Reviews of Evidence on Interventions to Prevent Dental Caries, Oral and Pharyngeal Cancers, and Sports-Related Craniofacial Injuries

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Overview: This report presents the results of systematic reviews of effectiveness, applicability, other positive and negative effects, economic evaluations, and barriers to use of selected population-based interventions intended to prevent or control dental caries, oral and pharyngeal cancers, and sports-related craniofacial injuries. The related systematic reviews are linked by a common conceptual approach. These reviews form the basis of recommendations by the Task Force on Community Preventive Services (the Task Force) about the use of these selected interventions. The Task Force recommendations are presented in this supplement.[1]

Medical Subject Headings (MeSH): cariostatic agents, community dentistry, community health planning, community health services, decision making, dental caries, evidence-based medicine, facial injuries, intervention studies, mouth protectors, oral health, oral and pharyngeal neoplasms, pit and fissure sealants, practice guidelines, preventive dentistry, preventive health services, public health dentistry, public health practice, review literature, tooth injuries

Introduction

Despite substantial improvements in oral health for most Americans during the 20th century, the United States still spends an estimated $60 billion annually on dental services,[2] including about $451 million in inpatient hospital charges for diseases of the mouth and disorders of the teeth and jaw.[3] Use of dental services includes about 500 million visits to dental offices.[4] In addition, people aged 5 to 24 years make about 600,000 visits each year to hospital emergency departments for sports-related craniofacial injuries.[5]

In its systematic review of interventions to promote and improve oral health, the independent, nonfederal Task Force focused on dental caries (tooth decay), oral (mouth) and pharyngeal (throat) cancers, and sports-related craniofacial injuries because these conditions are common, costly in resources and quality of life, sometimes life-threatening in the case of oral and pharyngeal cancers and head injury, or potentially preventable by interventions already widely used. (Other important craniofacial health conditions, such as periodontal diseases and developmental anomalies, have recently been reviewed elsewhere.[6]) For additional details about the topic-selection process, see the "Conceptual Approach" section and Appendix A (Methods).

By reviewing the effectiveness of selected oral health interventions alongside more visible public health topics (e.g., vaccine-preventable diseases, tobacco use prevention and control, and motor vehicle occupant injury), the Task Force asserts that promoting oral health is solidly in the mainstream of public health practice and not exclusively the concern of dental health practitioners.

More widespread use of effective population-based interventions can help reduce the morbidity, mortality, and economic burden associated with oral health conditions. This report presents the results of systematic reviews of effectiveness, applicability, other effects, economic evaluations, and barriers to the use of selected

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population-based interventions intended to prevent or control dental caries, oral and pharyngeal cancers, and sports-related craniofacial injuries. The related systematic reviews, linked by a common conceptual approach, form the basis of recommendations by the Task Force about the use of these selected interventions.[1] Unlike a clinical preventive service that primarily benefits an individual,[7] a community preventive service is an intervention (activity) that prevents disease or injury or promotes health in a group of people.[8]

The *Guide to Community Preventive Services*

The systematic reviews in this report represent the work of the independent, nonfederal Task Force on Community Preventive Services. The Task Force is developing the *Guide to Community Preventive Services* (the *Community Guide*) with the support of the U.S. Department of Health and Human Services in collaboration with public and private partners. The Centers for Disease Control and Prevention (CDC) provides staff support to the Task Force for development of the *Community Guide*. The background of and methods used to develop the *Community Guide* have been published previously.[9]

This report and related publications can provide guidance from the Task Force to personnel in state and local health departments, managed care organizations, purchasers of health care, people responsible for funding public health programs, and others who have interest in or responsibility for improving oral and related general health in any segment of the population. The remainder of this report provides an overview of the process used by the Task Force to select and review evidence, and presents the evidence on which the Task Force based its recommendations on community interventions to reduce dental caries, oral and pharyngeal cancers, and sports-related craniofacial injuries.[1]

Healthy People 2010 Goals and Objectives for Promoting Oral Health

The interventions reviewed in this report can be useful in achieving the oral health promotion objectives contained in *Healthy People 2010*,[10] the prevention agenda for the United States. These objectives identify significant threats to oral health and focus public and private efforts on selected prevention services and health system changes to reduce those threats. Many of the proposed *Healthy People* objectives in chapters 3, 15, and 21 (Cancer, Injury and Violence Prevention, and Oral Health, respectively) relate directly to the goals of preventing and controlling oral and craniofacial diseases, conditions, and injuries and improving access to related services (Table 1). The evidence reviews in this article, in combination with the accompanying recommendations,[1] provide information on interventions that can help communities and healthcare systems reach *Healthy People 2010* objectives.

Recommendations of Other Groups

Published in June 2000, the Surgeon General's Report on Oral Health[6] described the principal components of the National Oral Health Plan for promoting and improving oral health: increasing awareness (among the public, policymakers, and health providers) that the health of the mouth and other parts of the body are related, accelerating the growth of research and application of scientific evidence on intervention effectiveness, building an integrated infrastructure, removing barriers between services and people in need, and using public–private partnerships to reduce disparities. This model of oral health promotion aims to achieve universal oral health literacy through education; prevention and control of common or life-threatening craniofacial diseases, disorders, and injuries; and improvement in general health through better oral health.[6] A comparison of the recommendations derived from reviews in the current report and recommendations developed recently by others also is published in this supplement.[11]

Methods

The methods used to conduct the systematic reviews and derive the evidence-based recommendations contained in this report are described in Appendix A. Tables and figures that summarize effectiveness findings and tables that summarize economic analyses are available at the website (www.thecommunityguide.org).

Conceptual Approach

The logic framework (Figure 1) depicts our conceptual approach to the subject of promoting oral health by preventing and controlling selected diseases and injuries. It portrays the hypothesized relationships between each of the five interventions, modifiable determinants, intermediate outcomes, and reductions in selected oral disease outcomes. Modifiable determinants are knowledge, attitudes, behaviors, access to care, and other fluoride sources (e.g., prescribed rinse, gel, or tablet). Intermediate outcomes are sealant use and retention, stage-shift from late to early stages of oral and pharyngeal cancers, and use of dental and craniofacial protectors. Desirable effects of the interventions are reductions in oral disease outcomes, such as dental caries, enamel fluorosis, oral and pharyngeal cancers, sports-related craniofacial injury, disability, and death.

In selecting the interventions evaluated in this report, the coordination and consultation teams (see

Table 1. Selected oral health objectives—*Healthy People 2010*[10]

Targeted condition	Age of population	Percentage of population or other units of observation	
		Baseline (year)[a]	2010 objective
Dental caries			
Dental caries experience (i.e., lifetime number of decayed, missing, or filled teeth measured at a single point in time) in primary or permanent teeth	2–4 years	18% (1988–1994)	11%
	6–8 years	52% (1988–1994)	42%
	15 years	61% (1988–1994)	51%
Untreated dental decay	2–4 years	16% (1988–1994)	9%
	6–8 years	29% (1988–1994)	21%
	15 years	20% (1988–1994)	15%
	35–44 years	27% (1988–1994)	15%
Never had a permanent tooth extracted because of dental caries or periodontal disease	35–44 years	31% (1988–1994)	42%
Have had all their natural teeth extracted	65–74 years	26%[b] (1997)	20%
Proportion of children who have received dental sealants on their molar teeth	8 years	23% (1988–1994)	50%
	14 years	15% (1988–1994)	50%
Proportion of the U.S. population served by community water systems with optimally fluoridated water	All ages	62% (1992)	75%
Oral and pharyngeal cancers			
Proportion of oral and pharyngeal cancers detected at the earliest stage (stage 1, localized)	All ages	35% (1990–1995)	50%
Proportion of adults who, in the past 12 months, report having had an examination to detect oral and pharyngeal cancer	>40 years	13%[b] (1998)	20%
Annual oropharyngeal cancer deaths per 100,000 population	All ages	3.0 (1998)	2.7
Sports-related craniofacial injuries			
Increase the proportion of public and private schools that require use of appropriate head, face, eye, and mouth protection for students participating in school-sponsored physical activities	Unspecified	Developmental Unknown	

[a]Years indicate when the data were analyzed to establish baseline estimates. Some estimates are age-adjusted to the year 2000 standard population.
[b]Based on self-report in National Health Interview Survey, 1997 or 1998.

Acknowledgments) initially prepared a list of five strategies comprising ten interventions. In selecting interventions for this list, we emphasized those that are widely practiced, whether considered effective or not; considered important even if not widely recognized, evaluated, or implemented; address a high yet preventable burden of disease; present new information in controversial areas (e.g., screening for early detection of oral cancer); explore issues of particular interest to oral health audiences; and emphasize particular oral health outcomes. For the final list of strategies investigated for effectiveness, we grouped interventions by oral disease outcomes because we expected the limited oral health promotion literature to be disease-oriented, and our subject-matter consultants advised that practitioners might find it easier to use information presented in the familiar disease-oriented format (Appendix Table A2).

This report contains evidence reviews of five interventions organized into three groups on the basis of oral disease outcome of interest: (1) interventions to prevent or control dental caries; (2) interventions to prevent or control oral and pharyngeal cancers; and (3) interventions to prevent or control sports-related craniofacial injuries. Time and resource constraints precluded review of some candidate interventions (e.g.,

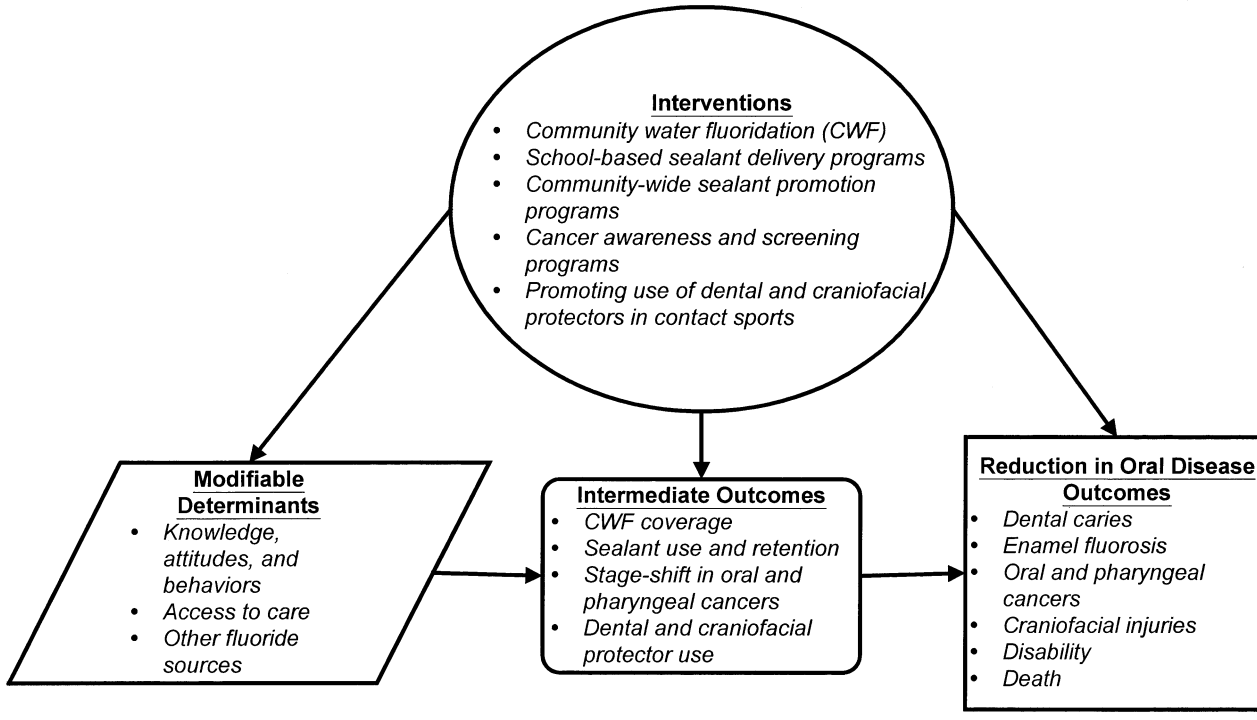

Figure 1. Logic framework depicting interventions, modifiable determinants, and intermediate and ultimate oral disease outcomes used in these reviews.

multicomponent interventions to prevent infant caries, public education, professional education, school-based education, and multicomponent interventions that target many health outcomes) (Appendix Table A1).

