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ORIGINAL ARTICLE

A systematic review on fluoridated food in caries prevention

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Abstract

Objective. This paper aims to provide a systematic review of the caries-prevention effect of fluoridated food, excluding water. The main aim of this review was to evaluate the presence of scientific evidence relating to the effects of fluoride intake via food on the occurrence of carious lesions. The outcome was defined as a clinical outcome, so only papers evaluating a decrease in caries indices were included. ***Materials and methods.*** Relevant databases (Medline®, Embase®, The Cochrane Library) were searched. The date range was set from 01.01.1966 to 03.31.2011. One hundred and thirty-nine reports were identified and assessed. Only three papers fulfilled the inclusion criteria and were discussed in detail. ***Results.*** No paper related to the use of fluoridated salt in caries prevention fulfilled the inclusion criteria. The use of milk as a vehicle for providing additional fluoride in a dental public health programme was evaluated in two papers. The consumption of fluoridated milk was an effective measure to prevent caries in the primary teeth. The use of fluoridated sugar demonstrated a reduction in caries increment in the permanent dentition in one paper. ***Conclusions.*** Literature on the effectiveness of fluoridation in foods in caries prevention is scant and almost all the studies have been conducted in children. There is low evidence that the use of milk fluoridation is effective in reducing the caries increment.

Key Words: *caries, fluoride, food, prevention, systematic review*

Introduction

Systematic reviews provide the foundation for improved practice and new research in all areas of healthcare and have already answered important questions regarding the effects of various fluoride regimens on caries prevention. Fluoride is an element in the halogen family and it forms inorganic and organic compounds called fluorides. Living organisms are mainly exposed to inorganic fluorides through food, water and air. Several additional sources of fluoride are present in the environment and they can occur naturally or as a result of industrial processes [1].

The safety of the fluoridation of public water supplies is widely described [2]. The WHO emphasizes the beneficial effects of fluoride on the health of tooth substance and the importance of the effective use of fluoride in caries prevention [3]. In the last five decades, an outstanding decrease in caries prevalence has been observed in the industrialized countries. The caries disease is still an endemic chronic disease among some population sub-groups, particularly those with a lower socio-economic status and in people living in developing countries [4,5]. It is becoming more imperative to commit the limited dental public health resources to those subjects who are most in need of prevention and treatment [6–8].

Several studies have demonstrated the caries-prevention effect of fluoride when administered through toothpaste, gel and other topical vehicles [9–11], but few studies of the effectiveness of fluoride as a food supplement are accessible.

The cariostatic effect of fluoride is well documented, although its mechanism of action is still under discussion [12]. Fluoride controls the initiation and progression of carious lesions. Fluoride is able to shift the balance between de- and remineralization

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towards the latter condition. Foods and drinks may represent natural or artificial sources of fluoride.

Water fluoridation is 'one of the 10 great public health achievements of the 20th century' according to the Centers for Disease Control and Prevention (CDC) [13]. Furthermore, water fluoridation is still considered by the World Health Organization (WHO) to be a fundamental part of the basic human right to life [3,14]. Studies of the effectiveness of water fluoridation have been based on observational study designs, because water fluoridation is an economical strategy when instituted at a city level. The only method to investigate the effectiveness of this measure is to compare caries rates in fluoridated and non-fluoridated cities. Nevertheless, these studies are regarded as low in quality and the weight of the evidence derived from cross-sectional and observational studies can be questionable [15]. In addition, major studies of the effectiveness of water fluoridation (e.g. the Grand Rapids, Tiel-Culemborg and Hartlepool studies) were conducted prior to 1966. For all these reasons, water fluoridation was excluded from the review.

Fluoridated foods were originally thought to reproduce the effect of water fluoridation on caries prevention, particularly in countries where water fluoridation has not been implemented. Fluoridated salt and milk and, to a lesser extent, sugar, bread and cereals were proposed and used as sources of the element [12].

When fluoridated water is present an increase in the mean content of fluoride in soft drinks and fruit juices was found [16]. Tea trees and bushes accumulate and store fluoride, absorbing it selectively from the air and soil; the fluoride concentration of tea was reported to be in a range from 0.34–3.71 ppm (mean = 1.50 ppm) in caffeinated tea (black and green) [17]. The daily consumption of tea in large quantities may lead to exposure to a high amount of fluoride, especially in countries where water fluoridation is present [18]. Vineyards planted and beer brewed in areas with high fluoride water levels may increase the daily fluoride intake [19]. Bony and canned fish and shellfish may represent a potential source of fluoride, such as sardines [20]. Finally, the estimate dietary fluoride intake might be high, but it is related to the diet regime behaviors and the appropriateness of dietary fluoride must be questioned.

