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## The potential of fluorides and sealants to deal with problems of dental decay

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The prevalence of oral diseases in many parts of the world is staggering.<sup>1</sup> Consequently, many countries have, or are developing, a large cadre of professional and auxiliary personnel trained to deliver dental services. The education of these persons has tended to stress skills for reconstructing teeth and their supporting tissues after disease has occurred; teachers in most dental schools seldom emphasize preventive methods.

The potential to be able to prevent dental caries as a major oral health problem is great because, of all oral diseases, dental caries is at present the most nearly preventable. Three factors must be present for dental caries to occur: (1) a susceptible host—inasmuch as any tooth will develop caries if challenged sufficiently, all persons with teeth must be considered susceptible; (2) the presence in dental plaque of bacteria that can produce acids which attack the teeth; and (3) a diet suitable for bacterial fermentation.<sup>2,3</sup>

Efforts to prevent dental caries have focused upon attempts to: (1) increase the resistance of teeth with various fluorides and adhesive pit and fissure sealants;<sup>4-9</sup> (2) lower the number or reduce the cariogenic activity of bacteria in contact with the teeth by mechanical means or with chemical agents;<sup>10-13</sup> and (3) modify dietary practices by urging people to eat sweets, cookies and soft drinks less frequently.<sup>14-16</sup>

Dental plaque adheres tenaciously to teeth,<sup>17-19</sup> but it can be removed mechanically by toothbrushing and, from areas between the teeth, by the use of dental floss and other cleaning devices. School-based studies, however, have shown that efforts to control plaque by daily, supervised toothbrushing and flossing for periods up to three years have failed to reduce the incidence of dental caries in children.<sup>20,21</sup> Most persons cannot achieve, with current mechanical methods, the level of oral cleanliness necessary to prevent dental caries in approximal and fissured tooth surfaces. It is unrealistic to believe that we can control dental caries as a public health problem simply by urging people to remove dental plaque fastidiously each day.

The prospects for reducing dental decay by altering the dietary habits of the public are equally unpromising.<sup>22,23</sup> Diets have changed radically within the last 50 years in the U. S., as they surely have in other countries. More and more sugar is hidden in commercially prepared foods and not consciously taken from the sugar bowl. Sugar obviously plays a pervasive role in today's lifestyle. Getting people to change their dietary practices for the purpose of improving oral health is a difficult task.<sup>22,24</sup> However, dental benefits are readily apparent in persons who practice dietary control of sugar, such as those with hereditary fructose intolerance. Although the likelihood of success from a public health aspect is small, restricting the frequent ingestion of sugars should continue to be advocated.

Today, the most feasible way to prevent dental caries is to increase the tooth's resistance to decay. The best individual and public health defense against dental decay is the proper use of fluorides. But, the proper use of fluorides does not preclude the need for regular dental care or educating the public about good oral hygiene and dietary practices.

Until about 10 years ago, most dental experts believed that fluorides worked principally by increasing the resistance of enamel to acids produced in dental plaque by bacteria.<sup>25</sup> More recent research clearly shows that other actions of fluoride, such as remineralization of initial or precarious lesions and a host of antimicrobial effects, are also important.<sup>26-28</sup>

The mechanisms by which fluorides prevent dental decay probably vary, depending upon the agent used, its route of administration, its concentration and frequency of use, and the vehicle used to deliver it.<sup>29</sup> More than one mechanism may operate simultaneously. Perhaps the most important element is the frequent provision of low concentrations of fluoride to dental plaque.<sup>27</sup>

### Community Water Fluoridation

Fluoride compounds are among the most common components of the earth's crust. Nearly all natural water

sources contain a measurable quantity, which varies according to the amount and solubility of the fluoride in adjacent mineral deposits. Only distilled water and uncontaminated rain and snow are completely free of fluoride.

Many common foods also contain appreciable amounts of fluoride. Fish and tea are particularly rich sources. Fluoride also is found in fowl and other meats and in such cereals as rye, wheat, and rice. In fact, fluoride is present in so many foods that some is probably ingested at every meal.

Because naturally occurring water-borne fluoride is not always present in a concentration sufficient to produce dental benefits, the natural level should be adjusted. The process of adjusting the amount of fluoride in a community's water to an optimal concentration for the prevention of dental caries is known as community water fluoridation. Because the original water is likely to contain some fluoride already, a key word in this definition is adjustment.