Results. Part I: Prevention or Control of Dental Caries

The percentage of people in whom caries has caused one or more decayed, missing, or filled permanent teeth increases with age: from 26% among people aged 5 to 11 years to 67% among people aged 12 to 17 years and 94% for adults with one or more natural teeth.[12,13] Overall, the prevalence of dental caries among children aged 12 to 17 years has declined from 90% in 1971–1974 to 67% in 1988–1991, and the mean number of teeth that are decayed, missing, or filled as a result of caries has declined from 6.2 to 2.8 during this period.[12,14,15] Today, 80% of the permanent teeth that are decayed, missing, or filled because of caries are found in 25% of U.S. children aged 5 to 17 years who have at least one permanent tooth.[10,12,15] Lower-income, Mexican-American, and African-American children have more untreated decayed teeth than their higher-income or non-Hispanic white counterparts. Among low-income or poor children, more than one third have untreated caries in their primary teeth, which may be associated with difficulty in eating and underweight.[16] Root caries is common: approximately 30% of adults aged 45 to 54 years and 50% of adults aged ≥75 years who have one or more of their own teeth have decayed or filled root surfaces.[13]

Comprehensive population-based strategies to prevent or control dental caries aim to (1) increase public and professional awareness of caries and ways to address the problem; (2) promote healthy oral health practices (e.g., reducing consumption of refined sugar and brushing with toothpaste that contains fluoride); (3) ensure optimal exposure to fluoride from all sources including community water fluoridation; and (4) ensure access to and efficient use of regular preventive and restorative dental care including optimal use of sealants delivered in school-based or school-linked settings.[6] This section reports on three community interventions to prevent and control dental caries: community water fluoridation, school-based or school-linked pit and fissure sealant delivery programs, and statewide or community-wide sealant promotion programs.

Community Water Fluoridation

For this review, we used the definition of community water fluoridation (CWF) as adjusting and monitoring fluoride in public water supplies to reach optimal fluoride concentrations in community drinking water. Since 1962, the U.S. Public Health Service has recommended that community drinking waters contain 0.7 to

Table 2. Community water fluoridation (CWF): descriptive information about included studies

Study characteristics	# of studies
Studies meeting inclusion criteria	30[19–48]
Studies excluded	9[20,25,28,35,37,40,42,44,48]
Limitations in execution or design	6[20,25,28,35,37,40]
Lack of appropriate effect measure	3[42,44,48]
Qualifying studies	21[19,21–24,26,27,29–34,36,38,39,41,43,45–47]
Study designs	
Cross-sectional survey	8[26,29,30,34,41,43,46,47]
Nonrandomized trial	1[19]
Prospective cohort	8[21,22,27,32,33,36,39,45]
Time series	4[23,24,31,38]
Studies estimating effects of:	
Starting or continuing CWF	15[19,22–24,27,30–34,39,41,43,46,47]
Stopping or reducing CWF	5[21,26,29,36,45]
Changes in both directions	1[38]

1.2 ppm of fluoride.[17] We also reviewed situations in which ongoing community water fluoridation was stopped.

In 1992, more than 144 million people in the United States (56% of the population and 62% of those on public water systems) were being supplied with water containing the optimal level of fluoride to protect teeth from caries. The national objective is for at least 75% of the population to be served by community water systems providing optimal levels of fluoride by the year 2010.[10]

CWF has been the basis for primary prevention of dental decay for 55 years. It has been recognized as one of ten great achievements in public health of the 20th century because of its causal links to large reductions in tooth decay in many industrialized countries during the latter half of the century.[17,18]

Despite these successes, the appropriateness of CWF is often the subject of intense public debate throughout the world. Proponents of CWF emphasize a long historical record of safety, effectiveness, and cost effectiveness, and opponents often raise questions about safety, personal autonomy, and the relevance of the scientific evidence of effectiveness derived from studies conducted in the 1950s and 1960s. Because of a decline in caries and increase in alternative sources of fluoride over time, some commentators have questioned whether water fluoridation prevents as much dental caries in the 1990s as it did in 1950–1980. (Alternative sources of fluoride include toothpaste, acidulated rinses, varnishes and other fluoride-containing products applied by dentists and other health professionals, and beverages made with fluoridated water and consumed by people served by nonfluoridated drinking water [the "halo effect"].) Others argue that even small benefits for individuals today may amount to large benefits for populations. In some instances, such public debates lead to state or local legislation or public referenda (e.g., in November 2000, residents of San Antonio, Texas voted in favor of CWF).

In all such instances of controversy and public uncertainty, up-to-date systematic reviews of the scientific evidence of effectiveness and safety can be crucial. The research reviewed below, linking water fluoridation to the prevention of dental caries, began in the mid-1940s and has continued into the 1990s with a declining focus on effectiveness and an increasing focus on cost effectiveness and safety.

Reviews of evidence

Effectiveness. Our systematic search identified 30 studies (in 31 reports) of the effectiveness of starting or stopping CWF in reducing dental caries prevalence (Table 2).[19–49] Of these 30 studies, 6 were excluded because of limitations in their execution or design, and 3 were excluded because they lacked an appropriate effect measure (i.e., change in caries prevalence associated with exposure to CWF). From each of the remaining 21 qualifying studies, we abstracted multiple estimates of effect ($n = 114$) because different estimates of effect were associated with varying exposures to CWF defined by time, place, fluoride dose, or direction of change, in diverse subgroups of the populations defined by time, place, age, and dentition, or over various durations of follow-up. We calculated estimates of effectiveness using the procedures and formulas described in Appendix A (Methods). Additional details of the 21 qualifying studies are provided below, in Appendix B (15 studies from analysis Groups A and B), and at the website (www.thecommunityguide.org).

The 21 qualifying studies varied by study design, analysis models, levels of analysis, measures of dental caries occurrence, differences in fluoride concentrations being compared, and direction of change in exposure to CWF over time. To summarize the magnitude and strength of the evidence of effectiveness on a uniform or continuous scale, and to allow the Task Force to match the strength of evidence with the strength of the recommendation, we grouped the 21 qualifying studies (114 estimates of effect) into three

Table 3. Effectiveness of community water fluoridation (CWF) on dental caries: summary effects from the body of evidence

Study characteristics	Studies	# of measures	Median change	Range
Group A—Effects[a] of ***starting CWF*** based on before-and-after measurements of caries at the tooth level in concurrent comparison groups				
Relative change	7[19,23,24,30,32,38,39]	21	29.1% decrease	66.8% increase in caries to 110.5% decrease
CWF effective	6[19,23,24,32,38,39]	16	41.2% decrease	14.5% to 110.5% decrease in caries
CWF ineffective	2[30,38]	5	32.4% increase	9.1% to 66.8% increase in caries
Absolute change	7[19,23,24,30,32,38,39]	21	1.3 decrease	2.7 increase to 3.3 decrease in affected teeth
CWF effective	6[19,23,24,32,38,39]	16	1.7 decrease	0.6 to 3.3 decrease in affected teeth
CWF ineffective	2[30,38]	5	1.2 increase	0.2 to 2.7 increase in affected teeth
Group A—Effects[a] of ***stopping CWF*** based on before-and-after measurements of caries at the tooth level in concurrent comparison groups				
Relative change	3[21,36,38]	5	17.9% increase	31.7% increase to 42.2% decrease in caries
CWF effective	2[21,36]	3	29.1% increase	17.9% to 31.7% increase in caries
CWF ineffective	1[38]	2	21.6% decrease	1.1% to 42.2% decrease in caries
Absolute change	3[21,36,38]	5	0.6 increase	0.4 decrease to 4.1 increase in affected teeth
CWF effective	2[21,36]	3	3.3 increase	0.6 to 4.1 increase in affected teeth
CWF ineffective	1[38]	2	0.2 decrease	0.04 to 0.35 decrease in affected teeth
Group B—Effects[b] of ***starting CWF*** based on post exposure measurements of caries at the tooth level in concurrent comparison groups				
Relative change (CWF effective)	7[27,30–32,34,41,43]	20	50.7% decrease	22.3% to 68.8% decrease in caries
Absolute change (CWF effective)	7[27,30–32,34,41,43]	20	1.5 decrease	0.3 to 6.3 decrease in affected teeth
Group B—Effects[b] of ***stopping CWF*** based on post exposure measurements of caries at the tooth level in concurrent comparison groups				
Relative change (CWF effective)	1[26]	1	59.5% increase in caries	Not applicable
Absolute change (CWF effective)	1[26]	1	0.44 increase in affected teeth	Not applicable

[a]Effects = ((Fpre − Fpost) − (NoFpre − NoFpost))/NoFpre.
[b]Effects = (Fpost − NoFpost)/NoFpost.
Fpre, dental caries prevalence in fluoridated community before fluoridation (or at first measurement during ongoing fluoridation); Fpost, dental caries prevalence in fluoridated community after fluoridation (or at second measurement during ongoing fluoridation); NoFpre, dental caries prevalence in nonfluoridated community before fluoridation (or at first measurement during ongoing fluoridation); NoFpost, dental caries prevalence in nonfluoridated community after fluoridation (or at second measurement during ongoing fluoridation).

subsets. (Some studies were in more than one group because they used more than one kind of measurement.) The groups are also distinguishable by the method of computing estimates of effectiveness as described in Appendix A (Methods).

- Group A: Before-and-after measurements of caries at the tooth level, in studies with concurrent comparison groups.
- Group B: Post-exposure measurements of caries at the tooth level, in studies with concurrent comparison groups.
- Group C: Measured effects of CWF on caries at any level (tooth surface or child), using any study design. Because this group of studies was heterogeneous, we did not combine estimates across designs and tooth levels. Overall, this subset of effect measures (data not shown) did not alter the main findings of the analyses in groups A and B. To save manuscript space and to simplify the presentation, details of the study design, execution, and results of six studies in this group are presented only at the website (www.thecommunityguide.org). The remaining 14 studies in group C that provided estimates of this type also contributed estimates of a different type to analysis Groups A and B.

Of the nine studies in Group A (26 estimates of effect), seven (21 estimates of effect) measured the effect of starting (or continuing) community water fluoridation, and three (5 estimates of effect) measured the effect of stopping (or reducing) community water fluoridation (Table 3, Figure 2). One of the nine studies examined the effect of both starting and stopping CWF.

In the seven Group A studies, starting (or continuing) water fluoridation decreased dental caries experience among children aged 4 to 17 years by a median of 29.1% during 3 to 12 years of follow-up (Table 3). Two

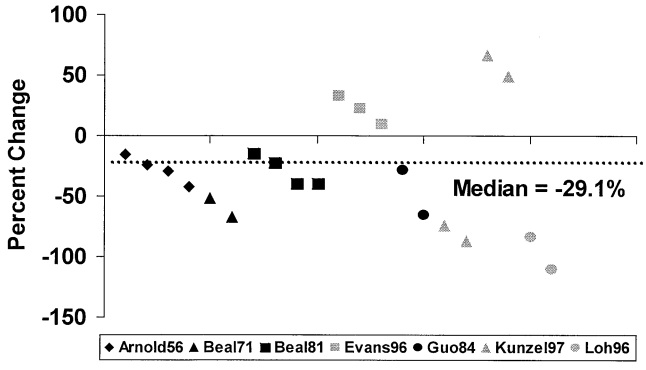

Figure 2. Percent change in dental caries associated with starting community water fluoridation based on 7 studies (21 estimates) in analysis Group A. Negative values reflect decreases in caries prevalence.

studies (five measures) by Kunzel and Fischer[38] and Evans et al.,[49] respectively, showed negative effects (increased dental caries) of continuing water fluoridation (Table 3). These inconsistent estimates of effectiveness appear to have resulted from inadequate control of confounding due to notably lower baseline caries prevalence in fluoridated compared with nonfluoridated areas. If these five inconsistent estimates were excluded from the analysis, then starting water fluoridation decreased dental caries experience by a median of 41.2% (range, 14.5% to 110%). In the three Group A studies that evaluated stopping fluoridation, this intervention was associated with a median 17.9% increase in dental caries during 6 to 10 years of follow-up (Table 3, Figure 3).