Dietary fluoride supplements, such as tablets, drops, lozenges and chewing gum, were also introduced in areas where water fluoridation was not available. The Recommended Daily Allowance (RDA) of fluoride varies from 1.5–4.0 mg, in relation to age and gender [21]. Fluoride intake can vary between subjects depending on dietary constituents and the use of fluoridated products [22]. As a result of the intake of food, water and supplements containing fluoride, the concentrations in saliva of the element increase [23,24].

Objectives

To determine the effectiveness of fluoridated food in caries prevention, the following null hypothesis was tested: there is no difference in dental caries increment in subjects who have received fluoridated food or non-fluoridated food.

Materials and methods

Inclusion criteria

The outcome was defined as a clinical outcome. Only randomized controlled trials (RCTs) and clinical trials, which have evaluated the change in caries indices after fluoridation in foods were enrolled.

Exclusion criteria

The reasons for exclusion were defined as follows:

- *In vitro* study: including all *in vitro* studies;
- Search noise: including all studies not focusing on caries prevention and fluoride use;
- Different study design: including all studies where fluoridated food was used in combination with one or more different fluoridated vehicles in caries prevention or studies where the fluoride supplementation was carried out indirectly (i.e. fluoridation during pregnancy);
- Different outcome: including all studies where fluoride was used for reasons other than caries prevention;
- No food fluoridation: including all studies where different fluoride vehicles from fluoridated food were used for caries prevention.

Search strategy

The three main important electronic databases were searched: Medline® (from 01.01.1966 to 03.31.2011), Embase® (from 1973 to 03.31.2011) and The Cochrane Library.

The search was restricted to papers written in the English language and to clinical trials and randomized, controlled trials as the types of article; only human studies were included.

First, the terms fluoride, caries and food, such as milk, salt and sugar, were searched separately; afterwards, a combination of fluoride vs caries was used. The result of this first comparison was added to every other term (milk, salt, sugar) separately. Furthermore, the terms food fluoridation, milk fluoridation, salt fluoridation and sugar fluoridation were also searched separately and in combination with caries.

The abstracts of all papers identified through the electronic databases were examined independently and in duplicate by two authors (MGC and GC). For studies which appeared to meet the inclusion criteria, the full text was obtained. The full texts were scrutinized and assessed independently and in duplicate by two authors to establish whether or not the trials met the inclusion criteria. Disagreements were resolved by discussion. Where resolution was not possible, the other two authors were consulted. All studies meeting the inclusion criteria then underwent validity assessment. Studies rejected at this or subsequent stages were reported in the table of excluded studies with the reasons for exclusion (Table I). For each trial, the following information was recorded: citation details: including year of publication, country of origin; participants: including demographic characteristics and criteria for inclusion; intervention: including type and duration of intervention, duration of follow-up and method of administration.

Table I. List of excluded studies.

	Reasons for exclusion
Milk	
Nicol et al. Caries Res 2008;42:305–11.	Different outcome
Weitz et al. [32]	See table comparative study
Riley et al. [30].	See table comparative study
Mariño et al. [29].	See table comparative study
Ketley et al. [31]	See table comparative study
Mulyani and McIntyre [34].	Included in sugar search
Mariño et al. [28].	See table comparative study
Blinkhorn et al. Int Dent J 2001;51:435–8.	Search noise
Chuckpaiwong et al. Southeast Asian J Trop Med Public Health 2000;31:583–6.	Search noise
Bergendal and Hamp. Swed Dent J 1985;9:1–7.	Different outcome
Stephen et al. Br Dent J 1981;151:287–92.	Different aim and outcome
Stephen. J Dent Res 1977;56:104–11.	Different outcome
Salt	
Feng et al. Am J Dent 2010;23:08B–11B	Different outcome
He et al. Am J Dent 2010;23:B:11B–16B.	Different outcome
Mulyani and McIntyre [34]	Different outcome
Estupinan-Day et al. [33]	See table comparative study
Koo and Cury. Am J Dent 1998;11:173–6.	Different outcome
Marthaler. J Dent Res 1990;69:797–800.	Different outcome
Ripa et al. J Clin Dent 1990;2:29–33.	Different outcome
Triol et al. J Clin Dent 1988;1:48–50.	Different outcome
Koch. Odontol Rev 1972;23:341–54.	Different outcome

Quality assessment and scientific evidence

Two examiners (MGC and GC) read the papers independently. The quality and relevance of each study were graded as follow: high, medium or low using a study-quality checklist. External validity, internal validity and study precision were analyzed to obtain an overall assessment of quality. The assessment was used as a basis for the discussion between the two examiners to grade the studies. In the case of disagreement, all authors discussed the paper until a consensus was found.

