoridation use urine as a biomarker to monitor compliance of individuals with a salt fluoridation program, as well as possible excessive fluoride ingestion.

Fluoridated salt was introduced in Switzerland in the 1950s based on the success of the use of iodized salt to prevent goiter. Switzerland had iodized salt since 1922, so salt fluoridation for the prevention of dental disease, based on experiences of fluoride in the prevention of dental caries, was considered a valid approach.[16] The objective of any fluoridation method in the 1950s was to promote the ingestion of fluoride in order to achieve its cariostatic effect. The concept of using salt fluoridation has a different aim today, which is to reach communities and regions in the world where oral care prevention measures, and particularly fluoride toothpastes, are not available.[15]

In addition to iodide and fluoride, folic acid is added to salt in some countries, including Germany.[11] Folic acid is added to help prevent spina bifida and other neural tube defects during pregnancy. In 1998,

the Food and Drug Administration began requiring the fortification of enriched cereal grain products with folic acid.[17] Neither folic acid nor fluoride is added to salt in the U.S.

Effectiveness in Caries Prevention

The first epidemiological studies to evaluate the effectiveness of fluoridated salt in reducing caries prevalence were performed in Colombia, Hungary and Switzerland from around 1965 to 1985. The outcomes of these studies indicated that salt fluoridation generally showed very similar beneficial results to those observed for water fluoridation; the number of teeth affected by caries was reduced by approximately 50 percent.[18] The results of the early clinical experiments by Toth performed in Szeged, Hungary, showed, after 17 years, a caries reduction of about 66 percent.[19]

In a 1991 study from Hungary, adults were shown to benefit from fluoridated salt, where three groups were examined for dental caries status.[20] One group were lifetime residents in a community with access to 1.1 ppm natural fluoride in the drinking water (N=205; lowest caries experience), another group had access to fluoridated salt between 1966 and 1985 (N=213; intermediate caries experience) and a third group had minimal fluoride exposure (N=258; highest caries experience).

Availability

Salt fluoridation is available in nearly all Latin American countries, except Brazil, Chile and Panama. There are national regulations or authorizations for the production and marketing of fluoridated salt in eight European countries: Austria, Czech Republic, France, Germany, Romania, Slovakia, Spain and Switzerland.[15] In Europe, where there are major discounters, there are safeguards regarding importation of fluoridated salt across borders.

There are many variants of the commercial distribution or "channels" to reach the consumer. These channels include, domestic salt, meals at schools, large kitchens and in food items such as bread. The most extensive use of fluoridated salt is in Jamaica, Costa Rica and the canton of Vaud, Switzerland.[18] In other Swiss cantons, France and Germany, the salt fluoridation program is mainly based on domestic salt.

Planning new salt fluoridation programs requires mapping of the natural fluoride content of water, and necessary measures to keep fluoridated salt away from regions with more than 0.7 ppm F in water.[18] Marthaler and Petersen have reviewed the various technical issues associated with initiating and maintaining salt fluoridation programs.[18] As with water fluoridation, where salt fluoridation appears feasible, there will be regulatory and organizational issues to resolve.[18]

NO ADVERSE health effects have been reported related to the use of fluoridated salt.

Concerns About Salt Use

One point of concern is that promoting salt fluoridation could be contraindicated from the perspective of general public health, because greater salt consumption is linked to hypertension. However, people do not need to change their usual behavior to benefit, and if a secular decline in salt consumption were to take place, an increase in fluoride concentration could be considered. Preventing hypertension through restricting salt intake and eliminating iodine deficiency through iodized salt are not in conflict. It is estimated that among communities or groups usually consuming low-salt diets (<5 g NaCl per person per day), essential hypertension will be uncommon. Estimates of normal daily salt requirements for adults have ranged up to 15 g per day.[15]

There is a wide margin of safety regarding fluoride intake from fluoridated salt. It is estimated that fluoride intake from fluoridated salt is 0.5–0.75 mg per day.[11] The upper tolerable limit for fluoride intake has been estimated to be 0.12 mg/kg/day, which is equivalent to about 5 mg/day for children aged 9–14 years and 7 mg/day for aged 15 and older, including pregnant and lactating women.[11] No adverse health effects have been reported related to the use of fluoridated salt.[11]