All of the seven studies in Group B (20 estimates of effect) measured the effect of starting (or continuing) CWF (Table 3, Figure 4). Starting water fluoridation decreased dental caries experience among children aged 4 to 17 years by a median 50.7% during 3 to 12 years of follow-up. Although we could not quantitatively combine effect measures from groups A and B, both seem to support the conclusion that community water fluoridation reduces dental caries by 30% to 50% of what could be expected for people not consuming fluoridated water. In addition, stopping CWF may lead to the median 17.9% increase in caries described above, in situations in which alternative sources of fluoride are inadequate.

Applicability. We used the same body of evidence described above to assess the applicability of the findings on the effectiveness of CWF in a variety of settings and populations. This body of evidence encompassed studies that varied by time, place, population characteristics, and level and direction of change in fluoride concentration in the water consumed by comparison populations. Of the 21 qualifying studies, 3 were published in the 1950s and 1960s,[19,22,27] 1 in the 1970s,[23] 6 in the 1980s,[21,24,31–33,43] 10 in the 1990s,[26,29,30,34,36,38,39,41,45,46] and 1 in 2000.[47] Studies were conducted in the United Kingdom,[21,23,24,26,29,30,33,41–43] Australia,[31,46] the Netherlands,[22,36] the United States,[19] Canada,[27] Finland,[45] Germany,[38] Japan,[47] Libya,[34] Singapore,[39] and Taiwan.[32] Six of the 21 studies[21,26,29,36,38,45] examined the effects of stopping fluoridation that had been ongoing for many years, and 15[19,22–24,27,31–34,39,41,43,46,47,49] examined the effects of starting or continuing fluoridation. The fluoride concentration in intervention water systems varied from 0.6 to 1.8 parts per million (ppm), versus 0.0 to 0.8 ppm in comparison water systems. All of the study populations involved children aged 4 to 17 years, and caries experience was measured in both primary and permanent teeth.

The diverse CWF exposures and populations compared in the 21 qualifying studies are typical of the variety of circumstances encountered in the United States and other industrialized countries over the time span of the review. We conclude, therefore, that the results of the review should apply to most populations in the United States and other industrialized countries.

Other positive or negative effects. This report does not include a systematic review of other positive or negative effects of community water fluoridation. The occurrence of other positive effects of CWF has been explored by others. Potentially important positive effects include (1) reducing disparities in caries risk and experience across subgroups defined by socioeconomic status, race and ethnicity, and other predictors of caries risk,[50] and (2) the "halo" or "diffusion" benefits to residents of nonfluoridated communities by means of exposure to processed food and beverages made from fluoridated water.[51]

A detailed review of available evidence of the association, if any, of CWF with potential adverse effects (e.g., dental and skeletal fluorosis) and other possible negative effects (e.g., bone fracture, developmental abnormalities, or cancers) has been conducted by others.[50] A brief summary of those findings is presented in Appendix C.

Economic. Our systematic search for economic information identified 27 candidate studies (see Appendix A).[39,46,52–76] Of these,18 were excluded for the following reasons: they (1) were not primary studies (10 studies[39,52,60,63,65,70,71,73,75,76]); (2) did not report sufficient cost data (6 studies[55–57,62,63,69]); (3) compared costs between low fluoride and optimal fluoride exposure groups without controlling for confounding factors (1 study[54]); or (4) reported the cost of removing fluoride from water with extremely high levels of natural fluoride (1 study[74]). The remaining 9 studies were considered qualifying studies from which we present the following summary findings.[53,58,59,61,64,66–68,72]

Seven studies reported the program costs per person for 75 water systems receiving fluoridated water. Although costs varied greatly by system, ranking the

systems by size of population served suggests that much of the variation resulted from economies of scale (i.e., cost per person falls as number of people served by water system rises). The median cost per person per year ranged from $2.70 among 19 systems serving ≤5000 people to $0.40 among 35 systems serving ≥20,000 people.

Five studies included sufficient data to calculate a cost-effectiveness ratio (i.e., net cost per tooth surface spared from decay). Community water fluoridation was cost saving in all studies (i.e., saves money from a societal perspective and also reduces caries).

The studies included in this review were conducted from the early 1970s to the mid-1990s, a period during which caries prevalence in children declined. The most recent study,[68] however, still found fluoridation to be cost saving for a city of 1.6 million people after adjusting for population mobility and age. We estimated the annual decay incidence required for fluoridation to be cost saving for smaller communities (5000 to 20,000 residents) by using the average cost of a single-surface amalgam in 1997 reported by the American Dental Association (ADA) and the highest reported amortized cost per person of fluoridation. Where annual per person decay incidence in a community exceeds our estimated value of 0.06 surfaces, implementing water fluoridation would, on average, save more resources than those consumed in providing fluoridation.

Barriers to intervention implementation. Major barriers to the adoption or maintenance of CWF include limited knowledge among the general population and some health professionals of oral health promotion, some organized opposition to CWF, and some continuing debate about the net balance of benefits and risk of harm from excess fluoride ingested from all sources (of which CWF is one).

Conclusion. According to *Community Guide* rules of evidence,[8] strong evidence shows that CWF is effective

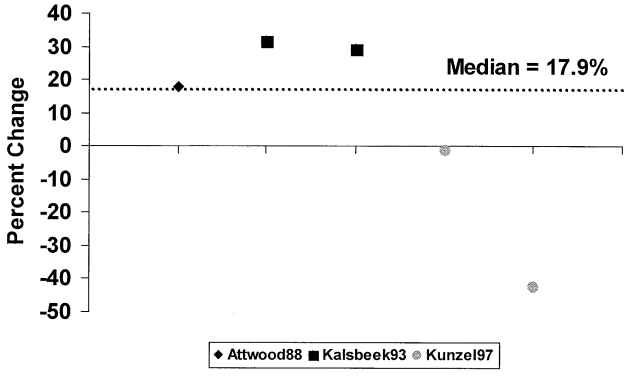

Figure 3. Percent change in dental caries associated with stopping community water fluoridation based on three studies (five estimates) in analysis Group A. Positive numbers indicate increases in caries prevalence associated with stopping exposure to community water fluoridation.

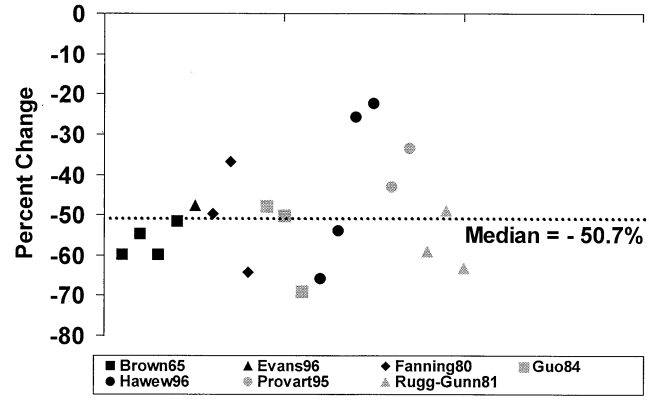

Figure 4. Percent change in dental caries associated with starting community water fluoridation based on 7 studies (20 estimates) in analysis Group B. Negative values reflect decreases in caries prevalence.

in reducing the cumulative experience of dental caries within communities.

School-Based or School-Linked Pit and Fissure Sealant Delivery Programs

Sealants are clear or opaque plastic materials applied to the pits and fissures of teeth to prevent dental caries. When applied to tooth surfaces that are susceptible to caries, sealants prevent food, bacteria, and debris from collecting within the pits and fissures of vulnerable teeth (mainly molars). Sealants are clinically effective in preventing caries for as long as the sealant material remains in place. Thus, ongoing monitoring of retention and periodic re-application of sealant may be necessary to ensure long-term effectiveness.

The appropriate application of pit and fissure sealants to at-risk teeth is one of many complementary strategies for preventing caries. Although sealants are necessary to further reduce pit and fissure caries, fluoride is necessary to prevent caries on all types of tooth surfaces. Since the early 1970s, childhood dental caries in smooth tooth surfaces (those without pits and fissures) has declined markedly because of widespread exposure to fluorides. By 1986–1987, approximately 90% of the decay in the permanent teeth of children occurred in tooth surfaces with pits and fissures, and almost two thirds was found in the chewing surfaces alone.[10,12,77]

School-based or school-linked pit and fissure sealant delivery programs provide pit and fissure sealants directly to children unlikely to receive them otherwise. School-based programs are conducted in schools, and school-linked programs are conducted in schools, private dental practices, and clinic settings outside of schools. Such programs define a target population within a school district; verify unmet need for sealants; get financial, material, and policy support; apply rules for selecting schools and students; screen

Table 4. School-based or school-linked pit and fissure sealant delivery programs: descriptive information about included papers

Study	# of studies
Studies meeting inclusion criteria	37[78–114]
Studies excluded	27[78,79,82,84–91,93–96,98–102,104,106,107,109,110,113,114]
Insufficient data for quality scoring	4[86,88,89,113]
Limitation in execution or design	15[79,82,84,85,87,91,93,95,96,98,99,101,102,104,110]
Lack of appropriate effect measure	8[78,90,94,100,106,107,109,114]
Qualifying studies	10[80,81,83,92,97,103,105,108,111,112]
Study designs	
Before-and-after	1[108]
Nonrandomized trial	4[80,97,103,111]
Retrospective cohort	1[105]
Randomized trial	3[81,83,92]
Time series	1[112]

and enroll students at school; and apply sealants at school, in private practices, or in clinics. A school-based or school-linked component often is an integral part of a community-wide sealant application program.

Nationally, 88 community-based sealant placement programs were in operation in the 1992–1993 school year, serving children in 1636 schools.[78] Of these programs, 83% targeted particular types of schools (e.g., those with high percentages of children who participate in free or reduced-cost meal programs). Within schools, children were selected most often on the basis of grade level (different combinations of grades 2 through 6) and eligibility for the free or reduced-cost meal programs. First and second permanent molar teeth were sealed most often. Since 1998, federal agencies—including the CDC, the National Institute of Dental and Craniofacial Research, the Health Resources and Services Administration, and the Indian Health Service—have supported state-level partnerships (including departments of health and education and private-sector businesses and organizations) to develop, expand, and evaluate school-based and school-linked models integrating oral health into their existing coordinated school health programs.

Experts have recommended that school-based and school-linked sealant delivery programs target the first and second permanent molars of children at high risk for dental caries.[6,10] High-risk children include vulnerable populations less likely to receive private dental care, such as children eligible for free or reduced-cost lunch programs.[6]

Review of evidence

Effectiveness. Our systematic search identified 37 studies[78–114] on the effectiveness of school-based or school-linked sealant delivery programs in reducing cumulative measures of dental caries incidence or prevalence (Table 4). Of these, 27 were excluded from the systematic reviews (Table 4). Details of the 10 qualifying studies are provided below and at the website (www.thecommunityguide.org). We abstracted 22 estimates of effect from the 10 qualifying studies because different estimates showed the effect of different exposures to sealant delivery modes (defined by time and place), in different subgroups of the populations being compared (defined by time, place, age, and dentition), over different durations of follow-up.

The 10 qualifying studies compared the pit and fissure dental caries experience of children served by a school-based or school-linked sealant program with children who did not receive sealants. Of the 10 studies, 7[81,83,92,97,103,105,111] reported on the effects of using sealant Bisphenol-A-glycidyl methacrylate (bis-GMA) resin as the only caries preventive intervention, and 3[80,108,112] reported on the effects of using bis-GMA sealant combined with other caries preventive interventions (e.g., fluoride gel or rinse, health education, or fluoridated water) (Table 5). Of the 10 studies (22 estimates of effect), exposure to school-based or school-linked sealant delivery programs was associated with a median relative decrease in dental caries experience of 60% (range, 5% to 93%) (Table 5, Figure 5).

Effect sizes were similar for studies in the United States (4 studies,[80,92,97,108] 10 estimates of effect) and those outside the United States (6 studies,[81,83,103,105,111,112] 12 estimates of effect). They showed a median relative decrease in cumulative caries experience of 60% (range, 23% to 78%) versus 60% (range, 5% to 93%), respectively. School-based programs[80,81,92,97,108,111] showed a higher median effect (65%; range, 23% to 93%) than school-linked programs[83,103,105,111,112] (37%; range, 5% to 93%). Programs in which sealants were re-applied at some point between initial application and follow-up showed a higher median effect (65%; range, 23% to 93%) than programs in which sealants were not re-applied (30%; range, 5% to 93%) (Table 5).

