A review of worldwide milk fluoridation programs used in caries prevention

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Summary

The aim of this review is to give an overview of milk fluoridation programs and draw conclusions about the applicability of the method in caries prevention. Fluoridated milk was first investigated in the early 1950s, almost simultaneously in Switzerland, the USA and Japan. Stimulated by the favourable results obtained from these early studies, the establishment of The Borrow Dental Milk Foundation (subsequently The Borrow Foundation) in England gave an excellent opportunity for further research, both clinical and non-clinical, and a productive collaboration with the World Health Organization (WHO). Clinical trials were initiated in the 1980s. Some of these can be classed as randomised controlled trials, while most of the clinical studies were community preventive programs. These evaluations showed clearly that the optimal daily intake of fluoride in milk is effective in preventing dental caries. At present, milk fluoridation programs are running continuously in about ten countries of the world. Fluoridation of milk can be 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. 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.

***Key words*: caries prevention, community programs, fluoridated milk, caries reduction**

Introduction

Despite great improvements in the oral health of populations across the world, problems still persist particularly among poor and disadvantaged groups in both developed and developing countries. According to a recent World Oral Health Report, dental caries remains a major public health problem in most industrialized countries, affecting 60–90% of schoolchildren and the vast majority of adults [1, 2].

The World Health Organization (WHO) recommends that every effort must be made to extend fluoride prevention, including the development of affordable fluoridated toothpastes for use in developing countries. Water fluoridation, where technically feasible and culturally acceptable, has substantial advantages in public health; alternatively, fluoridation of salt and milk fluoridation schemes may be considered for prevention of dental caries [2].

The fluoridation of drinking water, which began in America in 1945, was the first community program in the prevention of dental caries. In Romania water fluoridation was running in the 1960s in Targu-Mures. The program was initiated by Cs?gör and after ten years 25-30% caries

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reduction was observed among schoolchildren [3]. However, now in Romania there is no water fluoridation, and the 'fluoride-map' of drinking water was realised only in Constanta county by Amariei and co-workers [4, 5].

The idea of milk fluoridation emerged – simultaneously with salt fluoridation (1955) – in Switzerland (Ziegler, 1953), in Japan (Imamura, 1952) and in the USA (Rusoff, 1955). Based on contemporary investigations, fluoride added to milk does not change its taste or other characteristics, is absorbed well, although slower than from fluoridated water. It has been considered advantageous that fluoride is added to an important nutrient for infants and small children, and that its consumption is not mandatory for everybody, only for those who need it most and agree to receive it. The caries preventive effect of fluoride can even be enhanced by the milk vehicle, due to the cariostatic properties of its mineral content, milk proteins and fats [6]..

The aim of the present review is to summarize briefly the results of research regarding - caries prevention through the flouridation of milk in community-based programs in order to give an overview of the studies published in dental journals and monographs.

Early clinical investigations

The first results were reported by Imamura, in 1959, after a five-year study of Yokohama schoolchildren. Milk or soup, containing 2.0 to 2.5mg sodium fluoride, was consumed at lunch-time, 150 to 180 days per year, by 167 children. Compared with the control group, 29 to 34% caries reductions were observed in the permanent dentition [7].

In the USA (Baton Rouge, Louisiana) Rusoff and co-workers reported, in 1962, on 3.5 years' results in 171 (65 test and 64 control) children. In children consuming fluoridated milk at school meals, 35% less caries was recorded than in the control children; in those who were 6 years old at the beginning, the reduction was even larger at 70% [8].

In Winterthur, Switzerland, Ziegler and Wirz used 0.22 % sodium fluoride solution, prepared by pharmacies in plastic bottles, for the fluoridation of household milk added by the parents to the milk of the children. Participants were 749 test and 553 control children who were 9 to 44 months old at the start of the program. After six years, caries reductions were 17% for the deft index and 30% for the defs index in the primary dentition, and 64 % for DMFT and 65 % for DMFS in permanent molars. The proportion of caries-free children increased significantly in the fluoridated milk group [9, 10].