No adverse impact has been identified in combining iodide and fluoride in salt.[11]

Costs

The equipment costs for the initial operation of implementing salt fluoridation are similar to those for water fluoridation. However, during operation, salt fluoridation has an estimated cost 10 to 100 times lower than that associated with water fluoridation programs. The costs of salt fluoridation can vary from USD 0.015 up to USD 0.030 per capita/year, which is so low that many producers do not raise the price of the product after fluoridation is implemented.[15] Gillespie and Marthaler reported a cost of USD 2.5 to 5.0 for sodium fluoride chemical per ton of salt.[21]

Ethics: Choice

In contrast with water fluoridation, which is readily available to the whole community, salt fluoridation can provide a choice for the consumer. According to Jones et al.,[22] the individual choice is

one positive aspect of a fluoridated salt program because it can be sold alongside a nonfluoridated alternative. Individual choice makes salt fluoridation more acceptable for some people from ethical and social policy perspectives. On the other hand, it can weaken its caries-preventive impact because salt is not used similarly on an individual basis.

Combination of Multiple Fluoride Sources

As with fluoridated water, there has been some concern about the simultaneous combination of fluoride ingested from both salt and dentifrice. Available data suggest that this combination has not resulted in objectionable enamel fluorosis levels. However, increased mild dental fluorosis was observed in children who used fluoride tablets in association with fluoridated salt.[15]

Dental Fluorosis

Fluoride-associated opacities of enamel are caused by excessive fluoride intake during enamel development in the first years of life. The mildest form of dental fluorosis manifests as white horizontal lines in enamel and/or "snow caps" on the incisal edges and cusps of teeth. While this condition is not considered objectionable, should the condition be more severe, which is rare, there is a desire to reduce the sources of fluoride that contribute to the objectionable forms. However, it has been shown that teeth with fluorosis are at reduced risk for tooth decay.[23]

Dental fluorosis has been studied extensively. In Switzerland, the neighboring cantons Basel-Stadt and Basel-Landschaft had introduced different fluoridation schemes for caries prevention. Basel-Stadt provided drinking water fluoridated at 0.8–1 ppm F from 1962, while Basel-Landschaft introduced fluoridated domestic salt (250 ppm F from 1983). Representative samples of 12-year-old schoolchildren were studied to evaluate the prevalence of dental fluorosis, nonfluoride-associated enamel opacities and hypoplasia of the incisors using standardized photographs.[24] More than 800 children were examined between 1999-2001. In spite of different fluoridation schemes in the two cantons, the prevalences of dental fluorosis were identical; most fluoride-associated enamel opacities were mild or very mild. The authors concluded they did not represent an esthetic problem and certainly not a public health concern.[24]

THE MILDEST FORM of dental fluorosis manifests as white horizontal lines in enamel and/or "snow caps" on the incisal edges and cusps of teeth.

Dental fluorosis was assessed among Swiss army recruits from all cantons and third and fourth grade children in the canton of Zurich between 1996 and 2006.[25] Demonstrating the difficulty of assessing dental fluorosis and nonfluoride-associated enamel opacities, even using a blinded approach using photographs, the two examiners differed in their assessments, one finding an overall fluorosis prevalence of 22.7 percent and the other examiner only 9.0 percent. It was noted that the prevalence of dental fluorosis as assessed by each examiner had declined for both age groups, even though the salt fluoride concentration of salt had increased from 90 mg/kg to 250 mg/kg in 1983. However, there had been significant reduction in other fluoride sources; fluoride tablets had declined in use in the intervening years and from 1986, low fluoride toothpaste (250 ppm) became available for children increasing in use for the latter cohort.[25]

Europe

Switzerland

The market share of fluoridated salt in Switzerland is more than 80 percent.[11] Basel, Switzerland, was successfully fluoridating its water supply for many years, while the surrounding cantons were distributing fluoridated salt. In 2003, the Basel parliament voted to cease water fluoridation because of the complexity of fluoridated salt distribution — it was no longer possible for the people of Basel to avoid purchasing fluoridated salt.[26] In addition, some surplus Basel water was being purchased by neighboring communities in France.

