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REVIEW

Community water fluoridation and caries prevention: a critical review

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Abstract The aim of this paper was to critically review the current role of community water fluoridation in preventing dental caries. Original articles and reviews published in English language from January 2001 to June 2006 were selected through MEDLINE database. Other sources were taken from the references of the selected papers. For the past 50 years community water fluoridation has been considered the milestone of caries prevention and as one of the major public health measures of the 20th century. However, it is now accepted that the primary cariostatic action of fluoride occurs after tooth eruption. Moreover, the caries reduction directly attributable to water fluoridation have declined in the last decades as the use of topical fluoride had become more widespread, whereas enamel fluorosis has been reported as an emerging problem in fluoridated areas. Several studies conducted in fluoridated and nonfluoridated communities suggested that this method of delivering fluoride may be unnecessary for caries prevention, particularly in the industrialized countries where the caries level has became low. Although water fluoridation may still be a relevant public health measure in poor and disadvantaged populations, the use of topical fluoride offers an optimal opportunity to prevent caries among people living in both industrialized and developing countries.

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Introduction

Community water fluoridation (CWF) is the addition of a controlled amount of fluoride to the public water supply with the intent to prevent dental caries in the population. The recommended fluoride concentration ranges from 0.7 to 1.2 part per million (ppm), depending on the climatic temperature and water intake in that area [6, 31]. The effectiveness of CWF in preventing caries has been well established and in 2001 the Centers for Disease Control and Prevention (CDC) recognized fluoridation as one of the major public health measures of the 20th century [6]. The early studies reported that reductions in caries experience attributable to fluoridation ranged from 50 to 70% [5]. By the mid-1980s, however, the relative effectiveness of CWF has declined, whereas there has been an increase in the prevalence of fluorosis [5, 23]. Moreover, in the last decades some European countries adopting CWF interrupted it [13, 19].

The aim of this paper was to critically review the current role of CWF in preventing dental caries. The historical development of fluoridation, the impact of topical fluorides in the relative effectiveness of CWF, and the emerging problem of fluorosis in fluoridated communities were analyzed. Original articles and reviews published in English language from January 2001 to June 2006 were selected through MEDLINE database (key words: Water fluoridation/systemic fluoridation and caries prevention, Water fluoridation and oral health, Water fluoridation and fluorosis, Water fluoridation and topical fluoride). Other sources were taken from the references of the selected papers.

Caries prevention and community water fluoridation: an historical perspective

At the beginning of the 20th century, the American dentist Frederick McKay marked the start of the water fluoridation research [30, 35]. He noticed that many of his patients, native of Colorado Springs (CO), had distinctive brown stains on their teeth, which in turn were highly resistant to caries lesions. McKay observed the same peculiar stains, which he described as "mottled enamel", in other communities of the United States of America (USA) [5, 29, 30]. These findings led him to suspect that a substance in the drinking water was responsible for the brown stains and their high resistance to caries. At the beginning of 1930s, water analyses conducted by the chemist H. V. Churchill identified fluoride as the etiological agent of the "mottled enamel" disorder, later called enamel fluorosis for the causative factor [5, 29, 30]. During that period, H. Trendley Dean, a USA Public Health Service scientist, was prompted to start a series of epidemiological investigations to test the hypothesis that increased fluoride concentration in water supplies was associated with a reduction in caries prevalence [5]. This inverse relation was confirmed in a further investigation conducted in Colorado, Illinois, Indiana, and Ohio (the so-called 21-City Study) [5, 29]. Dean also observed that the prevalence of fluorosis was low (i.e., 10–12%) at fluoride levels up to 1.0 ppm in drinking water, with most of the fluorosis being of a very mild nature. On the other hand, when the fluoride in drinking water exceeded that level, prevalence and severity of fluorosis began to rise [5, 29]. These results provided the impetus for the initiation of CWF programs in the USA and Canada [6].