Fluoridation of community water supplies is the least expensive and most effective way to provide fluoride to large groups of people.<sup>30-32</sup> Optimal adjustment of the fluoride concentration of community water supplies should be the foundation for all programs of dental health because this public health method is nearly ideal. First and foremost, community fluoridation is highly effective.<sup>33,34</sup> Hundreds of studies done throughout the world have shown that children who consume optimally fluoridated water from birth have from 50-70% less dental decay than they would have experienced without fluoridation. As an example of the benefits produced after fluoridation, Table 1 shows comparative DMF tooth scores for 12- to 16-year-old children in Grand Rapids, MI before and after 15 years of community water fluoridation.

**Table 1.** Average number of DMF teeth in 12- to 16-year-old children in Grand Rapids before and after 15 years of community water fluoridation.

Age	DMF Teeth		Percentage difference
	1944-45 Before fluoridation	1959 After 15 years	
12	8.07	3.47	57.0
13	9.73	3.58	63.2
14	10.94	5.38	50.8
15	12.48	6.22	50.2
16	13.50	7.03	47.9

Consumption of fluoridated water is eminently safe.<sup>33,34</sup> No other health measure has been analyzed more critically than the fluoridation of city water supplies. The procedure is also inexpensive and greatly reduces the per capita costs of dental treatment.<sup>35-37</sup> On

the average, community fluoridation currently costs about 20 ¢ per person per year to operate in the U.S.<sup>33,34</sup> In addition, the entire community benefits from the procedure, regardless of socioeconomic level, educational achievement, individual motivation, or the availability of dentists. No cooperative effort or direct action need be taken by those who will benefit. Moreover, the improvement in dental health continues for life if consumption of fluoridated water continues.<sup>38,39</sup> A recent report shows that lifelong consumption of fluoridated water also significantly lowers the prevalence of root surface caries in older persons.<sup>40</sup>

Although the benefits of community fluoridation are truly impressive, the procedure is not a panacea for dental caries. Unfortunately, its implementation is limited to areas with central water supplies. Moreover, other methods of preventing decay are still necessary for particularly susceptible persons living in fluoridated communities, and obviously, the use of fluoridated water is not a license for unrestricted consumption of confections between meals or for abandoning oral hygiene procedures.

Published estimates show that 185 million persons living in 6,470 communities in 40 countries drink water with an optimally adjusted fluoride concentration.<sup>41</sup> Another 39 million persons living in 4,096 communities in 39 countries consume drinking water with naturally occurring amounts of fluoride at optimal or greater concentrations. Nineteen of these 39 countries also have communities with controlled fluoridation. Thus, there are at least 60 countries in the world with adjusted or natural fluoridation, serving more than 10,000 communities and 224 million persons.<sup>41</sup> The Republic of Ireland implemented legislation for national fluoridation in the early 1960s. Approximately 112 million U.S. citizens (one-half the total population) live in communities served by fluoridated water supplies or by water that contains optimal or greater concentrations of fluoride as a natural constituent. The municipal water supplies in Hong Kong and Singapore are fluoridated. Thirty million persons in 85 communities in the Soviet Union consume fluoridated water.

Abundant data show that fluoridated water not only acts systemically during tooth formation to produce enamel more resistant to dental caries but also acts directly as a topically applied agent. Therefore, the procedure benefits both children and adults.

Studies of the effects of fluoridation in young children prove that the procedure effectively reduces the prevalence of dental caries in primary teeth by about 40%.<sup>42-44</sup> Marthaler has shown that consumption of fluoridated water should begin at birth to provide maximal protection to primary teeth.<sup>44</sup>

Many studies have confirmed the finding that fluoridation reduces the prevalence of dental caries in permanent teeth by an average of about 60%.<sup>33-34</sup> However,

the benefits are not uniformly conferred to all tooth surfaces. Approximal and other smooth tooth surfaces are protected to a far greater extent than are pit and fissure surfaces.<sup>44-46</sup> Using data from several studies, Marthaler<sup>44</sup> has shown rather conclusively that maximal caries protection to permanent teeth occurs only when children begin to consume water at birth. The protection lessens gradually with increasing age of children at the start of fluoridation, as shown for children in Grand Rapids in Figure 1.