The scientific evidence was assessed following the Swedish Council on Health Technology Assessment (SBU) criteria [25]. The evidence was scored high when similar conclusions were obtained by at least two independent studies of high quality, medium when similar conclusions were supported by one study of high quality or by at least two studies of medium quality; finally, the scientific evidence was defined as low when similar conclusions were achieved by at least two studies of medium quality.

Results

No difference was found between Medline® and Embase®. A total of 139 papers were selected following the inclusion criteria, but only three fulfilled the criteria and were included in the assessment.

Milk fluoridation

Using the Medline® database, nine papers were recorded, nine using Embase® and zero using The Cochrane Library. Only two of these papers fulfilled the inclusion criteria [26,27]. Moreover, another five comparative studies on the effectiveness of fluoridated milk in preventing dental caries in children were also recorded [28–32] (Tables II and III). No studies of the effect of fluoridated milk in adults can be found, as expected.

Both studies fulfilling the inclusion criteria investigated the caries-prevention effect of milk fluoridation on primary teeth. In the first one [26], each participant consumed 200 ml of fluoridated milk (concentration 2.5 mg F- per litre) a day for 21 months. At the end of the experimental period, the mean net caries increment was 0.4 dmft for the test group and 1.3 dmft for the control group (*t*-test, $p < 0.001$). The authors concluded that the consumption of fluoridated milk was an effective measure of preventing caries in the primary teeth. This study was scored as medium quality.

The second study [27] evaluates the effect of fluoridated milk on caries development in pre-school

Table II. Clinical trials included in the revision.

	Subject characteristics			Treatment characteristics				Results		
Reference	Intervention sample size (total sample size)[a]	Mean age (years)[b]	Proportion of females in study group	Matrix	Daily intake of supplemental fluoride (mg)	Intervention length (months)	Intake episodes/day	Difference control—treatment in caries indices	Prevented caries fraction[c]	Grading
Stecksén-Blicks et al. [27]	110 (186)	3.5	n.a.	Milk	0.38	21	1	−1.3 dmfs	81% unadjusted 75% age adjusted	Medium
Bian et al. [26]	417 (664)	4.5	54% (52%)	Milk	0.5	21	1	−0.9 dmft	69%	Medium
Mulyani and McIntyre [34]	77 (128)	11–19	53% (44%)	Sugar[d]	0.58	18	3[e]	−1.17 DMFS	80%	Low

[a]Number of subjects who completed the study.
[b]At baseline.
[c]Prevented caries fraction in per cent; the percentage is calculated as the difference in the increase in caries parameter (control study) divided by the increase in the parameter in the control multiplied by 100: e.g. [Δdmfs(control) – Δdmfs (study)] Δdmfs (control) *100.
[d]Sugar was used as an ingredient in tea and porridge.
[e]To be considered as a minimum – typical value.

children. Children in the intervention group received 150 ml of milk supplemented with 2.5 mg of fluoride per litre for lunch, while the control group received standard milk for 21 months. The authors concluded that the daily consumption of milk containing fluoride reduced caries in pre-school children, with a prevented fraction of 75%. This study was scored as medium quality.

Two comparative studies [28,29] investigated the caries-prevention effect on primary teeth, one on permanent teeth [30] and a further two on either dentition [31,32]. One study investigated the effect of the cessation of a fluoridated milk program; it showed an increase in caries incidence in the children who had stopped drinking fluoridated milk [29]. Only one study [31] failed to demonstrate the caries-prevention effect of milk fluoridation. Four studies suggested that fluoridated milk has a beneficial effect, reducing caries incidence in both the deciduous and permanent dentitions.

The scientific evidence derived from the two papers on the effectiveness of fluoridated milk in the reduction of caries increment was scored low.

Salt fluoridation

Three papers were recorded using the Medline® database, three using Embase® and one using The Cochrane Library. None of these papers fulfilled the inclusion criteria.

A comparative study was conducted in 1987. In Jamaica a comprehensive island-wide salt fluoridation programme was carried out. A survey was conducted in 1995 to monitor the impact of salt fluoridation among children, where a high level of caries was reported before the beginning of the preventive salt program. Eight years after the introduction of fluoridated salt, the mean caries prevalence in children's permanent dentition was dramatically lower than the corresponding scores recorded at the baseline examination (the mean DMFT at 12 years of age changed from 6.7 to 1.1). The authors conclude that a reduction in caries prevalence can be obtained through salt fluoridation without changing knowledge or behavior [33]. The scientific evidence regarding fluoridated salt was not possible to assess.

