

## What is the evidence that fluoride works to prevent dental caries?

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### Summary

The Centers for Disease Control and Prevention of the U.S. Public Health Service conducted an excellent review of scientific articles on the use of fluorides for the prevention and control of dental caries in the United States [1]. That review is quoted here extensively as the basis to describe the evidence that fluoride works to prevent dental caries. Since fluoridated salt is not available in the U.S., other references have been used to examine the evidence that the use of fluoridated salt also works to prevent dental caries.

**Key words: fluoride, dental caries, water fluoridation, salt fluoridation.**

### Summary

#### Introduction

Dental caries (i.e., tooth decay) is an infectious disease with many risk factors afflicting most persons in industrialized countries and some developing countries.

Fluoride reduces the incidence of dental caries and slows or reverses the progression of existing lesions (i.e., prevents cavities). Although pit and fissure sealants, meticulous oral hygiene, and appropriate dietary practices contribute to caries prevention and control, the most effective and widely used approaches have included fluoride use. All U.S. residents are exposed to fluoride to some degree, and widespread use of fluoride has been a major factor in the decline in the prevalence and severity of dental caries in the United States and other economically developed countries [2].

The prevalence and severity of dental caries in the United States have decreased substantially. National surveys have reported that the prevalence of any dental caries among children aged 12-17 years declined from 90.4% in 1971-1974 to 67% in 1988-1991; severity (measured as the mean number of decayed, missing, or filled teeth) declined from 6.2 to 2.8 during this period. Fluoride works to prevent dental caries when

available and used in drinking water, beverages, food, toothpaste, mouthrinses, lozenges or drops.

Although this decline is a major public health achievement, the burden of disease is still considerable in all age groups. Because many fluoride modalities are effective, inexpensive, readily available, and can be used in both private and public health settings, their use is likely to continue. Fluoride's ability to inhibit or even reverse the initiation and progression of dental caries is well documented.

However, In Central and Eastern Europe, caries prevalence is still high and there are no signs of substantial improvements; in addition, misleading contentions of untoward effects of fluorides (as used for prevention of dental caries) are still widespread. On the global scale, only a minority of children benefit from caries prevention and fluorides [3].

#### Toothpaste

By the 1990s, fluoride toothpaste accounted for >90% of the toothpaste market in the United States, Canada, and other developed countries. Because water fluoridation is not available in many countries, toothpaste might be the most important source of fluoride globally [4].

Studies of 2-3 years duration have reported that fluoride toothpaste reduces caries experience among children by a median of 15-30%. This reduction is modest compared with the effect of water fluoridation, but water fluoridation studies usually measured lifetime - rather than a few years' - exposure. Regular lifetime use of fluoride toothpaste likely provides ongoing benefits that might approach those of fluoridated water. Combined use of fluoride toothpaste and fluoridated water offers protection above either used alone.

The propensity of young children to swallow toothpaste has led to development of "child-strength" toothpaste with lower fluoride concentrations. Such a product would be a desirable alternative to currently available products for many young children.

Toothpaste containing 500-550 ppm fluoride might be almost as efficacious as that containing 1,000 ppm fluoride [5]. A British study reported that the prevalence of diffuse enamel opacities (an indicator of mild enamel fluorosis) in the upper anterior incisors was substantially lower among children who used toothpaste containing 550 ppm fluoride than among those who used toothpaste containing 1,050 ppm fluoride [6].

Such a toothpaste is not yet available in the US, primarily because a U.S. clinical trial of the efficacy of toothpaste with lower fluoride concentrations, required by FDA before approval for marketing and distribution, has not been conducted.

## Water Fluoridation

Initial studies of community water fluoridation demonstrated that reductions in childhood dental caries attributable to fluoridation were approximately 50-60% [7, 8, 9, 10]. More recent estimates are lower - 18-40% [11, 12]. This decrease in attributable benefit is likely caused by the increasing use of fluoride from other sources, with the widespread use of fluoride toothpaste probably the most important.

The diffusion or "halo" effect of beverages and food processed in fluoridated areas but consumed in nonfluoridated areas also indirectly spreads some benefit of fluoridated water to non-fluoridated communities. This effect lessens the differences in caries experience among communities [13].

Quantifying the benefits of water fluoridation among adults is more complicated because adults are rarely surveyed; their fluoride histories are potentially more varied, and their tooth loss or restorations might be caused by dental problems other than caries (e.g., trauma or periodontal diseases). Nevertheless, adults are reported to receive caries-preventive benefits from community water fluoridation [14, 15, 16].