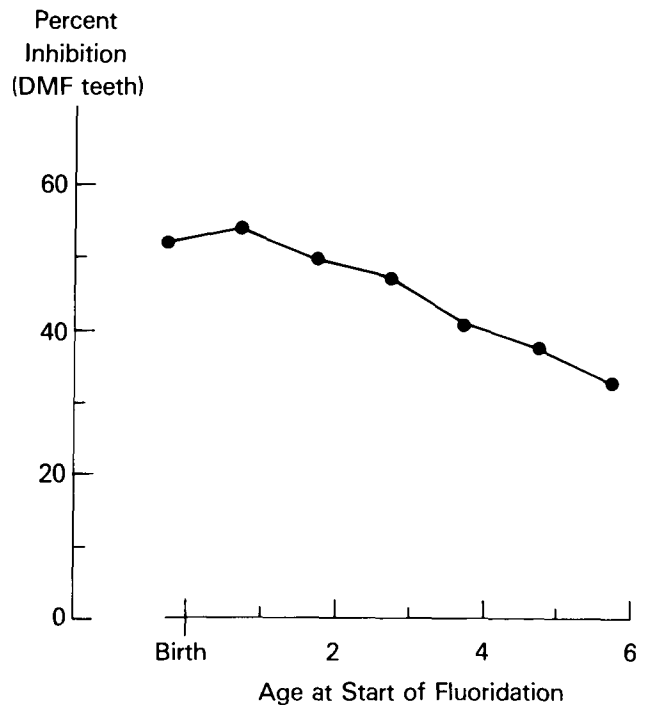
After community fluoridation has existed for many years, there will be:

1. about six times as many children who are free from dental caries
2. about a 60% lower prevalence of dental caries
3. almost a 75% decrease in extracted first permanent molars
4. approximately 95% fewer carious lesions in approximal surfaces of maxillary incisors.<sup>45</sup>

Studies carried out among adults who lived continuously in fluoride and nonfluoride areas have demonstrated that the dental benefits from fluorides in water are not limited to children. For example, adults 20-44 years of age in Colorado Springs who had consumed water that contained 2.5 ppm of fluoride all their lives had lower DMF tooth scores than did adults of the same ages in Boulder who had consumed water with only trace levels of fluoride.<sup>39</sup> For each five-year age grouping between 20 and 44, the average DMF score was approximately 60% lower in Colorado Springs than in Boulder (Figure 2). Natives of Boulder had lost three to four times as many teeth because of dental caries as had natives of Colorado Springs. Consuming drinking water with adequate amounts of fluoride does not merely delay the development of dental caries, but gives substantial life-long protection.

Because fluoridation protects smooth tooth surfaces best, including approximal surfaces of posterior teeth, proportionally fewer complex, multisurface fillings are placed in optimally fluoridated communities than in areas with fluoride-deficient water. Pits and fissures of teeth also receive protection from consumption of fluoridated water, but to a lesser extent. Hence, caries in pits and fissures persists as the predominant type of decay in fluoridated communities. These cavities are easy to detect and, because they are generally easier to restore than approximal cavities, they require less of a dentist's time.

Analysis of cost and time factors required to provide regular, periodic dental care for children in fluoridated Newburgh, NY, and fluoride-deficient Kingston, NY, demonstrated that costs of treating the backlog of accumulated dental needs at the initiation of the care program were 60% lower in Newburgh than in Kingston, and the costs for incremental care for six years were 50% lower. The average chairtime required to provide both initial



**Figure 1.** Percentage inhibition of dental caries in permanent teeth of children in Grand Rapids, MI according to age when first exposed to fluoridated water.

and incremental care was 1.6 times greater in Kingston than in Newburgh.<sup>35,47,48</sup> Similar findings have been reported from New Zealand<sup>36</sup> and, relative to the need for care of primary teeth, from Canada.<sup>49</sup>

Efforts to implement fluoridation have frequently been unsuccessful.<sup>50</sup> It is unfortunate that a public health measure as inexpensive, safe, easily implemented, and effective as fluoridation should create, on occasion, such public controversy. In many areas, proposals to fluoridate have become political issues, decided on by public referendum or by elected officials without expertise in health. Doubts raised in voters' minds frequently have led them to reject fluoridation.

There are five steps that must be taken to overcome the obstacles to community water fluoridation.