Applicability. We used the same body of evidence described above to assess the applicability of the findings on the effectiveness of school-based or school-linked sealant delivery programs in a variety of circumstances. This body of evidence encompassed studies that varied

Table 5. Effectiveness of school-based or school-linked pit and fissure sealant delivery programs in reducing dental caries: summary effects from the body of evidence

Study characteristics	# of studies	# of measures	Median caries reduction	Range
All qualifying studies	10[80,81,83,92,97,103,105,108,111,112]	22	60%	5% to 93%
Sealants only	7[81,83,92,97,103,105,111]	15	52%	5% to 93%
Sealants plus other interventions[a]	3[80,108,112]	7	65%	24% to 78%
School-based	6[80,81,92,97,108,111]	14	65%	23% to 93%
School-linked	5[83,103,105,111,112]	8	37%	5% to 93%
Sealants re-applied	5[80,81,97,111,112]	14	65%	23% to 93%
Sealants not re-applied	5[83,92,103,105,108]	8	30%	5% to 93%
Inside United States	4[80,92,97,108]	10	60%	23% to 78%
Outside United States[b]	6[81,83,103,105,111,112]	12	60%	5% to 93%
Time to follow-up				
2 years	6[81,83,103,105,111,112]	11	52%	5% to 93%
3 years	2[80,103]	2	79%	73% to 85%
4 years	3[81,97,108]	5	65%	23% to 78%
5 years	3[80,92,112]	4	56%	35% to 70%

[a]Other interventions included topical fluoride, health education, or water fluoridation in various combinations.
[b]Includes one study done in Guam.

by time, place, population characteristics, number of times sealant was applied to the same tooth surface, and duration of follow-up between sealant application and primary endpoint (caries status).

Of the 10 qualifying studies, 5[80,83,92,97,103] were started (baseline caries measure) in the 1970s, 3[105,108,112] in the 1980s, and 2[81,111] in the 1990s. Studies were conducted in the United States, Guam, the United Kingdom, Australia, Spain, Thailand, and Colombia. All of the study populations involved children aged 6 to 17 years, and caries experience was measured in both primary and permanent teeth. The findings should apply broadly to populations of school-aged children in a range of school settings.

Other positive or negative effects. Other potential positive effects of school-based or school-linked sealant delivery programs include increased support for coordinated school-based programs to address related dental and nondental needs of children from low-income families

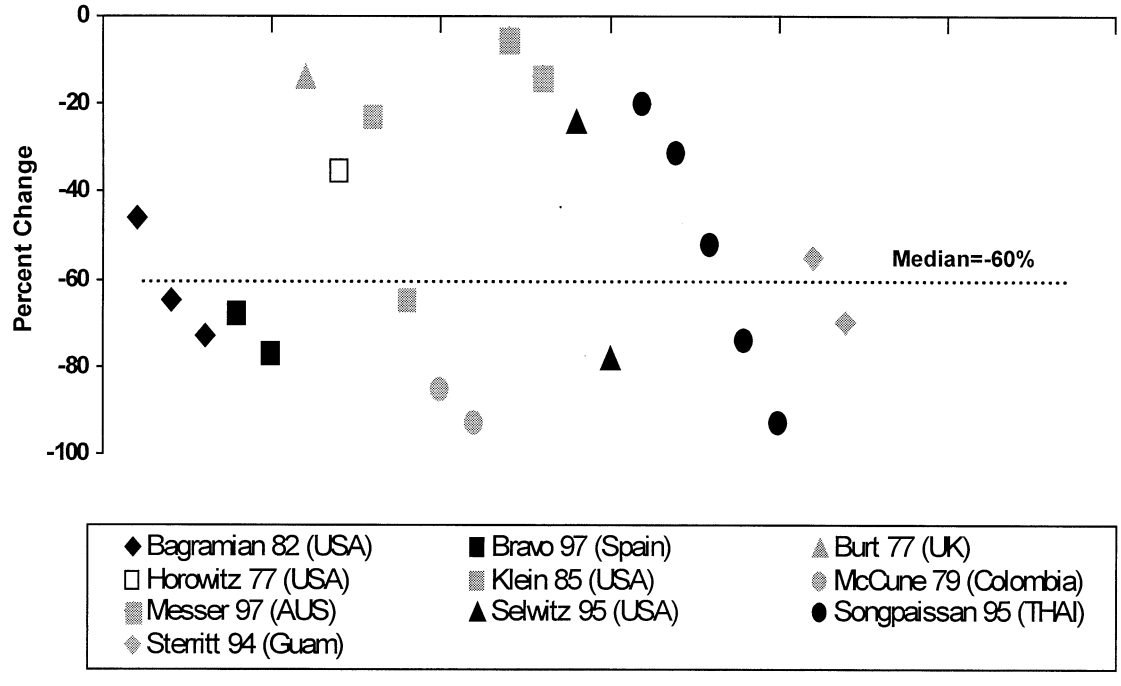

Figure 5. Percent change in occlusal caries associated with school-based or school-linked sealant delivery programs based on 10 studies (22 estimates).

(e.g., immunization and better nutrition), and increased willingness of insurers to pay for sealants applied in other settings. It is also possible that these programs might compete for time and resources with other school-related activities. In addition, some dentists in private practice are concerned that children who receive dental services in school-based programs may be less likely to keep appointments for regularly scheduled checkups.

Economic. The systematic search identified 37 candidate studies that met the inclusion criteria (see Appendix A).[61,67,94,97,98,100,102,115–144] Of these, 31 were excluded because they were not primary studies (10 studies[115,116,118,125,128,129,131,134,136,143]); did not report sufficient cost data (9 studies[98,102,120,121,126,130,133,137,141]); were epidemiologic rather than economic analyses (5 studies[94,117,127,139,140]); evaluated sealants delivered in a clinical setting or to a population other than elementary or secondary school students (5 studies[100,122,124,142,144]); or provided additional descriptive information on an economic analysis reported in another study (2 studies[123,137]). The remaining 6 studies[61,67,97,119,132,138] were considered qualifying studies from which we present the following summary findings.

The number of teeth sealed and resealed varied among school-based and school-linked sealant programs. Sealant program costs per person served (n =10 estimates) ranged from $18.50 to $59.83 (median = $39.10). Most studies included labor, capital expenditures, supplies, and travel costs. Four studies included sufficient data to calculate cost-effectiveness ratios. The adjusted cost per averted decayed surface ranged from cost saving (<$0) to $487. All studies used dental charges for amalgams as a proxy for resources consumed in treating disease. This measure would tend to overestimate the cost of averted disease if dental markets are not competitive and cause the cost-effectiveness ratio to be artificially low. However, the failure to account for more expensive restorations, productivity losses, or pain and suffering would cause the cost-effectiveness ratio to be artificially high. All but one study[138] assumed costs were the same for each year of the program. The studies with the highest costs per outcome were those by Leake and Martinello[132] and Klein et al.[97] These studies may have reported higher costs per outcome on the basis of lower rather than typical effectiveness estimates and sealing a larger number of lower-risk teeth, respectively.

Because of the large variation among parameters used to calculate the cost-effectiveness ratios reported in the studies, we estimated the circumstances in which a hypothetical sealant delivery program would be cost saving. Using the average cost for a single-surface amalgam in 1997 (according to the ADA), the median reported annual per person sealant cost ($39.10), and the *Community Guide* estimate of 5-year effectiveness for programs that do not re-apply lost sealants (29.5%), a program that sealed first permanent molars would be cost saving if unsealed molars were decaying at the average rate of >0.47 surfaces per year. Sealants protect the occlusal, upper lingual, and lower buccal surfaces from decay. Almost no data exist on annual decay increment by type of surface. A study of New York schoolchildren, aged 10 to 13 years, found the annual occlusal decay increment among first molars was 0.105 surfaces per tooth, or 0.42 surfaces for all first molars.[145] School-based or school-linked sealant programs usually target low-income children who are at high risk for decay because of limited access to preventive services and to a regular source of dental care.[6] Decision makers can compare decay rates in their communities to this threshold value to determine if a school-based sealant program would be an attractive investment.

Barriers to intervention implementation. Major barriers to the adoption or maintenance of school-based or school-linked sealant delivery programs include (1) limited knowledge of oral health promotion among the general population and some health professionals; (2) limited resources and limited political and administrative support in some school districts; (3) state dental practice laws and regulations that limit the authority to apply sealants to selected categories of dental care professionals; and (4) resistance of the private practice dental community.

Conclusion. According to *Community Guide* rules of evidence,[8] strong evidence shows that school-based and school-linked sealant delivery programs are effective in reducing decay in pits and fissures of children's teeth.

Statewide or Community-Wide Sealant Promotion Programs

Statewide or community-wide sealant promotion programs encourage sealant use among private practitioners and through community-based programs (often including school-based programs). Program activities include continuing education courses for dental health professionals[6,109]; educational campaigns for consumers, community leaders, and third-party payers[146,147]; and efforts to promote school-based or school-linked sealant delivery programs (see section on School-Based or School-Linked Pit and Fissure Sealant Delivery Programs).

Statewide or community-wide sealant promotion programs aim to increase (1) public and professional awareness of the health benefits of sealants; (2) appropriate use of sealants by practitioners; and (3) access to sealants (e.g., through school-based programs) for disadvantaged populations that might not otherwise receive them, as well as to encourage third-party reimbursement for sealants. Today, sealant application is supported in several federally funded programs for women and children (e.g., Indian Health Service, and

Health Resources and Services Administration, Maternal and Child Health Bureau) and is listed among covered services in all state Medicaid programs.[6] The 1994 Workshop on Guidelines for Sealant Use produced recommendations for sealant use in both community-based and individual care programs.[148] Nationwide surveys of state dental directors identified 120 community-based programs that operated in 29 states in the 1991–1992[149] and 1992–1993 school years.[146]

Review of evidence. The systematic search identified one study[109] that met the inclusion criteria (see Appendix A). That study provided insufficient evidence of effectiveness to support a Task Force recommendation on statewide or community-wide sealant promotion programs to prevent dental caries because the change in sealant use or caries experience attributable to the intervention could not be estimated from the data presented.

Evidence on applicability, other positive or negative effects, economic efficiency, and barriers to intervention implementation was not sought, because effectiveness of the intervention was not established.

Conclusion. According to *Community Guide* rules of evidence,[8] evidence is insufficient to determine the effectiveness of statewide or community-wide sealant promotion programs to prevent dental caries.

Research Issues for Preventing and Controlling Dental Caries Using CWF and Sealants

We identified the following gaps in knowledge relating to community water fluoridation and use of pit and fissure sealants.

Community water fluoridation. The preponderance of the evidence indicates that CWF is safe and effective in reducing dental caries in communities. However, important research questions with practical applications remain unanswered, including:

- What is the effectiveness of laws, policies, and incentives to encourage communities to start or continue water fluoridation?
- What is the effectiveness of CWF in reducing socioeconomic or racial and ethnic disparities in caries burden?
- What is the effectiveness of CWF among adults (aged ≥18 years)?
- What, if any, are the effects of the increasing use of bottled water and in-home water filtration systems (which may not be fluoridated or remove fluoride, respectively) on the benefits gained through CWF?
- How effective is CWF in preventing root-surface caries?

School-based or school-linked pit and fissure sealant delivery programs. The evidence is clear and convincing that sealants delivered through schools and school-affiliated clinics are safe and effective in preventing dental caries among children. Important research questions yet to be answered include:

- What is the effect of sealant delivery programs among adults aged ≥18 years (e.g., military recruits)?
- How do state dental practice laws and regulations affect use of sealants in school-based programs?
- How do school district oral health policies and curricula affect use of sealants?
- What is the effectiveness of sealants in primary teeth?

Statewide or community-wide sealant promotion programs. The available evidence of the effectiveness of statewide or community-wide sealant promotion programs was insufficient to support a recommendation by the Task Force. Therefore, research in the following areas is a high priority:

- What is the effect of public education on awareness, community mobilization (through coalitions), and resource allocation for sealant promotion?
- What is the effect of professional education, combined with provider reminders and other system-oriented strategies, on knowledge, skills, and appropriate use of sealants?
- What is the effect of insurance coverage and managed care plans on access to and use of sealants?
- How cost effective are models of sealant delivery other than school based?