France

Salt fluoridation, available since 1986 in France, has been weakly promoted and is used by less than 30 percent of schoolchildren.[27] While the market share was 60 percent in 1993 it dwindled to 14 percent in 2009.[11] In a 2003-2004 study of 282 4 and 5-year-olds and their parents in Clermont-Ferrand, a deprived community in central France, the mean dental caries experience showed mean number of decayed and filled primary teeth (dft) was 1.94 (SD 3.31) and 30 percent of the children had >1 carious teeth.[27] Children whose parents did not know what kind of salt they used experienced more dental caries. However, the authors suggest that it is the level of

parental knowledge that is associated with the dental status of the children rather than the F salt consumption. Several previous studies conducted in France have failed to find a significant relationship between fluoridated salt use and dental status. The poor level of use of fluoridated salt in France, particularly among low socioeconomic status families reduces the potential preventive effect of this measure. Fluoridated salt is recommended as well as fluoride supplements for high-risk children after the age of 6 months. Two-thirds of the children had used fluoride supplements from birth to age 2. Children who had never used fluoride supplements had more carious teeth than other children did. Children whose parents knew that toothpastes were fluoridated had fewer decayed teeth.[27]

Germany

Fluoridated salt was introduced in Germany in 1991 and the market share is reported as 65-70 percent.[11] Tooth decay has declined among 12-year-old German children from a mean number of decayed, missing and filled permanent teeth (DMFT) of 2.4 in 1994 when there was only a 5 percent market share of fluoridated domestic salt to 1.0 DMFT in 2004 with a 61 percent share. However, during this time there was an increase in the percent of children receiving dental sealants from 6 percent to 66 percent. Parenthetically, it should be noted that there has been an increase in sealant application in communities with water fluoridation.[28] This may be related to the decline in smooth-surface and approximal caries as a result of increased fluoride exposure which then allows for sealant application to prevent pit and fissure caries on the particularly vulnerable occlusal surfaces of otherwise caries-free permanent molars.

Spain

The market share of fluoridated salt in Spain is low and was reported to be only 10 percent in 2006.[11] This may be due in part to the fact that some regions of Spain have community water fluoridation programs accessed by more than 4 million people.

North America

Mexico

Mexico began a fluoridated salt program in 1991. Of the total Mexican population of 112 million in 2010, an estimated 90 million had access to fluoridated salt, with another 20 million with access to water with naturally occurring fluoride concentrations at or above optimal.[11] A cross-sectional study was conducted in 1998 of 1,373 6 to 12-year-old (mean 8.8 years) lifetime residents attending elementary schools in the city of Campeche in southeast Mexico.[29] Fluorosis prevalence was 51.9 percent overall, with increasing prevalence among cohorts born after 1990, particularly among those born in 1991 (71.4 percent prevalence) and 1992 (86.7 percent prevalence). The authors of the study propose that there was increased consistency in the concentration of fluoride in salt after 1993. The study also confirmed previous reports with regard to toothbrushing frequency, as well as type and quantity of toothpaste, being risk factors for dental fluorosis. A review of 14 studies in Mexico found that the prevalence of dental fluorosis ranged from 30 percent to 100 percent in areas where water is naturally fluoridated at or above optimal concentration and from 52 percent to 82 percent in areas where fluoridated salt is used.[30] Fluorosis risk increases where natural fluoride concentrations in water are relatively high and fluoridated salt is also being used.[31] Children living at high altitudes experience increased risk for dental fluorosis.[32] Further studies have been recommended to determine if the prevalence of dental fluorosis in Mexico is rising or if it constitutes a public health problem.