1. Supporters of fluoridation must recognize that the decision to fluoridate has become a political issue.
2. The public must be made aware of its benefits.
3. A national strategy and information exchange for fluoridation matters must be developed.
4. Federal agencies must provide incentives for communities to fluoridate.
5. Schools of dentistry must stress the benefits of fluoridation in their curricula.<sup>51</sup>

### School Water Fluoridation

Children who live in areas without public water supplies cannot benefit from optimally fluoridated drinking water. One effective way to bring them these benefits is to fluoridate their school water supplies. Rural schools usually have private wells, and the water from these wells can easily be fluoridated. Researchers in the late

1950s hypothesized that prevention of dental caries could be produced by part-time consumption of fluoridated water only on schools days, even if consumption did not begin until age five or six. Higher than optimal fluoride concentrations for community fluoridation were suggested for school fluoridation to compensate for the part-time and belated exposures. Studies of school fluoridation have been conducted in the U.S. Virgin Islands,<sup>52</sup> Kentucky,<sup>53</sup> Pennsylvania,<sup>54</sup> and North Carolina,<sup>55</sup> in which fluorides were added to school water supplies at levels of 2.3, 3.0, 5.0, and 6.3 ppm, respectively.

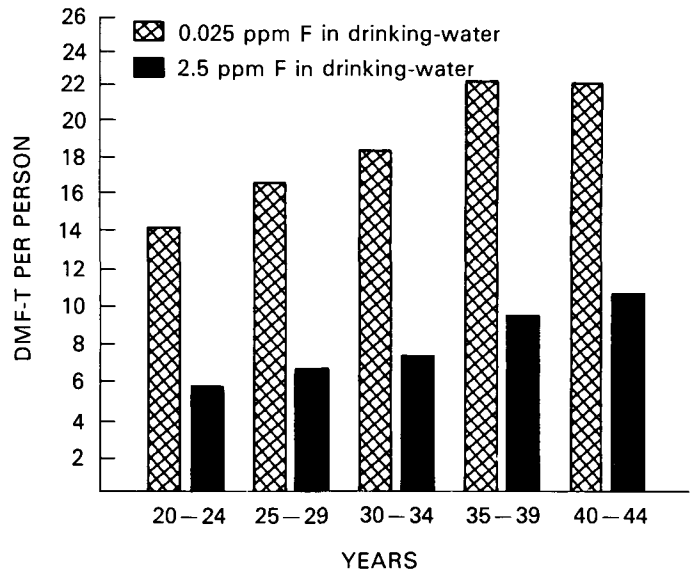
After 12 years of school fluoridation at 5.0 ppm, or 4½ times the optimum recommended for community fluoridation in the same geographic area, children at Elk Lake School in Pennsylvania demonstrated 40% fewer DMF surfaces than their baseline counterparts.<sup>54</sup> The findings showed a differential effectiveness according to time of tooth eruption. Earlier erupting teeth (incisors and first molars) that were already in place when the children began to attend school showed a protective effect that resulted in 31% fewer DMF surfaces, whereas surfaces of later erupting teeth (canines, premolars, and second molars) that could derive both topical and systemic exposure to the fluoridated water in school yielded 57% fewer DMF surfaces (Table 2). Both eruptive classes of teeth showed superior effects in proximal surfaces—as great as a 69% lower prevalence of decay in proximal surfaces of later erupting teeth. The rate of extractions per 100 teeth decreased overall by 65% during the 12-year period of the study. No objectionable dental fluorosis resulted from the procedure.

More than 400 schools in 14 U.S. states now are fluoridating their water supplies at about 4.5 times the concentration appropriate for community fluoridation in the same geographic area.<sup>33,56</sup>

One major disadvantage of school fluoridation is that its application is limited to geographic areas where both school and home water supplies of the students have uniformly low concentrations of fluoride. If some students drink nearly optimal concentrations of fluoride in water at home and others only trace levels, it is impossible to determine the proper concentration for the school's water supply.

**Table 2.** Average DMF surface scores by eruptive status among school children in Elk Lake, PA before (1958) and after 12 years (1970) of school fluoridation.

Year	DMFS		
	In all teeth	In early erupting teeth	In late erupting teeth
1958 (N = 1,030)	13.51	9.03	4.47
1970 (N = 1,149)	8.13	6.23	1.91
% Difference from 1958	40	31	57



**Figure 2.** Mean numbers of DMF teeth per adult. Natives of Boulder (0.025 ppm F) and Colorado Springs (2.5 ppm F), excluding third molars.

The engineering aspects of fluoridating school water resemble those of community water fluoridation.<sup>57,58</sup> In both instances, the maintenance of equipment and the surveillance of fluoride levels must be done regularly and conscientiously.