Results. Part II: Prevention or Control of Oral and Pharyngeal Cancers

Each year, cancers of the oral cavity (mouth) or pharynx (throat) are diagnosed in about 30,000 Americans; these are mainly squamous cell carcinomas and about 8000 people die of these malignancies.[10,150,151] Tobacco use and excessive alcohol consumption are independent risk factors that together account for 90% of all oral cancers.[10,152] Oral and pharyngeal cancers are the fourth, seventh, and fourteenth most common cancers among African-American men, white men, and all women, respectively.[150] They are most often diagnosed at late stages and treated by methods (surgery, radiation, and chemotherapy) that are often disfiguring and costly.[153] Overall relative 5-year survival rates are about 50%, and mortality is nearly twice as high among some minorities (especially African-American men) as among whites.[151]

Since 1992, organized efforts to develop and implement a national strategic plan for preventing and controlling oral and pharyngeal cancers have been gaining momentum in the United States.[154] In 1996, a coalition of national, state, and local health agencies

began promoting coordinated strategies in five areas: (1) advocacy, collaboration, and coalition building; (2) public health policy; (3) public education; (4) professional education and practice; and (5) data collection, evaluation, and research.

Despite the organized efforts previously described, controversy surrounds the conduct of interventions to prevent and control oral and pharyngeal cancers. Some of the issues being debated include:

- Should studies of the effectiveness of community-based interventions be deferred until clinical effectiveness in reducing morbidity and mortality has been established?
- What distinct roles should dental and medical practitioners play in early detection of oral and pharyngeal cancers?
- What roles should various clinical practitioners (i.e., dentists, dental hygienists, dental assistants, physicians, nurses, and others) play in early detection of oral and pharyngeal cancers?
- How can interest in preventing and controlling oral and pharyngeal cancers among nondental practitioners be increased?
- How should effort and other resources be allocated among strategies designed primarily to prevent these cancers (e.g., tobacco use prevention) versus strategies aimed at early detection?
- To what extent do early detection efforts reinforce messages about reducing tobacco and alcohol use?
- To what extent should efforts to reduce tobacco use and alcohol overuse emphasize their roles as primary causes of oral and pharyngeal cancers?

This systematic review aimed to summarize existing evidence of the effectiveness of population-based interventions to prevent or control oral and pharyngeal cancers through early detection of pre-cancers and cancers.

Population-Based Interventions for Early Detection of Pre-Cancers and Cancers

Population-based interventions for early detection of pre-cancers and cancers educate the public about risk factors, symptoms, signs, and the value of early detection; encourage high-risk or symptomatic people to examine themselves for suspicious lesions and to seek out a source of professional examination and follow-up; train health workers to detect suspicious lesions; examine people at the workplace, home, health fairs, field clinics, or the usual source of care; and refer eligible people with suspicious lesions (e.g., leukoplakia, erythroplakia, lichen planus, submucous fibrosis, and oral cancer) for follow-up and treatment.

Review of evidence

Effectiveness. Our systematic search identified 19 studies (reported in 24 articles) of population-based interventions to prevent or control oral and pharyngeal cancers.[155–178] Of the 19 studies, 7[158,161,162,164,169,171,178] measured the accuracy (sensitivity, specificity, and predictive value positive) of such interventions in detecting suspicious lesions for follow-up and treatment. Estimates of the accuracy of such screening activities varied widely (i.e., sensitivity, 59% to 97%; specificity, 69% to 99%; and predictive value positive, 31% to 87%) within ranges reported in other published reviews (e.g., in chapter 16 of the *Guide to Clinical Preventive Services*[7]).

No studies reported estimates of effect in terms of morbidity, mortality, or quality of life. Therefore, according to *Community Guide* rules of evidence,[8] there was insufficient evidence to assess the effectiveness of population-based interventions for early detection of pre-cancers and cancers in improving morbidity, mortality, or quality of life. Evidence about applicability, other positive or negative effects, economic efficiency, and barriers to intervention implementation was not sought, because effectiveness of the intervention was not established.

Conclusion. According to *Community Guide* rules of evidence,[8] evidence is insufficient to determine the effectiveness of population-based interventions for early detection of pre-cancers and cancers in improving morbidity, mortality, or quality of life.

Research Issues for Preventing and Controlling Oral and Pharyngeal Cancers

The available evidence on the effectiveness of population-based interventions for early detection of pre-cancers and cancers was insufficient to support a recommendation by the Task Force. Therefore, research in the following areas is a high priority:

- How sensitive and specific is oral examination as a screening tool?
- How valid and reliable is oral examination conducted by various dental and medical practitioners in detecting pre-cancerous and cancerous lesions?
- How sensitive and specific is oral examination aided by endoscopy, brush biopsy, vital staining, genetic markers, and other emerging clinical technologies?
- Is the use of oral self-examination kits feasible, valid, and reliable?
- How effective are individual or population-based interventions in detecting pre-cancers and reducing the incidence of invasive cancer?
- Are population-based interventions effective in detecting pre-cancers and early cancers? And is early detection of pre-cancers and cancers effective in reducing cancer morbidity and mortality or improving quality of life?
- How effective are population-based interventions in reducing disparities (e.g., socioeconomic, racial, and ethnic) in oral cancer incidence and mortality?

- What is the effect on oral cancer incidence, stage distribution, and mortality of reducing alcohol and tobacco exposure?
- What effects do education interventions and materials have on awareness of oral cancer and the prevention behavior of consumer groups, healthcare providers, healthcare organizations, and government agencies?
- What are the effects of early detection on morbidity, mortality, and quality of life among population subgroups at high risk for oral cancer (e.g., tobacco users, alcohol abusers, the elderly, racial or ethnic minorities, and the poor)?
- How effective are laws, policies, and incentives in encouraging healthcare providers to conduct oral examinations for cancer detection in high-risk populations?

Results. Part III: Prevention or Control of Sports-Related Craniofacial Injuries

Epidemiologic studies suggest that as many as one third of all dental injuries and up to 19% of head and face injuries are sports related.[5,6,10,179,180] In 1997–1998, people aged 5 to 24 years accounted for 2.6 million (70%) of the 3.7 million emergency department visits per year for sports-related injuries among people of all ages. About 22% of the average annual estimate of visits were for craniofacial injuries to the brain and skull, face, scalp, and neck.[5] In addition, 25% of people aged 6 to 50 years have had an injury that resulted in damage to one or more anterior teeth.[6,181]

Since the 1950s, organized football has led the way in promoting the use of helmets, facemasks, and mouthguards to protect athletes from craniofacial injury.[182] Starting in 1962, a growing number of governing bodies of organized sports mandated the use of helmets, facemasks, and mouthguards (alone or in combination) in practice and in competition.[183] All three protective devices are required in amateur boxing, football, ice hockey, and men's lacrosse, and mouthguards are required for participation in amateur women's lacrosse and in professional boxing.[182]

In addition, several professional health associations (the ADA, the American Academy of Pediatric Dentistry, the American Medical Association, and the American Academy of Pediatrics) have recommended the use of helmets, facemasks, mouthguards, or a combination of these protective devices in a variety of contact sports at all levels of competition, both organized and unorganized. These recommendations are based on expert opinion and epidemiologic evidence of decreases in the occurrence of craniofacial injuries in regulated sports (e.g., boxing, football, and ice hockey) since the late 1950s. Nevertheless, few children use the protective equipment mandated by governing bodies of many organized sports,[183] and little is known about their use in other collision or contact sports (e.g., karate, judo, and other martial arts).

Population-Based Interventions to Encourage Use of Helmets, Facemasks, and Mouthguards in Contact Sports

Population-based interventions to encourage the use of helmets, facemasks, and mouthguards when engaged in contact sports aim to prevent injuries to the head, face, and mouth. Rules of play concerning helmets, facemasks, goggles, and mouthguards vary by sport and position on the team. Intervention programs educate health professionals, parents, coaches, players, and officials of organized sports about the risk of injury and potential benefits of protective equipment, offer incentives for regular use of protective equipment at both practice and formal competition, and encourage the enforcement of rules of play involving safety equipment.

To make recommendations on population-based interventions that promote use of protective equipment in contact sports, the Task Force required that studies show increases in the use of such equipment or decreases in sports-related craniofacial injuries attributable to the intervention. Evidence of the efficacy of protective sports equipment in preventing injuries in individuals was not the focus of this review and has been summarized elsewhere.[6]

Review of evidence. Our systematic search identified 17 studies that met the inclusion criteria (see Appendix A).[184–200] Of these, 13 were excluded because of limitations in their execution or design (9 studies[184,187,188,190,192,194,197,198,200]) or lack of an appropriate effect measure (i.e., change in use of the protective equipment or injury rate attributable to the intervention, 4 studies[186,189,193,195]). The remaining 4 qualifying studies provided insufficient evidence to support a Task Force recommendation on population-based interventions to encourage use of helmets, facemasks, and mouthguards in contact sports.[185,191,196,199] The 4 studies, of fair quality, yielded 12 measures of effectiveness which failed to produce a body of evidence (considered separately or together) sufficient to meet minimum requirements for a Task Force recommendation. Individually, no study was of good quality, and no single effect was large enough to meet the least demanding criterion of sufficiency of the evidence of effectiveness. Together, the studies compared different exposures and reported inconsistent effects using different outcomes.

Evidence about applicability, other positive or negative effects, economic efficiency, and barriers to intervention implementation was not sought, because effectiveness of the intervention was not established.

Conclusion. According to *Community Guide* rules of evidence,[8] evidence is insufficient to determine the effectiveness of population-based interventions to encourage use of helmets, facemasks, and mouthguards in contact sports in increasing equipment use or reducing injury-related morbidity or mortality.

Research Issues for Preventing and Controlling Sports-Related Craniofacial Injuries

Because use of mandated equipment by children in many contact sports remains far too low,[183] important questions about the continuing prevalence of equipment use and of the effect of increasing equipment use on injuries remain to be answered. These questions include:

- How effective are laws, policies, and incentives in increasing the use of protective equipment in various sports?
- How effective are organized programs in increasing the use of protective equipment?
- What is the effect on injury risk of increasing use of protective equipment in particular sports?
- What are the extent and causes of disparities in equipment use and injury risk by age, gender, race or ethnicity, type of sport, and other factors?
- How effective are various kinds of helmets, mouthguards, and facemasks in preventing oral-facial injuries in contact sports (including karate, judo, and other martial arts)?

Discussion

Since the early 1940s, communities, individuals, and oral health professionals have used preventive and restorative interventions to achieve significant improvements in oral and dental health.[6] However, oral health improvements have been uneven among subgroups of the U.S. population defined by socioeconomic status, disability status, race or ethnicity, and other factors. The current burden of poor oral health continues to disproportionately affect communities with large numbers of African Americans, American Indians, Hispanics, the poor, and the disabled of any race or ethnic group.

Our effort to translate published prevention effectiveness research into the practice of oral health promotion encountered several important challenges. We envisioned a starting conceptual framework that emphasized an ecologic approach[201,202] to oral health promotion. This ecologic approach tries to influence the oral health status of a group of people by influencing individuals, their interacting groups members, and their environment simultaneously. Thus, promising interventions would (1) influence environments and behavior at individual, family, organizational, and community levels; and (2) consist of multiple components and targets of change achieving synergistic effects on behavior, practice, and oral health outcomes. Unfortunately, the existing research literature consisted mainly of disease-oriented interventions, most often studied individually, which could not be easily grouped into ecologic blocks (community-wide, setting-specific, and group-focused) for presentation (Appendix Table A1).

Second, sparse but important literature in some areas spanned time periods in the distant past when the scientific rigor of research methods was evolving slowly (e.g., controlled prospective studies were not commonly conducted) and clinical techniques and materials under investigation were improving rapidly (e.g., sealants and their application).

Third, we wanted to differentiate the content of this systematic review from related information in other systematic reviews completed for the *Community Guide* (e.g., those on cancer and on preventing tobacco use) and in other publications on best practices (e.g., the Surgeon General's Report on Oral Health[6] and the National Health Service "York Review" on CWF[50]). This review, however, was developed in parallel with and often in collaboration with related efforts involving systematic reviews of the same literature and the shared time and expertise of the same subject matter specialists.

Finally, the Task Force remains sensitive to the concern that some practitioners and policymakers might justify discontinuing interventions for which we found insufficient evidence of effectiveness or ineffectiveness. Insufficient evidence should not be confused with evidence of ineffectiveness. Moreover, the Task Force notes that longitudinal studies of promising interventions of unknown effectiveness are necessary to answer questions about the effectiveness of the interventions.