Sugar

Using the Medline® database, one paper was recorded, one using Embase® and zero using The Cochrane Library. The paper fulfilled the inclusion criteria.

In Indonesia, 176 children aged 7–19 years at high caries risk who were residents at two orphanages were enrolled. The subjects were divided into two groups: one was used as a control group and the other used a sugar containing 10 ppm of fluoride. After 18 months, the incremental increase in DMFS scores was 1.47 in

Table III. Comparative studies not included in the revision.

Authors	Year of publication	Location	Years	Outcome	Effectiveness deciduous	Effectiveness permanent
Milk						
Mariño et al. [28]	2001	Codegua, Chile	1994–1999	dmfs	Yes	Not evaluated
Mariño et al. [29]	2004	Codegua, Chile	1999–2002	dmfs	Yes	Not evaluated
Riley et al. [30]	2005	Wirral, UK	1995–2003	DMFT DMFS	Not evaluated	Yes
Ketley et al. [31]	2003	Knowsley, UK	1997–2001	dmfs DMFS	No	No
Weitz et al. [32]	2007	Araucania, Chile	1999–2002	dmft DMFT	Yes	Yes
Salt						
Estupinan-Day et al. [33]	2001	Jamaica	1984–1995	DMFT	Not evaluated	Yes

the control group and 0.3 in the group consuming fluoridated sugar. The authors concluded that sugar could be considered as a further vehicle for supplementary dietary fluoride in communities where there is a high caries prevalence or a high caries risk and little exposure to fluoride [34]. This study was scored as low quality. The scientific evidence regarding fluoridated sugar was not possible to assess.

Discussion

This paper is the first to provide a comprehensive assessment of the literature data on the caries-prevention action of fluoride used as a food. The literature published over a period of 40 years was searched; 139 papers were identified and three of them were finally included. In terms of content, the effect of fluoridated milk and sugar on children and adolescents has been addressed, even if only a few papers described a clinical caries reduction as outcome. Adults or the elderly have not been studied at all.

Although the caries prevalence in most industrialized countries has decreased dramatically, it still represents a common health problem for a significant proportion of the population of all ages [35]. In developing countries, access to oral health services is limited and a significant part of the population is under-served [36]. For this reason, the need for effective preventive strategies is still evident.

The use of topical fluoridated products, mainly toothpaste and to a lesser extent mouth-rinses and gels, has been a huge increase in the last decades, ensuring a daily fluoride exposure. This change in fluoride administration made traditional preventative, such as water, salt and milk fluoridation no longer necessary for many subjects. This effect is shown in studies where the cessation of water fluoridation does not lead to an increase in caries rate, both in primary and permanent dentitions [37,38].

The use of milk as a vehicle for providing additional fluoride in a dental public health programme has some important attractions, because it represents an important part of children's diets. Milk fluoridation schemes have been established within the context of school caries-prevention programs and within healthy diet and nutrition projects [39].

Efficacy of milk fluoridation appears to be confirmed as reported in literature [40]. It is not possible to draw firm conclusions about other variables, such as fluoride dose, number of days per year, background caries experience, time of consumption and method of drinking fluoridated milk, although it would appear desirable to avoid too low a dose of fluoride and the number of days a child receives fluoridated milk should be as many as possible.

In Germany, France and Switzerland, fluoridated salt for domestic use is widely used, representing some 30–80% of the market [41]. Salt is a particularly effective vehicle because it is an essential component of the diet, reaches all sectors of society, has worldwide distribution and is not dependent on a limited distribution or treatment system [42]. Even if salt fluoridation has the same potential, no scientific evidence is possible to obtain.

Based on the present results, it is possible to draw the following conclusions: (a) fluoridated milk has shown some efficacy in reducing caries increment, but the scientific evidence is low; and (b) no studies have been conducted among adults or the elderly.

The literature on the effectiveness of fluoridation in food for caries prevention is scant. The availability of scientific data is strictly related to the concern that the topic might arise in the scientific world, industry, etc. In the last decades market, academies and institution were focused essentially on the effect of topical fluoride, therefore few studies were designed and performed on the effectiveness of fluoridation in food. Nevertheless, fluoride is a cornerstone in caries prevention in both adults and children and the development and implementation of fluoride programs represents an important preventive strategy. The efficacy of food fluoridation is lower nowadays than in previous decades, when the caries prevalence was higher and the use of other fluoride modalities was not spread globally. This evidence does not reduce the importance of fluoridation through food, which can still be useful.

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