### Dietary Fluoride Supplements

In communities with insufficient fluoride in drinking water, dietary fluoride supplements in the form of tablets, lozenges, solutions, or drops are recommended for children for the prevention of dental caries. In order to protect primary and permanent teeth as well as consuming fluoridated water does, fluoride supplements must be taken daily in correct dosage from birth until about age 14, when all permanent teeth other than third molars have erupted.<sup>59</sup> The Council on Dental Therapeutics of the ADA recommends the dosage schedule for dietary fluoride supplements shown in Table 3. The Committee on Nutrition of the American Academy of Pediatrics adopted a nearly identical dosage schedule in 1979. Until then, the academy had recommended 0.5 mg of fluoride from birth until age three. A high degree of motivation,

**Table 3.** Dosage schedule (in mg F/day) for dietary fluoride supplements according to fluoride concentration of drinking water and age.

Age (years)	Concentration of fluoride in water (ppm)		
	Less than 0.3	0.3 to 0.7	Greater than 0.7
Birth to <2	0.25	0	0
2 to <3	0.50	0.25	0
3 to 13	1.00	0.50	0

dedication, and perseverance of parents and children is needed to comply with the demanding regimen. For this reason, fluoride supplements lack appeal as a base for a community program. In addition, they are more costly than community water fluoridation. Therefore, dietary fluoride supplements should not be regarded as a substitute for community water fluoridation. Rather, they are best suited for low-fluoride areas without public water systems and as an interim measure in those communities with central water systems that have not yet implemented community fluoridation.

Because the concentration of fluoride in breast milk is very low, some health practitioners have suggested giving fluoride supplements to breast-fed infants in fluoridated communities.<sup>60</sup> However, this suggestion should be viewed with caution because the period of breast feeding for infants is highly variable.

In 1966 the U.S. Food and Drug Administration (FDA) banned manufacturers of fluoride supplements from claiming that dental caries would be prevented in the offspring of women who used their products during pregnancy because clinical evidence to substantiate such a claim was insufficient.<sup>61</sup> The FDA did not question the safety of the procedure because there was no indication that the recommended dosages of fluoride harmed either the pregnant woman or the fetus. Although the ban effectively stopped the pharmaceutical industry from promoting fluoride supplements for prenatal use, it did not prohibit physicians and dentists from prescribing them for pregnant women. Therefore, some practitioners who believe the procedure has value have continued to prescribe prenatal fluorides for their patients.

The collective data on the possible value to the offspring of pregnant women from exposure to fluoridated water or dietary fluoride supplements have been equivocal. A 1980 symposium studied the question in depth.<sup>62-67</sup>

From a theoretical standpoint it may be concluded that primary teeth can benefit from prenatal exposure to dietary fluoride supplements, but permanent teeth are unlikely to benefit from the procedure. Nevertheless, prenatal administration of dietary fluoride supplements cannot be recommended at this time because conclusive clinical evidence of its value is lacking. A need exists for well-controlled clinical trials to establish the value of prenatally administered dietary fluoride supplements.

Fluoride supplements are commercially available in the form of drops, solutions, lozenges, and tablets. The selection of a particular form of supplement should depend primarily on the personal preferences of the practitioner and patient, after consideration of the patient's age and the relative costs of various preparations. Fluoride drops are particularly convenient for use with infants because they can be dispensed directly into a child's mouth from a medicine dropper or drip bottle, or they can be added to foods or liquids. Tablets or lozenges

for infants must be crushed or dissolved in liquids, which makes the procedure more difficult for the parent.

Fluoride tablets are most commonly prescribed for children whose primary teeth have all erupted (about two years of age). Erupted teeth can derive a significant topical benefit from fluoride supplements if the supplement remains in contact with the teeth for a period of time before it is swallowed.<sup>68-70</sup> Therefore, tablets and lozenges should be chewed and the resulting salivary fluoride solution forcefully swished around the teeth before swallowing. They also can be dissolved slowly in the mouth. Similarly, if a solution is used by children with erupted teeth, they should swish it thoroughly in the mouth before swallowing.