Jamaica

A salt fluoridation program started in Jamaica in 1987. The salt fluoridation program was considered appropriate for the island because of geographical conditions, the low concentrations of water-borne fluoride (which do not exceed 0.3 mg/l) and the availability of bottled water also having the same levels of fluoride. A recent study observed that 96 percent of rural and 100 percent of urban Jamaican children in the sample were consuming fluoridated salt.[15] The oral health survey conducted in 1995 indicated a significant decline in dental caries compared with findings in 1984. The major change in Jamaica during the interval was the 1987 introduction of salt fluoridation. Dental fluorosis was low in the 1995 survey.[33] Fluoridated toothpaste first became available in 1972, 15 years before fluoridated salt was introduced. Data were not available on the use of fluoride toothpaste in Jamaica between the 1984 baseline and 1995.[33]

However, a more recent study in 2006 of the dental caries and fluorosis status of 5- and 6-year-olds and 11- and 12-year-olds found that every Jamaican child reported using imported fluoridated toothpaste.[34] It is therefore possible that there could have been an increase in the use of fluoridated toothpaste during the 1995 survey that could have also contributed to the decline of dental caries. A high level of dental fluorosis, particularly in the 6-year-olds was found in the 2006 study that did not seem

TABLE 3

Countries Using Milk Fluoridation on a Limited Basis

Bulgaria
Chile
China
Peru
Russia
Thailand
United Kingdom

to be predominately associated with water-borne fluoride, but could be associated with fluoride toothpaste use.[34] However, age 6 is younger than the age recommended for typical dental fluorosis studies,[35] as few permanent teeth would have erupted.

Fluoride exposure in recent years appears to be close to optimal. In 2008, nocturnal and diurnal urinary fluoride concentrations in a sample of urban (N=64; mean age 4.6 years) and rural (N=64;mean age 4.8 years) Jamaican children were found to be almost twice as high as was found in a similar 1987 study (when salt fluoridation started), yet considered to correspond to low fluoride intake.[36] The excreted fluoride mirrors the intake from all sources of fluoride, not only from fluoridated salt. Concerning fluoride toothpaste use, 76.5 percent in urban areas and 89 percent of rural children used adult toothpaste (1000-1100 ppm F). Regarding quantity of toothpaste placed on the toothbrush parents of urban children indicated that 58.6 percent used too much (more than a pea-size), 27.6 percent excessive (the entire head of the brush covered with toothpaste) and only 13.8 percent used a pea-size amount. In rural children, 70.2 percent use too much, 14.9 percent excessive and 14.9 percent a pea-size amount. All children of the sample were living in regions with less than 0.4 ppm F in the drinking water. With regard to dental fluorosis, the authors conclude in citing other studies, that the combination of fluoride used in both dentifrices and salt, does not lead to objectionable enamel fluorosis levels.[36]

South America

Colombia

A fluoridated salt trial was initiated in Colombia in 1963 and upon successful completion in 1972 was shown to have preventive results comparable to water fluoridation.[16]

Peru

In 1984, a law was passed in Peru mandating the addition of fluoride to salt for human consumption. In 1985, the Peruvian Ministry of Health agreed on a technical norm for enriching table salt for human consumption with F, as the main method for administering F to the Peruvian population. Fluoridated salt is widely available to consumers at supermarkets and retail stores throughout the country.[37]

Comparison of Data from Various Studies from Different Countries

In addition to Colombia and Peru, there are fluoridated salt programs in Belize, Bolivia, Costa Rica, Cuba, Dominican Republic, Ecuador, Uruguay and Venezuela.[11] A study in Costa Rica found a 72 percent reduction in the mean number of decayed, missing and filled permanent teeth (DMFT) of 12-year-olds from 8.4, in 1987 when salt fluoridation started, to 2.5 in 1999.[11] Another study in Uruguay showed a 41 percent reduction in DMFT for 11- to 14-year-olds between when salt fluoridation started in 1991 to 1999.[11]