In 1945, Grand Rapids (MI) became the first city in the world to adjust the fluoride level to 1 ppm in the public water supply [5, 29]. In the same year, two towns, Aurora (IL), which was naturally fluoridated (1.4 ppm), and Muskegon (MI), as control, were included in an important clinical study on the effects of water fluoridation on caries [5, 19]. A further study started at Newburgh with Kingston as the control city (NY). In 1946, surveys began at Evanston with Oak Park (IL) as control, and at Brantford with Sarnia as control and Stratford which was naturally fluoridated (Canada, Ontario) [5, 29]. After 6 years of observation, Dean reported that the caries experience of children living in Grand Rapids during the period of water fluoridation had declined by almost half compared to Muskegon (control town) and had similar levels to those seen in Aurora (naturally fluoridated town) [9]. Moreover, after conducting sequential cross-sectional investigations over 13–15 years, a caries reduction of 50–70% was found in children living in the fluoridated communities [5]. In the following years, as a result of these long-term community studies, water fluoridation was introduced in the USA and in a number of countries throughout the world, like Australia, New Zealand, Singapore, Israel, United Kingdom, and Ireland [6, 19, 29].

In the USA, since the 1950s, the so-called antifluoridationists resisted the idea and practice of CWF. That movement represented the start for many organizations that in the last decades opposed the addition of fluoride in public water system. Their principal reasons of contrast included the freedom-of-choice issue and the potential dangerousness of fluoride to human health [8, 31]. Several diseases, including cancer, Down's syndrome, and an increase in fracture rate have been linked to CWF, but, to date, no evidence is available to support claims of harmful effects [28, 29, 31]. Nowadays, a number of countries, particularly in Europe, do not adopt artificial water fluoridation schemes or discontinued them as fluoridation can be viewed as a violation of medical ethics (silicofluorides used in water fluoridation are unlicensed medicinal substances) and human rights (silicofluorides are administered to large populations without informed consent or medical supervision) [8, 13, 19].

Water fluoridation in the world

It is estimated that over 300 million people in 39 countries worldwide live in areas where water supplies are fluoridated [3, 29]. In the USA, over 170 million people (67% of the population) currently benefit from artificially fluoridated water [31]. Apart from the USA, other countries employ CWF schemes, like Canada, Brazil, Argentina, Columbia, Chile, Australia, New Zealand, Malaysia, Israel, and cities like Hong Kong and Singapore [13, 17, 19, 29].

Based on the experience of overseas countries, CWF started also in Europe, but the European countries where CWF is actually in force are the Republic of Ireland (71% of the population covered) [37], Great Britain, and Spain (only 10% of the population covered) [29]. Some countries started with water fluoridation to interrupt it later (the Netherlands, Sweden, East Germany, and Finland), other countries (Switzerland, Hungary, France, West Germany, and Denmark) never started it or preferred different fluoride vehicles (i.e., salt) [13, 19]. Austria, Belgium, France, Norway, and Italy are instead convinced that fluoridation is a good health measure, but no decision regarding it has ever been made [13, 19]. CWF is not being currently adopted in Italy because in a number of areas throughout the country, water is naturally fluoridated, reaching the optimal level for caries prevention [13]. Another important reason is a sustained expansion of the use of bottled water, with a wide range of fluoride concentration, which is almost the major source of drinking water in this country [16].

Role of water fluoridation in caries prevention: current key issues

Systemic vs topical effect of fluoride

A dogma has existed for many decades, that fluoride acts mainly preeruptively with its incorporation into the hydroxyapatite crystals, leading to the formation of fluorapatite, a less soluble enamel apatite [12]. Research over the last 20 years, however, has changed our understanding of this concept [6, 12, 15, 23]. A number of studies showed that the differences in fluoride concentration in surface enamel between permanent teeth from low-fluoride and fluoridated areas were minimal, whereas an inverse relationship between fluoride levels in enamel surface and caries experience was not found [12, 15]. Several laboratory investigations have clearly demonstrated that the presence of low levels of fluoride (0.03 ppm or higher) in saliva and plaque fluid reduces the rates of enamel demineralization during the caries process and promotes the remineralization of early caries lesions [11, 12, 15]. On the other hand, the level of fluoride incorporated into enamel by systemic ingestion was proved to have no significant effect in preventing/reversing caries [11]. Moreover, the reexamination of clinical/epidemiological data from early and recent CWF studies supported the current view that the cariostatic effect of fluoride is almost exclusively posteruptive and the mechanism of action is topical [12, 15, 23]. A person living in a fluoridated community, in fact, may increase this level to about 0.04 ppm several times during the day [23]. In addition, it has been found that fluoride may also affect oral plaque bacteria by the interference with acid production [3, 6, 11]. The implications of these concepts are that frequent exposure to low concentration of fluoride in the oral cavity is the most important factor in preventing/controlling caries; on the other hand, the anticaries effects of systemic fluoride are recognized to be minimal [6, 11, 23, 38].