Dietary fluoride supplements may be obtained as fluoride-vitamin combinations. Several clinical studies have shown that fluoride-vitamin combinations reduce dental caries effectively,<sup>60,71-73</sup> and, in one study, as effectively as fluoride supplements without vitamins.<sup>73</sup> There is no evidence that vitamins enhance the effect of fluoride. The determining factor in choosing a fluoride-vitamin combination should be a clear indication that a vitamin supplement is needed. If a need does not exist, then a fluoride supplement without vitamins should be prescribed; vitamins should not be used merely as a vehicle for delivering fluoride. However, if vitamins as well as fluorides are indicated, it is sometimes convenient to prescribe a combined fluoride-vitamin supplement. When a combined supplement is prescribed, parents should know the importance of the fluoride itself aside from the value of the vitamin component because the need for fluoride supplementation usually continues beyond the age at which vitamins usually are discontinued.

The success of dietary fluoride supplementation depends upon the interest of prescribers and the cooperation of parents and children in following the consistent and continuous regimen required from birth through age 13. Strong motivation and a clear realization of the need for daily intake are essential. These demands limit the effectiveness of home consumption of dietary fluoride supplements as a broadly applicable procedure for preventing dental caries.

### Salt Fluoridation

The successful use of salt enriched with iodine to prevent goiter has facilitated the use in some countries of salt as a vehicle for administering fluoride to prevent dental caries. Salt first was used for this purpose in 1946 in Switzerland.<sup>74</sup> By 1961 fluoridated salt was available in 16 of the 25 cantons of Switzerland. Several studies in Switzerland, Hungary, and Colombia have established the value of fluoridated salt.<sup>75</sup> In the early programs and studies, 90 mg of fluoride per kilogram of salt produced a limited caries-preventive benefit, which led to recommendations that the concentration of fluoride in salt be

raised to between 200 and 300 mg per kilogram.<sup>76,77</sup> It is thought that when the concentration of fluoride in salt is such that excretion levels of urinary fluoride are similar to those found in communities with optimally fluoridated water, the caries-preventive effects are similar.<sup>75</sup>

Some find it paradoxical that salt, which has been associated with hypertension, should be a vehicle for preventing another disease. Proponents of salt fluoridation point out that the concentration of fluoride in salt can be adjusted so that a small amount of salt will still provide an optimal amount of fluoride for caries prevention. However, the inconsistency of advising reduced consumption for one purpose while implicitly encouraging ingestion for another purpose jars the sensibilities of some public health officials. Nevertheless, fluoridation of salt may be an effective and practical method to prevent caries in some countries where water fluoridation is uncommon or unattainable, and where the production or importation of salt is state-controlled.

### Milk Fluoridation

Few studies with humans have explored the use of milk as a vehicle for fluoride supplementation, and these have had few participants.<sup>78,79</sup> Although the results have been encouraging, more clinical data are needed before the fluoridation of milk can be recommended as a caries-preventive measure. Interest in this research persists thanks to support of the Borrow Dental Milk Foundation in Great Britain.

Theoretically, milk fluoridation has certain inherent disadvantages. The amount of milk consumed by children, particularly among those in different socioeconomic groups, varies considerably. Also, unlike consumption of water, the consumption of milk tends to decrease as a child grows older, whereas the need for fluoride to prevent dental decay increases with age. Therefore, the long-term benefits of milk fluoridation may be less than those afforded by continual exposure to fluoridated drinking water. Moreover, the absorption of fluoride from milk has been shown to be lower than from water, and fluoride is incompletely ionized in milk.<sup>80-82</sup>

Milk fluoridation also has some technical disadvantages not shared by water fluoridation. For example, water fluoridation can usually be accomplished by installing fluoridating units at only one or, at most, a few main points in a water system. In contrast, milk often is processed in many different facilities within or surrounding a community. Thus, the problems of inspecting facilities and monitoring fluoride concentrations are likely to be more complex with milk fluoridation. Problems of distribution, particularly in areas with varying levels of natural fluoride in the drinking water, and of costs also are likely to restrict the widespread adoption of milk as a vehicle for fluoride administration.

Fluoridated milk could be useful in a school-based program in which an optimal daily dosage is provided at one time. However, the costs of fluoridating milk for distribution in schools are likely to be much greater than corresponding costs for a school-based fluoride tablet program.

### Professionally Applied Topical Fluorides

Hundreds of studies have shown that the incidence of dental caries in children who live where water is fluoride-deficient can be reduced about 30-40% by the application of solutions of 2% sodium fluoride (NaF) and 8% stannous fluoride (SnF<sub>2</sub>), solutions or gels of acidulated phosphate fluoride (APF) containing 1.23% fluoride ion, or varnishes that contain fluoride. Semiannual applications of stannous fluoride, APF, and varnishes are recommended in caries-susceptible patients. The advantages and disadvantages of each of these concentrated fluoride agents have been discussed in several reviews.<sup>83-87</sup> Although some laboratory data indicate that teeth need not be cleaned professionally prior to fluoride applications,<sup>88,89</sup> it is premature to recommend omitting prophylaxis before applying fluoride.