We offer the suggestions below for continuing research needed to make updating systematic reviews of the literature on oral health promotion less challenging and more rewarding. Toward that end, we advocate organizing some of the suggested areas of future inquiry through an increased focus on an ecologic rather than a disease-specific approach.

Ecologic Approaches Using Multiple Interventions with Many Targets of Change

Research on ecologic approaches in various settings (e.g., schools, healthcare systems, and communities) might involve multiple interventions (e.g., promoting use of sealants and craniofacial protection in contact sports, and preventing tobacco use and alcohol abuse) with many targets of change (e.g., children, teachers, administrators, health providers, parents, and health plan beneficiaries) and desirable health outcomes (e.g., preventing caries, periodontal diseases, craniofacial inju-

ries, and oral and pharyngeal cancers). Estimates of effectiveness might focus on increase in knowledge, behavioral intentions, and behaviors in the short term (e.g., use of sealants, craniofacial protectors, tobacco, and alcohol by all target populations) and the desirable health outcomes mentioned above in the long term.

Questions such as the following need to be answered:

- What is the effect on several oral health outcomes (e.g., dental caries and oral-facial injury) of community-wide interventions that combine environmental change (e.g., water fluoridation), legislative action (e.g., reimbursement for sealant use), policy change (e.g., incentives for use of protective equipment), and social support within families to encourage behavior change?
- What is the effect on several oral health outcomes (e.g., root-surface caries and periodontal diseases in the elderly) of community development coalitions, partnerships, mass media advocacy, and social marketing?
- What is the effect on several oral health outcomes (e.g., dental caries, periodontal diseases, and oral cancer) of multicomponent interventions in selected settings (e.g., schools, health plans, social service agencies, houses of worship, prisons, homeless shelters, and worksites)?

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Appendix A: Methods

Reviews of Effectiveness

In the *Guide to Community Preventive Services* (the *Community Guide*), evidence on the effectiveness of interventions is summarized. For each intervention with sufficient evidence to support a recommendation about its use, additional information is provided about (1) the applicability of evidence data to other populations and settings; (2) other positive or negative effects of the intervention, including positive or negative health and nonhealth outcomes; (3) economic impact; and (4) barriers to implementation of the intervention. The process used to review evidence systematically and then translate that evidence into the conclusions presented involves the following:

- Forming a systematic review development team (the "development team")
- Developing a conceptual approach to organizing, grouping, and selecting interventions
- Selecting interventions to evaluate
- Searching for and retrieving evidence
- Assessing the quality of and abstracting information from each study
- Assessing the quality of and drawing conclusions about the body of evidence of effectiveness
- Translating the evidence of effectiveness into recommendations
- Considering data about applicability, other effects, economic impact, and barriers to implementation for recommended interventions
- Identifying and summarizing research gaps

This appendix summarizes how these methods were used in developing the reviews of the effectiveness and economic efficiency of selected interventions to promote oral health. The *Community Guide*'s methods for systematic reviews and linking evidence to recommendations have been published elsewhere.[1] In brief, the development team of national and regional experts (see authorship and acknowledgment lists), representing a variety of disciplines and perspectives on oral health promotion and dental public health, drafted the conceptual approach to the systematic reviews (see main text) and selected interventions for evaluation.

Selecting Interventions for Evaluation

The coordination team, a subgroup of the development team consisting of eight scientists (the co-authors of this article) who interacted directly with the Task Force on Community Preventive Services (the Task Force) and carried out their decisions, prepared an initial, comprehensive list of 41 interventions, grouped by approach (Table A1). Interventions were ranked within subgroups, and subgroups were ranked in order of importance for each approach. Consultants were then asked to decide which items to add or delete from the list and to revise the initial ranking of interventions. They were asked to give high priority for evaluation to widely practiced interventions (whether considered effective or not) and interventions they considered important (even if not widely recognized, evaluated, or implemented). We considered important interventions to be those that address a high but preventable burden of disease, present new information in controversial areas, and explore issues of particular interest to oral health audiences.

Table A1. List of candidate interventions to promote oral health

Community-wide interventions			
Environmental change programs	**Legislative action or policy change programs**	**Community development coalitions and partnership programs**	**Mass media advocacy and social marketing programs**
• Community water fluoridation programs • Community salt fluoridation programs (special populations) • Universal availability of fluoride dentifrice • Increasing availability and use of other chemotherapeutic dentifrice (e.g., triclosan)	• Reducing financial barriers to regular nonemergency dental care, especially preventive services (e.g., sealants) through such safety-net programs as State Child Health Insurance Programs (SCHIP), Early Periodic Screening Detection and Treatment (EPSDT), Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), and Head Start centers • Revising licensing requirements for responsibilities of dental assistants, hygienists, and others • Drafting specifications for managed care contracts that ensure inclusion of effective preventive practices based on the available science (e.g., Medicaid) • Supporting training for dental public health residency programs • Injury protection laws (e.g., use of helmets)	• Promoting innovative strategies to increase access to care, including preventive services (e.g., Washington Oral Health Coalition, Oral Health 2000, enterprise zones)	• Using mass media approaches (e.g., commercials and American Dental Association endorsements) to promote use of fluoride dentifrices and other desirable oral health habits • Using social marketing approaches to discourage tobacco use and encourage screening for oral cancer

Community-based or setting-specific interventions			
School-based and school-linked programs (including preschool and college)	**Worksite-based programs (sponsored by employers and labor unions)**	**Faith-based programs**	**Health facility– (and social service–) based programs**
• Providing dental sealants • School water fluoridation programs • Dietary fluoride supplementation (tablets, rinse) • Self application of topical fluoride (brushing, rinsing, custom trays)	• Increasing insurance coverage for preventive services • Allowing time off and other incentives for employees and their families to obtain dental services • Integrating oral health messages into overall wellness programs including those for children (e.g., avoid bedtime bottle with cariogenic liquid, brushing with pea-sized amount of fluoride dentifrice)	• Encouraging partnerships in efforts to promote prevention strategies (e.g., sealants) • Partnering in efforts to ensure access to prevention and treatment services, especially among underserved populations	• Professional application of (pit and fissure) sealants • Professional removal of dental plaque and calculus • Self removal of dental plaque and adequate oral hygiene • Oral cancer screening

(*continued*)

Table A1. Continued

Community-based or setting-specific interventions			
School-based and school-linked programs (including preschool and college)	**Worksite-based programs (sponsored by employers and labor unions)**	**Faith-based programs**	**Health facility– (and social service–) based programs**
• Using therapeutic dentifrices in home dental hygiene programs			• Integrating oral health information into prenatal and postnatal classes and other wellness classes • Prescription for fluoride vitamins, drops, rinse, and gel, depending on status of water fluoridation and individual caries risk

Individual approaches (behavior modification and social learning)	
Family-centered programs	**Individually tailored programs**
• Personal oral hygiene programs (brushing, flossing, irrigating)	• Personal oral hygiene programs (brushing, flossing, irrigating)
• Modifying diet (reducing sucrose and increasing fibrous foods)	• Modifying diet (reducing sucrose and increasing fibrous foods)
• Preventing (through use of folates), treating, and rehabilitating cleft lip or palate	• Preventing (through use of folates), treating, and rehabilitating of cleft lip or palate
• Screening for early detection of oral cancer using health history and other modalities	• Reducing use of chewing tobacco, snuff, and pipe and cigarette smoking
• Educating those who care for elderly and disabled about importance of good oral hygiene and regular source of dental care	• Reducing alcohol abuse
• Educating those who care for infants and toddlers about appropriate bottle feeding practices and mouth care	• Using sun block (lip screen) to reduce exposure of lips to ultraviolet radiation among outdoor workers (e.g., farmers and fishermen

From this list, the development team selected for evaluation interventions to prevent and control dental caries (including community water fluoridation, school-based or school-linked pit and fissure sealant delivery programs, and statewide or community-wide sealant promotion programs), oral and pharyngeal cancers, and sports-related craniofacial injuries. We focused on these interventions because these important health problems contribute substantially to annual dental care expenditures, serve as selected indicators of the need for preventive services, and address several of the *Healthy People 2010* objectives.[2] The final priority strategies and list of interventions evaluated and not evaluated are presented in Table A2. We grouped interventions by oral health outcomes because we expected the limited oral health promotion literature to be disease oriented, and our subject-matter consultants advised that practitioners might find it easier to use information presented in the familiar disease-oriented format. Time and resource constraints precluded review of some candidate interventions shown in Table A2. The final list of interventions evaluated and outcomes of interest are shown in Table A3.

Search for Evidence

For each intervention reviewed, the coordination team developed an analytic framework indicating possible causal links between the intervention under study and predefined outcomes of interest (as shown in Table A3). The analytic frameworks were used to guide the search for primary studies of the effectiveness of each intervention on the predefined outcomes of interest. Electronic searches for literature were conducted in MEDLINE. The coordination team also reviewed the references listed in all retrieved articles including those recommended by experts who were not members of the development team. To be included in the review, a study had to:

Table A2. Final list of strategies, interventions evaluated, and interventions not evaluated[a]

Strategies	Interventions
Strategies to prevent and control dental caries	• Community water fluoridation • School-based or school-linked pit and fissure sealant delivery programs • Statewide or community-wide sealant promotion programs • *Multicomponent interventions to prevent infant caries*
Strategies to prevent or control oral and pharyngeal cancers	• Population-based interventions for early detection of oral and pharyngeal pre-cancers and cancers
Strategies to prevent or control sports-related craniofacial injuries	• Population-based interventions to encourage use of helmets, facemasks, and mouthguards in contact sports
Education interventions	• *Public education* • *Professional education* • *School-based education*
Combined approaches	• *Multicomponent interventions that target many health outcomes*

[a]Italics indicate interventions that were not evaluated.

- have a publication date between 1966 and December 2000;
- address at least one area in our conceptual framework;
- be a primary study rather than, for example, a guideline or review;
- be written in English;
- meet the development team's definition of the interventions;
- provide information on one or more outcomes related to the analytic frameworks; and
- compare a group of people who had been exposed to the intervention with a group of people who had not been exposed or who had been less exposed. The comparisons could be concurrent or in the same group over a period of time.

Database searches were conducted from May 1998 through January 2001.

Abstraction and Evaluation of Studies

Each study that met the inclusion criteria was read by two reviewers, who used a standardized abstraction form to record information from the study.[3] Recorded information included judgments about the suitability of the study design for estimating the effectiveness of the intervention and residual threats to the validity of conclusions about that effectiveness. On the basis of the

Table A3. Interventions evaluated and outcomes of interest

Interventions	Outcomes
Community water fluoridation School-based or school-linked pit and fissure sealant delivery programs	**Caries experience** • Decayed, missing, or filled primary or permanent teeth • Decayed, extracted, or filled primary or permanent teeth • Decayed, missing, or filled surfaces in primary or permanent teeth • Percentage of caries-free children
Statewide or community-wide sealant promotion programs	**Sealant use reported by dentists**
Population-based interventions for early detection of oral and pharyngeal pre-cancers and cancers	**Accuracy of early detection** • Sensitivity • Specificity • Positive predictive value • Negative predictive value **Effectiveness of early detection** • Percent yield of suspicious lesions, pre-cancers, or cancers • Cancer morbidity and mortality
Population-based interventions to encourage use of helmets, facemasks, and mouthguards in contact sports	• Injury rate (head, neck, face, mouth, teeth) • Use of helmets, facemasks, and mouthguards

number of threats to validity, studies were characterized as having good, fair, or limited execution. Any disagreements between the reviewers were reconciled by consensus among the coordination team members. In addition, to determine the best approach to summarizing the body of evidence for a particular intervention, evaluated studies were presented and discussed in meetings of the coordination team.

Assessing the Suitability of Study Design

Design suitability was assessed for every included study. Study designs of greatest suitability had concurrent comparison groups and prospective measurement of exposure and outcome; study designs of moderate suitability included all retrospective designs or multiple before or after measurements but no concurrent comparison group; and study designs of least suitability involved single before-and-after measurements and no concurrent comparison group or exposure, with outcome measured in a single group at the same point in time.

Our study design classifications, chosen to ensure consistency in the review process, sometimes differ from the classification or nomenclature used in the original studies. Noncomparative studies were excluded from further evaluation. We included all comparative studies in all of our evaluations whether they had greatest, moderate, or least suitable designs.