The Borrow Foundation

The establishment of a charity foundation in England by Edgar Wilfred Borrow (1902-1990) for the promotion of milk fluoridation in order to prevent dental caries in children, brought important progress in the field of research and clinical studies. E.W. Borrow (Fig. 1), a wealthy farmer and mechanical engineer in south England, constantly interested in the technical aspects of fluoridation of milk, set up a foundation in 1971, named the 'Borrow Dental Milk Foundation', for the above purposes. In recognition of his humanitarian services, E.W. Borrow received an Honorary Doctorate from Lousiana University, USA, in 1983.

The aims were mainly "to promote and support research of fluoridated milk for human consumption by the help of grants, equipment, lectures, scientific publications, and to disseminate knowledge about this method". The aims were extended in 1993 to include "the support of activities on health promotion and education,… and on healthy nutrition, including milk and milk products" [6].

The name of the foundation was changed in 2002 to 'The Borrow Foundation'. Two of the authors of this present review, J. Bánóczy and A.J. Rugg-Gunn, are'Trustees' of the Foundation.

The results of clinical and basic research studies, supported by The Foundation, have made the creation and extension of milk fluoridation programs possible in numerous countries of the world. Based on discussions initiated in the 1980s between The Borrow Foundation and the WHO, the Bulgarian milk fluoridation program was initiated, and a 'Memorandum for Understanding' was signed by the Foundation and WHO in 1991 and this has been renewed every three years. As a result of this collaboration, a book was published in 1996, summarizing the studies of basic and clinical research into milk fluoridation [11]. A new, revised edition is expected to be published in 2008 as a WHO document [12].

Clinical examinations

Long-term human studies with fluoridated milk on children, undertaken in about twelve countries have been reported in numerous peer-reviewed papers. Only some of these studies can be classified as RCTs (randomised controlled trials) according to the criteria used in evidence-based medicine; the others can be classed as community-based programs [6]. In the following paragraphs, the main features of the evaluations of these milk fluoridation programs in different countries of the world, will be summarized, but without the detailed numerical results which can be found in the relevant literature (Table 1).

Scotland: Glasgow

Due to the strong criticism of the early clinical studies (for example, small numbers of participants, lack of baseline examinations, etc.), Stephen et al. initiated in Glasgow, in 1976, a double blind clinical trial on 4 ½ and 5 ½ year old schoolchildren [13]. The group of test children consumed 200 ml milk each school day (about 200 days per year), containing 1.5 mg fluoride, while the control group received plain milk. The results published in 1984, after five years, reported a 36% reduction in DMFT and a 48% reduction in DMFS values for the first permanent molars which were not yet erupted at baseline in the test group compared with the control group. Fluoride excretion in urine was monitored constantly during the study [14].

This evaluation (together with the Volgograd program by Maslak: see later) is one of the programs accepted as an RCT by the Cochrane Centre for Systematic Reviews [6].

Hungary: Fót

In the 'Children's City' of Fót, a milk fluoridation program was initiated by Bánóczy et al. in 1979, involving about 1,000 children aged 2 to18 years. The results were published after 3, 5 and 10 years [15, 16, 17]. The children drank for breakfast milk or cocoa, containing 0.4 mg fluoride for kindergarten children and 0.75 mg fluoride for the schoolchildren. The sodium fluoride solutions were prepared by the Pharmacy of Semmelweis University in closed glass bottles, then added to the milk in the kitchen of the home, stirred thoroughly for 15 minutes, and consumed within 30 minutes by the children. After five years, in the test group (165) children compared with a control group, a considerable caries reduction was observed in both the primary and permanent dentitions. In 7 to 10 years old children, these percentage reductions were 54% in DMFT and 53% in DMFS values. The reduction in the total permanent dentition was 60% for DMFT, and 67% for DMFS, respectively [16]. The highest reductions were found in the children who had consumed fluoridated milk from 2 to 3 years

Table 1. List of published reports of studies regarding the caries prevention through milk fluoridation.