The impact of fluoride-containing products

In the past decades, a number of authors focused their attention on caries trend of the communities that interrupted water fluoridation in comparison to communities without water fluoridation (Kuopio and Jyvaskyla, Finland; Chemnitz and Plauen, Germany; Tiel and Culemborg, Holland; La Salud, Cuba) [1, 5, 15, 19, 21, 23]. In these communities, during the years of water fluoridation, a caries reduction had been observed, but after the cessation, caries prevalence did not rise, remained almost the same or even decreased further [15, 21, 23]. These findings do indicate that the interruption of CWF had no negative effects on caries prevalence.

Several epidemiologic studies have also demonstrated that caries reductions directly attributable to water fluoridation have declined in the last decades. In the USA, by the mid-1980s, caries levels in the permanent dentition of children living in fluoridated areas was only 18% lower compared to children living in nonfluoridated areas [5]. In the same years (1979–1980), the caries reduction attributable to CWF was 8–37% (mean: 26.5%) among the USA adolescents [5]. Recent differences in caries prevalence between fluoridated and nonfluoridated communities have been confirmed to be much smaller than in the past [6, 9, 19, 23, 26]. Moreover, in most European countries, where CWF has never been adopted, a substantial decline in caries prevalence has been reported in the last decades, with reductions in lifetime caries experience exceeding 75% [26].

The main reason for the decline in the caries prevalence in industrialized countries is recognized to be the introduction of fluoridated toothpaste in the early 1970s [6, 9, 11, 26, 29]. The diminishing benefit from CWF has been also attributed to the large use of the other fluoride-containing products, including mouthrinse, dietary supplements, and professionally applied or prescribed gel, foam, or varnish [6, 26]. The use of topical fluoride results in an additional caries reduction beyond what is provided by CWF [36]. When these products are used, in fact, fluoride can be retained for 2–6 h in saliva and plaque at concentration which can have a significant effect on enamel demineralization/remineralization [11, 23, 24]. Fluoride toothpaste and mouthrinse have shown to reduce the prevalence of caries by 24–26%, instead of CWF that nowadays reduces caries trend by 15% [32, 36]. Specific reduction in caries rates has been estimated to be 26–28% for gel and foam, and 46% for fluoride varnish [6, 36].

Water fluoridation and socioeconomic dental health inequalities

Although caries prevalence is in constant decrease in the western world, caries still remains a major public health problem for the vast majority of individuals living in developing countries and for the populations with low socioeconomic status in developed countries [9, 17, 20, 26]. Some studies in the United States, Britain, Australia, and New Zealand suggested that fluoridation may reduce the inequalities of dental health between social classes [4, 18, 33], but, to date, there is limited evidence to support the view that fluoridation reduced the disparities in caries [27]. Most of the improvements in children's dental health, in fact, are attributable to the widespread availability of fluoride-containing toothpastes since the 1970s [6, 9, 11, 26, 29]. Other factors such as socioeconomic status, lifestyle, food habits can also affect the incidence of caries that cannot be predicted by fluoridation alone [10, 34].

Nevertheless, for underprivileged groups in both developing and developed countries, the safety and effectiveness of water fluoridation has been endorsed, even in recent years, by international and national agencies and dental associations throughout the world [6, 17, 29, 31, 32]. It must be noted, however, that the WHO World Oral Report 2003 recommended the development of affordable fluoride toothpaste for use in developing countries [32]. WHO also emphasized the importance of updating current information on the cost-effectiveness of CWF against a background of the now universal use of fluoride toothpastes [32].

Fluorosis: an emerging problem in fluoridated communities

Fluorosis occurs as a result of long-term intake of fluoride during the preeruptive development of teeth. It is a hypomineralization of enamel characterized by an increased surface and subsurface porosity causing opacity, pitting or staining of the enamel [3, 6, 31]. At a level of 1 ppm fluoride in domestic water supplies, the prevalence of fluorosis has been estimated to be approximately 51%, but most of the fluorosis is of a very mild nature and it is not generally noticed by the public [3, 6]. In the last decades, there has been a trend toward an increase in the prevalence of fluorosis in the USA and other western countries adopting CWF [3, 6, 7, 14, 37]. A recent systematic review concluded that fluorosis of aesthetic concern affected 12.5% of residents in fluoridated communities in the United Kingdom [28]. It is important to emphasize, however, that fluorosis, whether of aesthetic concern or not, is the first visible sign of an excessive intake of fluoride during the period of enamel formation.