Assessing the Quality and Summarizing the Body of Evidence of Effectiveness

Quality of study execution was systematically assessed according to *Community Guide* methods.[1,3] The quality of execution of each study was characterized as good, fair, or limited on the basis of the total number of categories with limitations. Good studies had one or no assessed limitations, fair studies had two to four, and limited studies had five or more. Studies with limited execution were excluded from analysis. We abstracted information from the studies about the outcomes of interest specific to the intervention under evaluation. We presented results of each study as point estimates (i.e., absolute effect) for the change in oral health outcome (caries, cancer, or injury) attributable to the interventions. We also calculated change in oral health outcome (caries, cancer, or injury) attributable to the interventions as a percentage of the best available baseline measure (i.e., percent effect) using different formulas for different health outcomes as shown below.

Calculating the effect of community water fluoridation on dental caries. For studies with before-and-after measurements and concurrent comparison groups:

$$(\text{Fpre} - \text{Fpost}) - (\text{NoFpre} - \text{NoFpost})/\text{NoFpre}$$

where:[a]

Fpre = Dental caries prevalence in fluoridated community before fluoridation (or at first measurement during ongoing fluoridation)
Fpost = Dental caries prevalence in fluoridated community after fluoridation (or at second measurement during ongoing fluoridation)
NoFpre = Dental caries prevalence in nonfluoridated community before fluoridation (or at first measurement during ongoing fluoridation)
NoFpost = Dental caries prevalence in nonfluoridated community after fluoridation (or at second measurement during ongoing fluoridation)

For studies with post measurements only and concurrent comparison groups[a]:

$$\text{Fpost} - \text{NoFpost}/\text{NoFpost}$$

For studies with before-and-after measurements but no concurrent comparison[a]:

$$\text{Fpost} - \text{Fpre}/\text{Fpre}$$

Calculating the effect of school-based or school-linked sealant delivery programs on dental caries. The 10 qualifying studies (22 measures of effect) used a variety of formulas to estimate the effectiveness of school-based or school-linked sealant delivery programs. We reported the measures of effect as published by the authors of the original articles. Both crude effect measures and those that had been adjusted for potential confounders were used when available, without regard for statistical significance. Published effect measures of interest were used as reported by the authors.

Effect of all interventions evaluated. To summarize the findings on the effectiveness of an intervention across the studies in a body of evidence, we displayed results of individual studies in tables and figures and reported median and range of effect measures. We summarized the strength of the body of evidence on the basis of the numbers of available studies, the strength of their design and execution, and the size and consistency of reported effects as previously described in detail.[1]

Other Effects

The *Community Guide* reviews of community water fluoridation and school-based or school-linked sealant delivery programs sought information on other effects (i.e., positive and negative health or nonhealth "side effects"). We sought evidence of potential harms of these population-based interventions if they were men-

[a]To aid interpretation of Figures 2, 3, and 5, we multiplied the formulas by −1 so that decreases and increases in caries prevalence were represented by negative and positive numbers, respectively. For example,

$$-[(\text{Fpre} - \text{Fpost}) - (\text{NoFpre} - \text{NoFpost})/\text{NoFpre}]$$

$$= (\text{NoFpre} - \text{NoFpost}) - (\text{Fpre} - \text{Fpost})/\text{NoFpre}$$

tioned in the effectiveness literature or thought to be of importance by the development team.

This report does not include a systematic review of other positive or negative effects of community water fluoridation.[4] A detailed review of available evidence of the association, if any, of CWF with potential adverse effects such as dental fluorosis, bone fracture or developmental abnormalities, cancers, and other possible negative effects, has been conducted by others.[5] Because of time and resource constraints, and the availability of a recently conducted, exhaustive review, the Task Force decided to summarize the main findings of that review instead of conducting an independent review of the potential harms of CWF (see Appendix C).

Economic Evaluations

Methods used to conduct systematic reviews of economic evaluations of effective interventions (those recommended by the Task Force) have been described previously.[6] In brief, for the oral health systematic review, a team of scientists with training and expertise in economic evaluations assessed the quality of eligible studies, abstracted detailed information about the studies and their findings, and made statistical adjustments to standardize the data using explicit procedures and a standard instrument.

To be included in the review of economic evaluations of effective interventions (i.e., community water fluoridation and school-based and school-linked sealant delivery programs) studies had to:

- use cost, cost-effectiveness, cost-benefit, or cost-utility analysis;
- provide sufficient data to enable use and adjustment of results;
- itemize costs or refer to a source of cost data;
- be a primary study rather than a guideline or review;
- be conducted in one or more established market economies[b];
- be published between 1969 and December 2000; and
- be written in English.

Summarizing Barriers to Implementation of Interventions

Information about barriers to implementation of the interventions was abstracted from reviewed studies, evaluated on the suggestion of the development team, or both. In some cases, additional information was obtained. For several reviews we included references to more detailed descriptions. Information on barriers did not affect recommendations of the Task Force.

[b]Established market economies as defined by the World Bank are Andorra, Australia, Austria, Belgium, Bermuda, Canada, Channel Islands, Denmark, Faeroe Islands, Finland, France, Germany, Gibraltar, Greece, Greenland, Holy See, Iceland, Ireland, Isle of Man, Italy, Japan, Liechtenstein, Luxembourg, Monaco, the Netherlands, New Zealand, Norway, Portugal, San Marino, Spain, St. Pierre and Miquelon, Sweden, Switzerland, the United Kingdom, and the United States.

Summarizing Research Gaps

Systematic reviews in the *Community Guide* identify existing information on which to base public health decisions. An important additional benefit of these reviews is identification of areas where information is lacking or of poor quality. To summarize these research gaps, we used the following process:

- We identified remaining research questions for each intervention evaluated.
  - Where evidence of effectiveness was sufficient or strong, we summarized remaining questions about effectiveness, applicability, other effects, economic consequences, and barriers.
  - Where evidence of effectiveness was insufficient, we summarized remaining questions about effectiveness and other effects. We summarized applicability issues only if they affected the assessment of effectiveness. We decided that it would be premature to identify research gaps in barriers or economic evaluations before effectiveness was demonstrated.
- For each category of evidence, we identified issues that had emerged from the review, based on the informed judgment of the development team. Several factors influenced that judgment. In general,
  - If no information or inadequate information existed to draw a conclusion about effectiveness, applicability, other effects, or economic evaluations, we listed these as evidence gaps.
  - When a conclusion was drawn about evidence, the development team decided if additional issues remained.

  In terms of effectiveness,
  - If effectiveness was demonstrated using some but not all outcomes, we did not necessarily list all other possible outcomes as evidence gaps.

  In terms of applicability,
  - If the available evidence was thought to generalize, we did not necessarily identify as evidence gaps all subpopulations or settings where studies had not been done.

  In terms of methods,
  - Within each body of evidence, the coordination team considered whether overriding methodologic issues existed.

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Appendix B: Studies Measuring the Effectiveness of Community Water Fluoridation (CWF)

Author & year (study period) Design suitability: design Quality of execution Evaluation setting	Intervention and comparison elements (fluoride concentration)	Study population description Sample size [a]	Results			
			Effect measure	Caries at baseline	Values used in summary [b]	Follow-up time
Analysis Group A studies[c] measuring the effect of starting or continuing CWF on dental caries						
Arnold 1956[1] (1944–1951) Greatest: Nonrandomized trial Fair Community-wide	Intervention: CWF (1.2ppm) started in Grand Rapids, Michigan in 1945 (Grand Rapids) Comparison: Nonfluoridated (NF) water (<0.02ppm) consumed in Muskegon, Michigan during 1944 to 1951	White children aged 4–15 yrs, lifelong residents of city Baseline N (1944): I= 323–1647 C = 20–376 Follow-up N (1951): I = 53–470 C = 21–275	Caries experience: decayed, missing, extracted, or filled teeth; either permanent (DMFT), or primary (deft) Baseline in 1944 Follow-up in 1951	Intervention 4 yrs (prim) = 4.19 8 yrs (prim) = 5.78 8 yrs (perm) =2.95 15 yrs (perm) =12.48	Absolute Effect:[d] 4 yrs (prim) = 1.47 deft (NR) 8 yrs (prim) = 0.92 deft (NR) 8 yrs (perm) = 1.19 DMFT (NR) 15 yrs (perm) = 3.09 DMFT (NR) Percent Effect:[e] 4 yrs = 29.1% (NR) 8 yrs = 15.2% (NR) 8 yrs = 42.3% (NR) 15 yrs = 24.0% (NR)	7 years
Beal, 1971[2] (1967–1970) Moderate: Time series Good Community-wide	Intervention 1: CWF (1.0ppm) (fluoridation started in Birmingham [Balsall health district], U.K. in 1964) Intervention 2: CWF (1.0ppm) started in Birmingham (Northfield health district), U.K. in 1964 Comparison: NF (0.02–0.09ppm) Dudley, U.K.	All residents (including poor immigrants); outcome measured in 5-year-olds: N=189 in Balsall health district; N= 192 in Northfield health district	deft, DEFT Baseline in 1967 Follow-up in 1970	Intervention Balsall = 5.16 Northfield= 4.91	Absolute Effect Balsall: 3.34 deft or DMFT (p<0.01) Northfield: 2.58 deft or DMFT (p<0.01) Percent Effect Balsall: 67.2% (p<0.01) Northfield: 51.9% (p<0.01)	3 years

Appendix Continued

Author & year (study period) Design suitability: design Quality of execution Evaluation setting	Intervention and comparison elements (fluoride concentration)	Study population description Sample size [a]	Results			
			Effect measure	Caries at baseline	Values used in summary [b]	Follow-up time
Beal, 1981[3] (1969–1975) Moderate: Time series Good Community-wide	Intervention: CWF (0.85 - 0.90ppm) (fluoridation started in Scunthorpe, Lincolnshire Co., U.K. in 1968) Comparison: NF (0.35ppm) Corby, Northampton Co., U.K.	Lifetime residents, aged 5–12 yrs (*n*=115–196) 5 yrs (prim) (*n*=182) 8 yrs (prim) (*n*=189) 8 yrs (perm) (*n*=115) 12 yrs (perm)(*n*=196)	dmft, DMFT Baseline in 1969 Follow-up in 1975	Intervention 5 yrs (prim) = 4.29 8 yrs (prim) = 5.0 8 yrs (perm) = 1.48 12 yrs (perm) = 3.53	Absolute Effect 5 years (primary=1.7 dmft (p<0.01) 8 years (primary)=1.19 dmft (p<0.01) 8 years (permanent)=0.62 DMFT (p<0.01) 12 years (permanent)=0.62 DMFT (p<0.01) Percent Effect 5 years (primary)=39.7% (NR) 8 years (primary)=22.2% (p<0.01) 8 years (permanent)=40.0% (NR) 12 years (permanent)=14.5% (p<0.01)	6 years
Evans, 1996[4] (1987–1994) Least: Cross-sectional surveys Fair Community-wide	Intervention: CWF (1.0ppm) in Newcastle, U.K. (fluoridation started in 1969) Comparison: NF (<0.1ppm) Southeast Northumberland, U.K.	White lifetime residents, all social classes, aged 5 yrs Social Class (SC) I&II (*n*=127) Social Class III (*n*=170) Social Class IV&V (*n*=52)	dmft Baseline in 1987 Follow-up in 1994	Intervention SC I&II=1.1 SC III=1.7 SC IV&V=2.4	Absolute Effect SC I&II = -0.2 dmft (NR) SC III = -1.2 dmft (NR) SC IV&V = -1.1 dmft (NR) Percent Effect SC I&II = -9.1% (NR) SC III = -32.4% (NR) SC IV&V = -22% (NR)	7 years
Guo, 1984[5] (1971–1981) Greatest: Prospective cohort Fair Community-wide	Intervention: CWF (0.6ppm) in Chung-Hsing New Village, Taiwan (fluoridation started in 1972) Comparison: NF (0.08ppm) in Tsao-Tun, Taiwan	Lifetime residents, aged 4–8 yrs 4 yrs (*n*=354) 8 yrs (*n*=392)	deft Baseline in 1971 Follow-up in 1981	Intervention 4 yrs (prim) = 4.6 8 yrs (prim) = 4.2	Absolute Effect 4 yrs (prim) = 1.6 deft (p<0.001) 8 yrs (prim) = 2.3 deft (p<0.001) Percent Effect 4 yrs (prim) = 28.6% (NR) 8 yrs (prim) = 65.7% (NR)	10 years
Kunzel, 1997[6] (1959–1987) Moderate: Time series Fair Community-wide	Intervention: CWF (1.0 then 0.18ppm) in Chemnitz, Germany (fluoridation started in 1959 and stopped in 1990) Comparison: NF (0.4–0.9ppm from 1972 to 1984 then 0.18ppm thereafter), in Plauen, E. Germany (unified Germany after 1990)	Lifetime residents, aged 6–15 yrs (*n* =12,000 –30,000 per year, all groups)	DMFT Baseline in 1959 Follow-up in 1971 Baseline in 1971 Follow-up in 1987	Intervention: 6–10 yrs (1959–1971) = 1.6 11–15 yrs (1959–1971) = 4.4 6–10 yrs (1971–1987) = 0.7 11–15 yrs (1971–1987) = 2.6	Absolute Effect: / Percent Effect 1.3 DMFT (NR) / 86.7% (NR) 3.1 DMFT (NR) / 73.8% (NR) -1.3 DMFT (NR) / -66.8% (NR) -2.7 DMFT (NR) / -49.1% (NR)	12 years 16 years