Study	Year of study	Authors		Caries prevention in:	
				Primary teeth	Permanent teeth
Yokohama, Japan	1952–956	Imamura	1959		+
Baton Rouge, USA	1955–1959	Rusoff et al.	1962		+
Winterthur, Switzerland	1958–1964	Wirz	1964	+	+
		Ziegler	1964		
Agudos, Brazil	1976–1979	Lopes et al	1984		
Glasgow, UK	1976–1981	Stephen et al	1981		+
		Stephen et al	1984		
Fót, Hungary	1979–1990	Bánóczy et al.	1983		
		Bánóczy et al.	1985	+	+
		Gyurkovics et al.	1992		
Louisiana, USA	1982–1985	Legett et al	1987		+
Bethlehem, Israel	1983–1986	Zahlaka et al.	1987	+	+
Asenovgrad, Bulgaria	1988–1993	Pakhomov et al.	1995	+	+
		Atanassov et al.	1999		
Codegua, Chile	1994–1999	Mariño et al.	2001	+	
Voronezh, Russia	1994–2004	Pakhomov et al.	2005	+	
Wirral, UK	1995–2003	Riley et al.	2005		+
Beijing, China	1997–1999	Bian et al.	2003	+	
Knowsley, UK	1997–2001	Ketley et al.	2003		
Volgograd, Russia	1998–2002	Maslak et al.	2004	+	+
Araucania, Chile	1999–2002	Weitz and Villa	2004		+

of age. The difference between the caries prevalence of the test and control groups was, in spite of loss of children from the study, still statistically significant after 10 years [17].

Israel: Bethlehem

Zahlaka et al. reported in 1987 the results of a study on 273 children who were aged 4 to 7 years at baseline and who had consumed fluoridated milk for three years. The fluoridated milk was produced from milk powder, and the dissolved milk contained 1 mg fluoride per litre. A 63% caries reduction was observed in both the primary and permanent dentitions [18].

USA: Lousiana, Baton Rouge

In the second Lousiana community program, schoolchildren consumed fluoridated milk, containing cocoa and sugar, for lunch for two or three years. After two years, a significant caries reduction was observed in the permanent dentition: however, due to the loss of children, three year results could not be evaluated [19]. The organiser of the experiment, Legett, planned also to establish a research institute for milk

fluoridation which, however, could not be realised [6].

Bulgaria: Asenovgrad

One of the most extensive milk fluoridation programs, which is still functioning, was initiated by Pakhomov et al. in Bulgaria in 1988 with the support of WHO. The objective was to see if such a program was feasable under everyday life conditions. Bulgaria seemed to be an excellent choice for this community-based program due to the regular consumption of milk and milk products (for example, yoghurt) by children.

The city Asenovgrad in south Bulgaria was selected as the test community and the nearby city of Panaguriche as the control community; later, Karlovo became the control community. The fluoridated milk was produced and transferred from the Plovdiv dairy, in plastic bags containing 1 mg fluoride per day. About 3,000 children aged 3 to 10 years entered the program in Asenovgrad [20].

The baseline caries examinations and the examinations after 3 and 5 years were performed by dentists calibrated by a WHO epidemiologist. Urine monitoring was carried out regularly. After five years, mean dmft values were 52% lower in the test group children aged 6 ½ years and 40% lower in the 8 ½ year olds. The reduction in mean DMFT in these two age groups were 89% and 79% – statistically highly significant. After 10 years of the program, Atanassov et al. recorded further significant differences in the proportion of caries-free children and in mean DMFT values of the test and control groups [21].

The fluoridated milk program has been extended steadily to other parts of Bulgaria; in some communities there is a preference for fluoridated yoghurt. The next examination and evaluation is planned by WHO in the year 2007 [6].

South America: Brazil, Peru and Chile

From **Brazil** (Agudos) Lopes et al. reported in 1984 a small milk fluoridation study lasting 16 months. However, due to the short period, the results were not significant [22].

In **Peru,** a milk fluoridation program, controlled by the University of Trujillo, started in the 2000s, based on the government program 'vaso di leche', which provides one glass milk for children each day. The children received their milk in the 'Mother's clubs', where the fluoride solution prepared by the pharmacies was added to the fresh milk brought in by farmers, stirred thoroughly for 15 minutes, and consumed shortly after. However, the program was stopped after a few years because of the expanding salt fluoridation program in that country and the migration of children: no evaluation was made [6].