These benefits might be particularly advantageous for adults aged >50 years, many of whom are at increased risk for dental caries. Besides coronal caries, older adults typically experience gingival recession, which results in teeth with exposed root surfaces. Unlike the crowns of teeth, these root surfaces are not covered by enamel and are more susceptible to caries. Because tooth retention among older age groups has increased in recent decades in the United States, these groups' risk for caries will increase as the country's population ages. Older adults also frequently require multiple medications for chronic conditions, and many of these medications can reduce salivary output. Drinking water containing an optimal concentration of fluoride can mitigate the risk factors for caries among older adults. Studies have reported that the prevalence of root caries among adults is inversely related to fluoride concentration in the community drinking water [17, 18, 19].

Water fluoridation also reduces the disparities in caries experience among poor and non-poor children [20, 21, 22, 23]. Caries experience is considerably higher among persons in low SES strata than among those in high SES strata. The reasons for this discrepancy are not well understood; perhaps persons in low SES strata have less knowledge of oral diseases, have less access to dental care, are less likely to follow recommended self-care practices, or are harder to reach through traditional approaches, including public health programs and private dental care. Thus, these persons might receive more benefit from fluoridated community water than persons from high SES strata. Regardless of SES, water fluoridation is the most effective and efficient strategy to reduce dental caries [24].

A systematic review of published studies, conducted on behalf of the Task Force on Community Preventive Services by a team of experts, found that community water fluoridation was effective in reducing tooth decay

among populations. Based on strong evidence of effectiveness, the Task Force recommends that community water fluoridation be included as part of a comprehensive population-based strategy to prevent or control tooth decay in communities [25].

### **Salt Fluoridation**

The fluoridation of community water supplies or salt fulfills the requirements of providing safe, effective protection from dental caries at reasonable cost [26]. 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 to four Mexican States that tend to have appreciable concentrations of fluoride in their drinking water sources [27]. In countries where caries prevalence is high, but the majority of the population cannot afford fluoridated toothpastes due to low socioeconomic conditions, the introduction and extension of salt fluoridation to the whole population is well founded and recommended from a public health view [28]. The results of the clinical experiments of Toth performed in Szeged, Hungary, showed, after 17 years, a caries reduction of about 66%. These results contributed significantly to the introduction of salt fluoridation in several countries (France, Costa Rica, Jamaica, Germany) [29]. Studies in Jamaican children between 1984 and 1995 have shown dramatic reductions in dental caries since the introduction of fluoridated salt in 1987 [30, 31]. More recent studies in 1999 in Jamaica have seen a continued trend in lowering of dental caries prevalence and severity, which has been attributed to multiple sources of fluoride [32].

### **Fluoride Mouthrinse**

Over-the-counter solutions of 0.05% sodium fluoride (230 ppm fluoride) for daily rinsing are available for use by persons aged >6 years. Solutions of 0.20% sodium fluoride (920 ppm fluoride) are used in supervised, school-based weekly rinsing programs. Studies indicating that

fluoride mouthrinse reduces caries experience among schoolchildren date mostly from the 1970s and early 1980s [33, 34, 35, 36, 37, 38, 39]. In one review, the average caries reduction in nonfluoridated communities attributable to fluoride mouthrinse was 31% [40]. Two studies reported benefits of fluoride mouthrinse approximately 2.5 and 7 years after completion of school-based mouthrinsing programs, [41, 42], but a more recent study did not find such benefits 4 years after completion of a mouthrinsing program [43]. The National Preventive Dentistry Demonstration Program (NPDDP), a large project conducted in 10 U.S. cities during 1976-1981 to compare the cost and effectiveness of combinations of caries-prevention procedures, reported that fluoride mouthrinse had little effect among schoolchildren, either among first-grade students with high and low caries experience, [44] or among all second- and fifth-grade students [45]. NPDDP documented only a limited reduction in dental caries attributable to fluoride mouthrinse, especially when children were also exposed to fluoridated water.

### **Dietary Fluoride Supplements**

Dietary fluoride supplements in the form of tablets, lozenges, or liquids (including fluoride-vitamin preparations) have been used throughout the world since the 1940s.

Most supplements contain sodium fluoride as the active ingredient. Tablets and lozenges are manufactured with 1.0, 0.5, or 0.25 mg fluoride. To maximize the topical effect of fluoride, tablets and lozenges are intended to be chewed or sucked for 1-2 minutes before being swallowed. For infants, supplements are available as a liquid and used with a dropper.