A major risk factor in fluorosis is the inappropriate use of fluoride toothpaste in young children who may not be able to expectorate it adequately [2, 3, 6, 14]. In addition, some risk of increasing fluorosis may be attributed to the ingestion of powdered infant formula reconstituted with fluoridated water (in fluoridated areas only) [3, 22, 25, 35]. Foods and beverages processed in fluoridated areas, as well as the bottled waters with high fluoride concentration, can be significant sources of ingested fluoride for young children [3, 22, 25, 35]. Furthermore, the use of dietary fluoride supplements during the first 6 years of life is associated with a significant increase in the risk of developing fluorosis [2, 3, 6, 7, 31, 35].

To limit individual exposure to dietary fluorides, in recent years there have been a number of recommendations for sharply reducing fluoride supplement schedules, particularly in fluoridated communities [2, 6, 25, 29, 31, 38]. Similarly, the proper use of fluoride delivery systems, which operate posteruptively has been increasingly supported by public health organizations and scientific dental associations [6, 23, 31, 38]. It has also been proposed to lower the fluoride level in water supplies to between 0.6 to 0.8 ppm; such measure, according to the Forum on Fluoridation 2002, would reduce the risk of fluorosis, without significant changes in caries prevalence [3].

Conclusions

For the past 50 years, CWF has been considered the most cost-effective measure for the control of caries at the community level [5, 6]. However, it is now accepted that systemic fluoride plays a limited role in caries prevention [12, 38]. Several epidemiologic studies conducted in fluoridated and nonfluoridated communities clearly indicated that CWF may be unnecessary for caries prevention [1, 5, 15, 19, 21, 23], particularly in the industrialized countries where the caries level has became low [16, 21]. Moreover, the evidence of an increased prevalence of fluorosis, particularly in fluoridated areas, needs to be considered [3, 22]. Nevertheless, water fluoridation may still be a relevant public health measure in populations where oral hygiene conditions are poor, lifestyle results in a high caries incidence, and access to a well-functioning oral health care system is limited. Instead, topical fluoride offers an optimal opportunity to prevent dental caries among people living in both industrialized and developing countries, and the use of fluoride-containing products, particularly the toothpaste, needs to be maintained and expanded [6, 17, 32, 36, 38].

References

1. Birkeland JM, Ibrahim YE, Ghandour IA, Haugejorden O (2005) Severity of dental caries among 12-year-old Sudanese children with different fluoride exposure. Clin Oral Investig 9:46–51
2. Bottenberg P, Declerck D, Ghidey W et al (2004) Prevalence and determinants of enamel fluorosis in Flemish schoolchildren. Caries Res 38:20–28
3. Browne D, Whelton H, O'Mullane D (2005) Fluoride metabolism and fluorosis. J Dent 33:177–186
4. Burt BA (2002) Fluoridation and social equity. J Public Health Dent 62:195–200
5. Centers for Disease Control and Prevention (1999) Achievements in public health, 1990–1999: fluoridation of drinking water to prevent dental caries. MMWR Morb Mortal Wkly Rep 48:933–940
6. Centers for Disease Control and Prevention (2001) Recommendations for using fluoride to prevent and control dental caries in the United States. MMWR Morb Mortal Wkly Rep 50:1–42
7. Cochran JA, Ketley CE, Árnadóttir IB et al (2004) A comparison of the prevalence of fluorosis in 8-year-old children from seven European study sites using a standardized methodology. Community Dent Oral Epidemiol 32(Suppl 1):28–33
8. Cross DW, Carton RJ (2003) Fluoridation: a violation of medical ethics and human rights. Int J Occup Environ Health 9:24–29