Chile: Codegua and Araucania

The Chilean milk fluoridation programs possess two features which differ from other programs. First, instead of using sodium fluoride they use sodium monofluorophosphate which, according to Villa et al., has a good bioavailability and other advantages and, second, the fluoride is added to powdered milk [23].

The community program which started in Chile in 1994 is based on the 'national nutrition complementing program' (PNAC) which has been in existence for more than 50 years. Under this scheme, every Chilean child, from birth to two years of age, receives two kilograms of milk powder every month, while children aged 2-6 years receive monthly one kilogram of milk powder with cereals. The PNAC program covers 90% of the child population, and was used by Mariño and co-workers for their fluoridated milk pilot program in the rural area of Codegua (test) and La Punta (control) [24].

Children between 0 and 6 years of age consumed for four years daily, 0.25, 0.5 or 0.75 mg fluoride mixed into the milk powder, according to their age-group. Fluoride-containing toothpaste was available and urine monitoring for fluoride excretion was performed regularly. After five years, the proportion of caries-free children was higher in Codegua than in the control La Punta, and mean dmfs values showed significant reductions in children in Codegua compared with children in La Punta. However, examinations performed three years after cessation of the program showed very small differences, pointing to the necessity of continuous maintenance of caries preventive programs [25].

In the IXth region of Chile, a new program started in 1999 with about 35,000 children aged 6 to 14 years, who were participants of the national powdered milk program (see above). In the community of Araucania, 6, 9 and 12 years old children received milk powder containing sodium monofluorophosphate, while the control children received milk powder without added fluoride. The control children were already participating in a community preventive program in which they received applications of APF gel. Examinations showed, historically, reductions in caries of 24 to 27 % in children aged 9 and 12 years, which was similar to the results of the fluoride gel program. Because the fluoride gel program was difficult to administer, the milk-powder fluoridation program has now been introduced into the majority of the Chilean regions as part of the caries preventive program for 6-14 year old children living in rural communities. While the main cities in Chile receive optimally fluoridated water as a public health measure, milk fluoridation is provided in the rural areas where water fluoridation is technically not possible, in order to ensure equity [25, 26].

China: Beijing

Due to the increasing caries prevalence in some parts of China, a milk fluoridation program was introduced between 1994-1997 for Chinese kindergarten children in a district of Beijing. An evaluation showed no effect, probably due to the high amount of sugar (7–10 %) added to milk. In the second phase of the program, therefore, no sugar or only small amount of sugar was added to the pasteurized milk which contained 2.5 ppm fluoride and which was consumed everyday in kindergartens. In addition, children brought home milk for weekends in boxes. Dentists calibrated to WHO standards examined the children after 21 months, recording also arrested caries. The mean dmft value in the test group showed a 69% reduction compared with the control. These results showed that fluoridated milk, when consumed daily, is able to prevent caries in the primary dentition and stop active dentinal caries from progressing – probably due to the topical effect of fluoridated milk [27].

United Kingdom: Knowsley and Wirral

In the UK, a milk fluoridation program was launched in 1997 in Knowsley by Ketley et al., where 4,060 3 to 5 year old children (mean age 4.7 years), consumed daily milk containing 0.5 mg fluoride; the control children in Skelmersdale drank plain milk. The number of days the children received milk was about 180 days per year. Caries evaluation was made, based on BASCD (British Association for Community Dentistry) criteria. After four years, no statistically significant differences in dmft and dmfs values of the two groups were found. The DMFT and DFS values were slightly, but not statistically significantly, smaller in the 7 to 9 year old children of the test group, than in the control. The assumption for these results was that the dose of fluoride in the milk was

too low and that the period of consumption was not long enough to show an effect [28].

In the Wirral region, examinations were made by Riley et al., using BASCD criteria, on 5,700 children, who were 5 years old when they entered the fluoridated milk program. Data for the four permanent molars were compared between 773 children who had been drinking fluoridated milk for six years at least, and 2,052 children from Shefton, who had received milk without added fluoride. Caries prevalence in the test group was 13 % less in the primary dentition and 16 % less in the permanent dentition. Mean DMFT values showed reductions of 31 %, and mean DFS a 37% reduction, compared with the control [29].