In 1986, an estimated 16% of U.S. children aged <2 years used fluoride supplements [46]. All fluoride supplements must be prescribed by a dentist or physician. The prescription should be consistent with the 1994 dosage schedule developed by ADA, AAPD, and AAP. Because fluoride supplements are intended to compensate for fluoride-deficient drinking water, the dosage schedule requires knowledge of the fluoride content of the child's primary drinking water; consideration should also be given to other sources of water (e.g., home, child care settings, school,

or bottled water) and to other sources of fluoride (e.g., toothpaste or mouthrinse), which can complicate the prescribing decision.

The evidence for using fluoride supplements to mitigate dental caries is mixed. Use of fluoride supplements by pregnant women does not benefit their offspring [47].

Several studies have reported that fluoride supplements taken by infants and children before their teeth erupt reduce the prevalence and severity of caries in teeth, but several other studies have not. Among children aged 6-16 years, fluoride supplements taken after teeth erupt reduce caries experience. Fluoride supplements might be beneficial among adults who have limitations with toothbrushing, but this use requires further study.

## **Professionally Applied Fluoride Compounds**

### ***Fluoride Gel and Foam***

Clinical trials conducted during 1940-1970 demonstrated that professionally applied fluorides effectively reduce caries experience in children. In more recent studies, semiannual treatments reportedly caused an average decrease of 26% in caries experience in the permanent teeth of children residing in nonfluoridated areas [48, 49, 50, 51]. The application time for the treatments was 4 minutes. In clinical practice, applying fluoride gel for 1 minute rather than 4 minutes is common, but the efficacy of this shorter application time has not been tested in human clinical trials. In addition, the optimal schedule for repeated application of fluoride gel has not been adequately studied to support definitive guidelines, and studies that have examined the efficacy of various gel application schedules in preventing and controlling dental caries have reported mixed results. On the basis of the available evidence, the usual recommended frequency is semiannual [52, 53, 54].

### ***Fluoride Varnish***

High-concentration fluoride varnish is painted directly onto the teeth. Fluoride varnish is not intended to adhere permanently; this method holds a high concentration of fluoride in a small amount of material in close contact with the teeth for many hours. Fluoride varnish has practical advantages (e.g., ease of application, a nonoffensive taste, and use of smaller amounts of fluoride

than required for gel applications). Such varnishes are available as sodium fluoride (2.26% [2,600 ppm] fluoride) or difluorsilane (0.1% [1,000 ppm] fluoride) preparations. Fluoride varnish has been widely used in Canada and Europe since the 1970s to prevent dental caries [55, 56]. FDA's Center for Devices and Radiological Health has cleared fluoride varnish as a medical device to be used as a cavity liner (i.e., to provide fluoride at the junction of filling material and tooth) and root desensitizer (i.e., to reduce sensitivity to temperature and touch that sometimes occurs on root surfaces exposed by receding gingiva) [57]; FDA has not yet approved this product as an anticaries agent. Caries prevention is regarded as a drug claim, and companies would be required to submit appropriate clinical trial evidence for review before this product could be marketed as an anticaries agent. However, a prescribing practitioner can use fluoride varnish for caries prevention as an "off-label" use, based on professional judgment [58].

Studies conducted in Canada [59] and Europe [60, 61, 62, 63] have reported that fluoride varnish is efficacious in preventing dental caries in children. Applied semiannually, this modality is as effective as professionally applied fluoride gel [64]. Some researchers advocate application of fluoride varnish as many as four times per year to achieve maximum effect, but the evidence of benefits from more than two applications per year remains inconclusive [65, 66, 67]. Other studies have reported that three applications in 1 week, once per year, might be more effective than the more conventional semiannual regimen [68, 69].

European studies have reported that fluoride varnish prevents decalcification (i.e., an early stage of dental caries) beneath orthodontic bands [70] and slows the progression of existing enamel lesions [71]. Studies examining the effectiveness of varnish in controlling early childhood caries are being conducted in the United States. Research on fluoride varnish (e.g., optimal fluoride concentration, the most effective application protocols, and its efficacy relative to other fluoride modalities) is likely to continue in both Europe and North America.

### ***Fluoride Paste***

Fluoride-containing paste is routinely used during dental prophylaxis (i.e., cleaning).

The abrasive paste, which contains 4,000-20,000 ppm fluoride, might restore the concentration of fluoride in the surface layer of enamel removed by polishing, but it is not an adequate substitute for fluoride gel or varnish in treating persons at high risk for dental caries [72]. Fluoride paste is not accepted by the U.S. Food and Drug Administration or the American Dental Association as an efficacious way to prevent dental caries.

## Conclusion

In countries where salt is fluoridated there appears to be good evidence to support its use.

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