9. Cury JA, Tenuta LMA, Ribeiro CCC et al (2004) The importance of fluoride dentifrices to the current dental caries prevalence in Brazil. Braz Dent J 15:167–174
10. Downer MC, Drugan CS, Blinkhorn AS (2005) Dental caries experience of British children in an international context. Community Dent Health 22:86–93
11. Featherstone JDB (1999) Prevention and reversal of dental caries: role of low level fluoride. Community Dent Oral Epidemiol 27:31–40
12. Fejerskov O (2004) Changing paradigms in concepts on dental caries: consequences for oral health care. Caries Res 38:182–191
13. Fluoride Action Network. Water fluoridation status worldwide. Available at: http://www.fluoridealert.org/fluoridation.htm (Accessed December 18, 2006)
14. Harding MA, Whelton H, O'Mullane DM et al (2005) Primary tooth fluorosis in 5-year-old schoolchildren in Ireland. Eur J Paediatr Dent 6:155–161
15. Hellwing E, Lennon AM (2004) Systemic versus topical fluoride. Caries Res 38:258–262
16. Istituto Superiore di Sanità-Centro Nazionale di Epidemiologia, Sorveglianza, Promozione della Salute (EpiCentro). La fluorazione delle acque in Italia. Available at: http://www.epicentro.iss.it/problemi/cavo_orale/nota.asp (Accessed December 18, 2006)
17. Jones S, Burt BA, Petersen PE et al (2005) The effective use of fluorides in public health. Bull World Health Organ 83:670–676
18. Jones CM, Worthington H (2000) Water fluoridation, poverty and tooth decay in 12-year-old children. J Dent 28:389–393
19. Kargul B, Caglar E, Tanboga I (2003) History of water fluoridation. J Clin Pediatr Dent 27:213–217
20. König KG (2000) Diet and oral health. Int Dent J 50:163–174
21. Künzel W, Fisher T (2000) Caries prevalence after cessation of water fluoridation in La Salud, Cuba. Caries Res 34:20–25
22. Levy SM (2003) An update on fluorides and fluorosis. J Can Dent Assoc 69:286–291
23. Limeback H (1999) A re-examination of the pre-eruptive and post-eruptive mechanism of the anti-caries effects of fluoride: is there any anti-caries benefit from swallowing fluoride? Community Dent Oral Epidemiol 27:62–71
24. Lynch RJM, Navada R, Walia R (2004) Low-levels of fluoride in plaque and saliva and their effects on the demineralisation and remineralisation of enamel; role of fluoride toothpastes. Int Dent J 54:304–309
25. Marshall TA, Levy SM, Warren JJ et al (2004) Associations between intakes of fluoride from beverages during infancy and dental fluorosis of primary teeth. J Am Coll Nutr 23:108–116
26. Marthaler TM (2004) Changes in dental caries 1953–2003. Caries Res 38:173–181
27. McDonagh M, Whiting P, Bradley M et al (2000) A systematic review of public water fluoridation. York, NHS Centre for Reviews and Dissemination, University of York (Report 18)
28. McDonagh MS, Whiting PF, Wilson PM et al (2000) Systematic review of water fluoridation. Br Med J 321:855–859
29. Mullen J (2005) History of water fluoridation. Br Dent J 199(7 Suppl):1–4
30. National Institute of Dental and Craniofacial Research. The story of fluoridation. Available at: http://www.nidcr.nih.gov/HealthInformation/DiseasesAndConditions/Fluoride/StoryFluoride.htm (Accessed December 18, 2006)
31. Palmer C, Wolfe SH (2006) Position of the American Dietetic Association: the impact of fluoride on health. J Am Diet Assoc 105:1620–1628
32. Petersen PE, Lennon MA (2004) Effective use of fluorides for the prevention of dental caries in the 21st century: the WHO approach. Community Dent Oral Epidemiol 32:319–321
33. Spencer AJ, Slade GD, Davies M (1996) Water fluoridation in Australia. Community Dent Health 13(Suppl 2):27–37
34. Wang B, Zheng B, Zhai C, Yu G, Liu X (2004) Relationship between fluorine in drinking water and dental health of residents in some large cities in China. Environ Int 30:1067–1073
35. Warren JJ, Levy SM (1999) Systemic fluoride-sources, amounts, and effects of ingestion. Dent Clin North Am 43:695–711
36. Weyant RJ (2004) Seven systematic reviews confirm topical fluoride therapy is effective in preventing dental caries. J Evid Dent Base Pract 3:129–135
37. Whelton H, Crowley E, O'Mullane D et al (2006) Dental caries and enamel fluorosis among the fluoridated population in the Republic of Ireland and non fluoridated population in Northern Ireland in 2002. Community Dent Health 23:37–43
38. Zimmer S, Jahn KR, Barthel CR (2003) Recommendations for the use of fluoride in caries prevention. Oral Health Prev Dent 1:45–51