Russia: Volgograd and Voronezh

Milk fluoridation programs in Russia started in 1993 as a collaboration between the WHO and The Borrow Foundation, in a multicentric form, with the participation of Voronezh, Maykop and Smolensk, later on in Volgograd and in several communities in Tatarstan. Kouzmina et al., evaluating three year results in 1999 for 15000 participating children, reported caries reductions between 55 and 68% [30].

Maslak et al., in a three year study, investigated the effect of fluoridated milk in children who were caries-free at 3 years of age. In this double-blind evaluation, undertaken by examiners calibrated according to WHO criteria, on 75 test and 91 control children, they found a statistically significant reduction both in dmft and DMFT values, in longitudinal, as well as in cross-sectional comparative analyses [31]. According to the evaluation by the Cochrane Centre for Systematic Reviews, this study, as well as that of Stephen et al. from Scotland, is accepted as an RCT and as evidence for the effectiveness of milk fluoridation [6].

The effect of the 10 year milk fluoridation program was evaluated on 15,000 kindergarten children in two horizontal comparative analyses. Pakhomov et al. compared data from 335 test and 175 control children after three years, and revealed a statistically significant reduction in dmft values and an increase in caries-free children in the test group. In a second analysis, data from 3, 6, 9 and 12 year old children were compared cross-sectionally with baseline data, and a statistically significant caries reduction was observed. Urinary fluoride monitoring showed that the daily consumption of 200 ml milk containing 2.5 ppm fluoride is an effective caries preventive method and that the fluoride intake corresponded to physiological norms [32].

Thailand: Bangkok

In Thailand the milk fluoridation program was launched in Bangkok in 2000. It was established through the national school milk program reaching children aged 4 to 11 years, drinking milk in 200ml units, containing 0.5mg F (sodium fluoride), each school day. This community scheme involved 14,000 children in 8 public and 6 private schools. An evaluation based on fluoride analysis of 8-hours time-controlled urine sampling method was published recently. Phantumvanit et al. compared data from 115 test and 103 control children aged 4, 6 and 8 years after 6, 12 and 24 months. The average total excreted urinary fluoride per hour in children in all age groups, after launching the fluoridated milk project, indicated that they received F at the optimum and safety level [33].

Romania: Targu-Mures

A project for dental caries prevention through fluoridated milk addressed to pre-school children attending the state maintained kindergartens in Targu-Mures has been proposed in 1999. A pilot study was conducted in 2001 to investigate the daily excretion of urinary fluoride of

kindergarten children under their customary conditions of fluoride intake. The study comprised 92 children, aged 3 to 7 years, attending two kindergartens. The method based on spot samples used in this study was the fluoride/creatinine (Q) ratio determination. The Q ratio can be used as an index of 24 hours urinary fluoride excretion and the daily fluoride dose for each subject can be estimated as well. The results seem to indicate that the fluoride intake of kindergarten children in Targu-Mures is below the optimal recommended range [34].

In order to obtain more reliable and relevant data a baseline study was conducted in 2002. The study comprised 35 children, 5 to 6 years old who had been involved in the previous study. This baseline study followed the 16-hours time-controlled urine sampling method recommended by the WHO [35, 36]. According to the results obtained from both methods, the fluoride intake of kindergarten children in Targu-Mures is below the optimal recommended range and it emphasizes the urgent need of establishing fluoride preventive programs in this community [37].

Conclusions

Summarising: the effectiveness of milk fluoridation in preventing dental caries is supported by studies reported in numerous papers. Of these, eight demonstrated caries prevention in primary teeth and 11 in the permanent dentition (Table 1). Two studies showed no effect in either dentition. After cessation of a pilot milk fluoridation program, caries incidence increased. Two RCTs showed caries reductions, and evaluations of the several community programs pointed to the feasibility of the method under real life conditions.

Based on the performed studies, it seems that to obtain good results with milk fluoridation, even in the primary dentition, the programs should start early, possibly before the age of four. In order to protect the permanent molars, the consumption of fluoridated milk is necessary after their eruption too. The introduction of milk fluoridation programs should be considered where the fluoride content of drinking water is low, where a regular school milk system is working and where the children are able to consume the fluoridated milk for at least 200 days in a year.

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