Data from clinical studies do not support the use of a fluoride-containing prophylaxis paste to enhance the effectiveness of a subsequent application of a fluoride solution or gel. Neither do data support the use of a fluoride prophylaxis paste alone as an effective caries preventive regimen.<sup>90</sup> However, because a thorough prophylaxis may abrade several microns of fluoride-rich outer enamel,<sup>91</sup> a fluoride prophylaxis paste is indicated as an attempt to replenish the fluoride removed by abrasion when a routine prophylaxis is not followed by a topical fluoride application.

When concentrated fluorides have been professionally applied to the teeth of children who have consumed fluoridated water all their lives, the results are equivocal.<sup>84,87</sup> Because community fluoridation already benefits the dental health of children so much, further protection from professional applications of fluorides to teeth is difficult to demonstrate. Such applications, therefore, are not cost-effective for all children living in fluoridated communities. However, for children who develop cavities readily despite water fluoridation, topical fluoride applications are definitely recommended.

Carious destruction is rapid and rampant when salivary flow is minimal; therefore, adults with xerostomia caused by therapeutic irradiation or by various medications are prone to develop rampant caries and should receive topically applied fluorides regularly and should use self-applied fluoride preparations at home.

Professionally applied fluoride procedures are inherently too expensive for public health programs because they require a one-to-one relation between the provider of the service and the recipient.<sup>31</sup> The shortage of dental personnel in some locations only accentuates the short-

comings of this method of caries prevention.

### Self-applications of Fluoride

In the last 15–20 years, several methods of self-applying fluorides have been developed to avoid the drawbacks of professionally administered procedures. These fall into six categories:<sup>90</sup> (1) solutions or gels applied with a toothbrush; (2) prophylaxis pastes applied with a toothbrush; (3) gels applied in trays; (4) dentrifices; (5) mouthrinses; and (6) dietary supplements, such as tablets or lozenges.

Self-application of fluorides may be carried out at home either *ad libitum*, as with dentrifices or mouthrinses, or as recommended by a physician or dentist in the case of dietary fluoride supplements or gel-trays for children with rampant caries. Two of the procedures, dietary fluoride supplements and fluoride mouthrinsing, are eminently suitable for school-based caries-preventive programs.<sup>92</sup> These preventive methods are carried out in school by children and are supervised, after appropriate training, by nondental personnel, such as teachers, nurses, teachers' aides, or volunteers.

More than 30 clinical trials have shown that mouthrinsing fortnightly, weekly, or daily with dilute solutions of fluoride will reduce the incidence of dental caries in children by about 35%.<sup>93–96</sup> Assuming that supervision is by volunteers, weekly fluoride mouthrinsing can be carried out for as little as 75¢ per child per year. Some advantages of weekly fluoride mouthrinsing in schools with 0.2% sodium fluoride are shown in Table 4. A few studies have shown that children who reside in fluoridated communities also benefit from the procedure.<sup>97–99</sup> Fluoride mouthrinsing is not recommended for preschool children because children of this age usually cannot control their swallowing reflexes.<sup>100</sup>

**Table 4.** Advantages of school-based, weekly fluoride mouthrinsing programs.

1. The technique is easy for school-age children to learn and perform.
2. Little classroom time is required—5 minutes or less per week.
3. The few materials required are inexpensive.
4. Nondental personnel with minimal training can easily supervise the procedure.
5. Many children can treat themselves with few supervisors—usually one supervisor per classroom.
6. The procedure is well accepted by participants and school personnel.
7. The method is effective in preventing dental caries.
8. The method is safe—even if a child accidentally swallows all the dispensed rinse.

The daily ingestion of dietary fluoride tablets in schools shares the advantages cited in Table 4 for fluoride mouthrinsing. Moreover, fluoride tablets confer systemic exposure to developing teeth as well as topical

exposure to erupted teeth. Children of preschool age can use fluoride tablets safely, and school-based tablet procedures do not generate problems of waste disposal. Because fluoride supplements are ingested, they should be used only in areas where fluoride in drinking water is inadequate.