Data are rarely collected on dental caries and fluorosis status that are representative of the country or state. The World Health Organization Examiners have also differed in their assessments of the same population sample using the same methods, while studies in different countries may also use somewhat different methods. Additionally, there have been changes in the practice of dentistry in some countries, particularly for young children, with an increase in the use of stainless steel crowns for primary teeth, increasing the number of tooth surfaces designated as filled when using dfs or DFS indices. Thus, comparison of data from different countries is not too meaningful when attempting to determine the reasons behind trends. Yet that has not prevented comparisons being made.[38,39] While many trends have shown a decline in dental caries prevalence and severity, others have focused on studies from countries that show an increase.[39] A review published in 1999 found that dental caries was a good proxy measure for socioeconomic development and that countries in the throes of socioeconomic transition had the highest DMFT scores.[40] The World Health Organization has established an Oral Health Database providing mean DMFT scores for 12-year-olds.[38] A weighted average of scores indicates that the year 2000 goal of reducing the mean DMFT for 12-year-olds to no more than three permanent teeth affected by tooth decay had been achieved by 70 percent of 128 countries in 2001 and by 78 percent of 189 countries in 2011.

Milk Fluoridation

The distribution and consumption of fluoridated milk in preschools and schools provides a cost-effective alternative when water or salt fluoridation are not feasible.[41] While the 2012 U.S. standards for school meals includes fat-free or low-fat milk,[42] fluoridated milk is not currently available in the U.S. However, fluoridated milk is available to almost 1 million schoolchildren in parts of Bulgaria, Chile, China, Peru, Russia, Thailand and the United Kingdom.[43,44] In

Louisiana, there were two small clinical trials of milk fluoridation, one started in 1955 and the other in 1982.[45] Both showed benefits of caries reduction compared to control groups. Overall, there have been 20 reports of 15 studies in 10 countries showing effectiveness of milk fluoridation in prevention of dental caries in primary teeth (eight of 10 studies) and in permanent teeth in 10 studies.[46]

Milk fluoridation for the prevention of dental caries was first proposed in the 1950s.[47] It has been demonstrated in an economic analysis that milk provides a relatively cost-effective vehicle for fluoride in the prevention of dental caries.[44]

A Cochrane review of studies in 2005 on the benefits of fluoridated milk in preventing dental caries found that there were insufficient good-quality studies.[44] However, the included studies suggested that fluoridated milk was beneficial to schoolchildren, especially their permanent dentition.[44] Two randomized controlled trials (RCTs) involving 353 children were included. For permanent teeth, after three years there was a significant reduction in the DMFT (78.4 percent, P <0.05) between the test and control groups in one trial, but not in the other. The latter study only showed a significant reduction in the DMFT until the fourth (35.5 percent, P <0.02) and fifth (31.2 percent, P <0.05) years. For primary teeth, again there was a significant reduction in the dmft (31.3 percent, P <0.05) between the test and control groups after three years in one study, but not in the other. The results could not be pooled because of the difference in concentration of fluoride in the milk.[44] A subsequent systematic review published in 2012 concluded that there is low evidence that the use of milk fluoridation is effective in reducing the caries increment.[5] Further research has been recommended to determine the age at which it is best to start drinking fluoridated milk, how many years milk consumption should continue, the frequency of consumption and the optimum concentration of fluoride.[44]

Fluoridation of milk has been recommended as a caries preventive measure where the fluoride concentration in drinking water is suboptimal, caries experience in children is significant and there is an existing school milk program. It has been recommended that the program should aim to provide fluoridated milk for at least 200 days per year and should commence before the children are 4 years of age.[47] The fluoride concentration of the fluoridated milk has ranged from 2.5 to 7.5 mg/L.[44] Children consumed the milk using a cup in one study and a straw in another.

Conclusions

The advantages of using salt as a vehicle for delivering fluoride outweigh the drawbacks related to this method, such as variation in ingestion, difficulties in maintaining the ideal concentration and concerns with hypertension.[15] Owing to the risk of increased fluoride intake from both fluoridated water and fluoridated salt, it is recommended that one or the other be used in individual countries. Countries where both are used have shown a higher prevalence of dental fluorosis or a resistance in promotion and distribution of fluoridated salt. In the U.S. where water fluoridation is extensively practiced, the alternative for those in nonfluoridated communities is the prescription of fluoride supplements for children at high risk for tooth decay. Water fluoridation is strong official policy of the World Health Organization; salt fluoridation and milk fluoridation are highly relevant alternatives if water fluoridation is not possible.[48] ■■■■

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