Some communities in the U.S. with fluoride-deficient water have adopted school programs that combine weekly fluoride mouthrinsing with daily chewing of fluoride tablets. This combination of methods may produce greater caries protection than either one used alone. Six-year results from a continuing study of these two methods combined with use of a fluoride dentifrice at home<sup>101</sup> showed a 45% lower prevalence of all DMF surfaces and 85% less decay in approximal tooth surfaces.

School-based programs of self-applied fluorides have grown rapidly in the past few years. According to current estimates, more than 12 million school children in the U.S. are enrolled in these programs,<sup>102</sup> but they comprise only about 20% of all U.S. school children. Therefore, continuing educational and promotional efforts are essential.

Many studies have shown that the incidence of dental caries may be reduced by about 20–30% by *ad libitum* use of dentrifices containing fluorides.<sup>103–105</sup> In countries where use of a dentifrice in conjunction with toothbrushing is widespread, everyone should be encouraged to use a fluoride dentifrice with demonstrated anticariogenic effects. The Council on Dental Therapeutics of the ADA currently recognizes five such dentrifices.<sup>106</sup> These dentrifices, in chronological order of their recognition, are: Crest, Colgate, Macleans, Aquafresh, and Aim. All contain about 1000 parts per million fluoride, although their fluoride compounds and abrasives differ.

Programs of toothbrushing with fluoride dentrifices in schools cannot be justified because they are expensive, have special sanitation requirements, and provide no additional protection when fluoride dentrifices also are used at home.<sup>107</sup>

Table 5 summarizes the reductions in dental caries reported for several methods of providing fluorides.

### Pit and Fissure Sealants

Adhesive sealants for preventing dental caries in occlusal pits and fissures of teeth fill a special need in caries prevention because fluorides prevent decay less effectively in pits and fissures than in smooth surfaces.<sup>108,109</sup> Although occlusal surfaces comprise only 20% of all surfaces of posterior teeth, dental caries in these surfaces account for 50–60% of all decay.<sup>110</sup>

Adhesive sealants, when fully retained, form a physical barrier to decalcification by acids. The successful placement of sealants requires fastidious attention to a meticulous technique. Studies have shown that dentists and trained auxiliaries can achieve similar results in

**Table 5.** Effectiveness of various methods of administering fluorides.

Method	Concentration or dose	Percentage reductions in dental caries
Community water fluoridation	0.7-1.2 ppm	50-65
School water fluoridation	4.5 x's optimum	40
Dietary fluoride supplements		
Home	Depends on age of child and F concentration of water	50-65
School only	2.2 mg NaF	30-35
Mouthrinses	0.05% NaF (daily)	20-50
	0.20% NaF (weekly)	
Dentifrices	0.40% SnF 0.76% MFP <sup>2</sup> 0.22% NaF	20-30
Professionally applied applications	2.0% NaF 8.0% SnF <sub>2</sub> APF (1.2%F)	30-40

placing successfully retained sealants.<sup>90,111</sup> Regardless of who applies sealants, the procedure is relatively expensive for public health programs because only one child can be treated at a time. The consensus to date, therefore, is that sealants are not cost-effective for public programs, and may be more expensive than restoring decayed occlusal surfaces of teeth.<sup>112,113</sup> This comparison, however, ignores the intangible benefits of avoiding operative dental procedures and preserving the natural structure of teeth.<sup>31</sup>

When sealants are used in a fluoridated community, they increase caries protection by about 20%.<sup>114</sup> A series of caries-preventive methods, including fluoridation, topically applied fluorides and sealants, can prevent 85% of all tooth decay.<sup>115</sup>

Some dentists have hesitated to use pit and fissure sealants from fear of inadvertently sealing over caries. Preliminary research results indicate, however, that sealed cavities deepen little, if any, and the decrease in viable organisms is marked.<sup>116</sup> Studies using sealants instead of amalgams for small occlusal carious lesions suggest that sealants used therapeutically are cost-effective.<sup>90</sup>

Sealants undoubtedly are important in the caries preventive armamentarium of dental practice. When they are combined with the use of fluorides, particularly with community fluoridation, dental decay can be entirely prevented in many children. Proliferation of rational, comprehensive, preventive programs should produce many more adults in the future with full and completely caries-free dentitions.

This paper was presented at a symposium, Problems in the Delivery of Dental Services—Can Preventive Dentistry Help Solve the Shortcomings of the Present Delivery Systems?, 10th Asian-Pacific Dental Congress, Singapore, March 26-31, 1981.

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