Appendix Continued

Author & year (study period) Design suitability: design Quality of execution Evaluation setting	Intervention and comparison elements (fluoride concentration)	Study population description Sample size [a]	Results			
			Effect measure	Caries at baseline	Values used in summary [b]	Follow-up time
Loh, 1996[7] (1957–1965) Greatest: Prospective cohort Fair Community-wide	Intervention: CWF (0.7 then 0.6ppm) in Singapore (fluoridation started in 1958, reduced to 0.6ppm in 1992) Comparison: NF in Malacca, W. Malaysia (fluoride deficient: ppm not reported)	Ethnic Chinese and Malays, age 7–9 yrs Chinese (*n*=2200) Malay (*n*=2200; in both fluoridated and nonfluoridated samples)	DMFT Baseline in 1957 Follow-up in 1965 (when Singapore became independent of Malaysia)	Intervention Chinese=4.4 Malay=2.9	Absolute Effect Chinese=3.1 DMFT (NR) Malay=2.1 DMFT (NR) Percent Effect Chinese= 83.8% (NR) Malay=110.5% (NR)	8 years
Analysis Group A studies[c] measuring the effect of stopping or reducing CWF on dental caries						
Atwood, 1988[8] (1980–1986) Greatest: Prospective cohort Fair Community-wide	Intervention: CWF (not reported) in Stanraer, Scotland (fluoridation started in 1970 and stopped in 1983) Comparison: NF (ppm not reported) in Annan, Scotland	Lifetime residents, aged 10 yrs *n*=147	DMFT Baseline in 1980 Follow-up in 1986	Intervention 1.7	Absolute Effect -0.6 DMFT (NR) Percent Effect -17.9% ($p<0.05$)	6 years
Kalsbeek, 1993[9] (1968–1980) Greatest: Prospective cohort Fair Community-wide	Intervention: CWF (1.1 then 0.1ppm) in Tiel, The Netherlands (fluoridation started in 1953 and stopped in 1973) Comparison: NF (0.1ppm) in Culemborg, the Netherlands	Effect measured in residents aged 15 yrs 1968–1979, *n*=285 1979–1987, *n*=369	DMFT Baseline in 1968 Follow-up in 1979 and 1987	Intervention 1968–1979 = 7.4 1979–1987 = 7.8	Absolute effect / Percent effect -4.1 DMFT (NR) / -29.1% (NR) -3.3 DMFT (NR) / -31.7% (NR)	10 years 8 years
Kunzel, 1997[6] (1987–1995) Moderate: Time series Fair Community-wide	Intervention: CWF (1.0 then 0.18ppm) in Chemnitz, Germany (fluoridation started in 1959 and stopped in 1990) Comparison: NF (0.4–0.9ppm from 1972 to 1984 then 0.18ppm thereafter), in Plauen, E. Germany (Unified Germany after 1990)	Lifetime residents, aged 6–15 yrs *n* = 12,000–30,000 per year, all groups	DMFT Baseline in 1987 Follow-up in 1995	Intervention: 6–10 yrs = 0.9 11–15 yrs = 3.36	Absolute effect: / Percent effect: 0.04 DMFT (NR) / 1.1% (NR) 0.4 DMFT (NR) / 42.2% (NR)	8 years

Author & year (study period) Design suitability: design Quality of execution Evaluation setting	Intervention and comparison elements (fluoride concentration)	Study population description Sample size [a]	Results			
			Effect measure	Caries at baseline	Values used in summary [b]	Follow-up time
Analysis Group B studies[c] measuring the effect of starting or continuing CWF on dental caries						
Brown, 1965[10] (1945–1963) Greatest: Prospective cohort Good Community-wide	 Intervention (1): CWF (1.0ppm) Brantford, Ontario, Canada (1945–1963) Intervention (2): Natural fluoride (ppm not reported) Stratford, Ontario Comparison (3): NF(<0.02ppm) Sarnia, Ontario, Canada	Lifetime residents aged 14–17 yrs Brantford 14–15 yrs (*n* = 650) 16–17 yrs (*n* = 356) Stratford 14–15 yrs (*n* = 342) 16–17 yrs (*n* = 227) Sarnia (*n*=482)	DMFT 1963	NA	Absolute effect 1 v 3, 14–15yrs = -4.14 DMFT (p<0.0027) 2 v 3, 14–15yrs = -4.81 DMFT (p<0.0027) 1 v 3, 16–17yrs = -5.70 DMFT (p<0.0027) 1 v 3, 16–17yrs = -6.25 DMFT (p<0.0027) Percent effect 1 v 3, 14–15yrs = -51.5% DMFT (NR) 2 v 3, 14–15yrs = -59.8% DMFT (NR) 1 v 3, 16–17yrs = -54.6% DMFT (NR) 1 v 3, 16–17yrs = -59.9% DMFT (NR)	NA
Evans, 1996[4] (1987, 1994) Least: Cross-sectional surveys Fair Community-wide	Intervention: CWF (1.0ppm) in Newcastle, U.K. (fluoridation started in 1969) Comparison: NF (<0.1ppm) Southeast Northumberland, U.K.	White lifetime residents, all social classes, aged 5 yrs All social classes (*n* = 349)	dmft in 1994	Intervention NA	Absolute effect -1.09 dmft (NR) Percent effect -47.6% (NR)	NA
Fanning, 1980[11] (1970,1976) Moderate: Time series Fair Community-wide	Intervention: CWF (not reported) in Adelaide, S. Australia (not reported) (fluoridation started in 1971) Comparison Adelaide, S. Australia (ppm not reported)	Children ages 3–6 yrs 3–4 yrs (*n* = 407) 4–5 yrs (*n* = 3512) 5–6 yrs (*n* = 339)	dmft 1970 through 1976	Intervention NA	Absolute effect 3–4 yrs: -0.86 dmft (NR) 4–5 yrs: -1.07 dmft (NR) 5–6 yrs: -1.06 dmft (NR) Percent effect 3–4 yrs: -64.2% (NR) 4–5 yrs: -49.8% (NR) 5–6 yrs: -36.7% (NR)	NA

Appendix Continued

Author & year (study period) Design suitability: design Quality of execution Evaluation setting	Intervention and comparison elements (fluoride concentration)	Study population description Sample size [a]	Results			
			Effect measure	Caries at baseline	Values used in summary [b]	Follow-up time
Guo, 1984[5] (1971–1981) Greatest: Prospective cohort Fair Community-wide	Intervention: CWF (0.6ppm) in Chung-Hsing New Village, Taiwan (fluoridation started in 1972) Comparison: NF (0.08ppm) in Tsao-Tun, Taiwan	Lifetime residents, aged 8–15 yrs 8 yrs (*n* = 325) 12 yrs (*n* = 94) 15 yrs (*n* = 94)	dmft 1971–1981	Intervention NA	Absolute effect 8 yrs = -1.1dmft (NR) 12 yrs = -1.7dmft (NR) 15 yrs = -2.0dmft (NR) Percent effect 8 yrs = -68.8% (NR) 12 yrs = -50.0% (NR) 15 yrs = -47.6% (NR)	NA
Hawew, 1996[12] (1994) Least: Cross-sectional surveys Fair Community-wide	Intervention: Natural (1.8ppm) in Jardinah, Libya Comparison: NF (0.8ppm) Benghazi, Libya	State and private school students, lifetime residents, aged 6–12 yrs 6 yrs, private school (*n*=94) 6 yrs, state school (*n*=94) 12 yrs, private school (*n*=126) 12 yrs, state school (*n*=126)	dmft, DMFT 1994	Intervention NA	Absolute effect 6 yrs, private school: -2.05 dmft (p<0.001) 6 yrs, state school: -1.25 dmft (p<0.001) 12 yrs, private school: -0.25 DMFT (NR) 12 yrs, state school: -0.3 DMFT (NR) Percent effect 6 yrs, private school: -65.7% (NR) 6 yrs, state school: -53.9% (NR) 12 yrs, private school: -22.3% (NR) 12 yrs, state school: -25.6% (NR)	NA
Provart, 1995[13] (1969–1995) Least: Cross-sectional surveys Fair Community-wide	Intervention: Natural (ppm not reported) in County Durham, U.K. (49 electoral wards) (fluoridation started in 1969) Comparison: NF (0.1–0.4ppm) in County Durham, U.K. (128 electoral wards)	Children with high or low material deprivation, aged 5 yrs (*n* = 325–389) High material deprivation (*n* = 389) Low material deprivation (*n* = 325)	dmft 1991–92	Intervention NA	Absolute effect -0.9 dmft (p<0.01) -0.4 dmft (p<0.05) Percent effect -42.9% (NR) -33.3% (NR)	NA

Appendix Continued

Author & year (study period) Design suitability: design Quality of execution Evaluation setting	Intervention and comparison elements (fluoride concentration)	Study population description Sample size [a]	Results			
			Effect measure	Caries at baseline	Values used in summary [b]	Follow-up time
Rugg-Gunn, 1981[14] (1969–1978) Least: Cross-sectional surveys Fair Community-wide	Intervention: Natural (1.0ppm) in Newcastle Upon Tyne, U.K. (fluoridation started in 1969) Comparison 1: NF(<0.1ppm) in Ashington, U.K. Comparison 2: NF (<0.2ppm) in Houghton, U.K. Comparison 3: NF (<0.5ppm) in Sunderland and South Tyneside, U.K.	White lifetime residents, aged 5 yrs (*n*=438) Ashington: aged 5 yrs (*n*=438) Houghton: aged 5 yrs (*n*=438) Sunderland: aged 5 yrs (*n*=438)	deft 1978	Intervention NA	Absolute effect Ashington: -3.6 deft (NR) Houghton: -2.4 deft (NR) Sunderland: -2.4 deft (p<0.01) Percent effect Ashington: -59.0% (NR) Houghton: -49.0% (NR) Sunderland: -63.2% (NR)	NA
Analysis Group B studies[c] measuring the effect of stopping or reducing CWF on dental caries						
Booth, 1992[15] (1970–1989) Least: Cross-sectional surveys Good Community-wide	Intervention: Natural (1.0ppm) in Huddersfield, Yorkshire Co., U.K. Comparison: Nonfluoridated (<0.3ppm) in Dewsbury, U.K.	White lifetime residents, aged 3 yrs (*n* = 121)	dmft 1989	Intervention NA	Absolute effect -0.44 (p = 0.03) Percent effect -59.5% (NR)	NA

[a] In fluoridated sample at baseline
[b] This is the value used to summarize the evidence and to develop the recommendation. In some cases, this column reflects values calculated because the effects reported by the authors were not consistent with effect measures used in other studies.
[c] Studies which also yielded effect measures in Tables 2 and 3 in the main text are not included in this table
[d] See numerators in formulas in section on "Calculating the effect of community water fluoridation on dental caries," in Appendix A
[e] Multiply formulas in section on "Calculating the effect of community water fluoridation on dental caries," in Appendix A, by 100 to get percentage

DEFT, decayed, extracted, or filled permament teeth; deft, decayed, extracted, or filled primary teeth; DMFT, decayed, missing, or filled permanent teeth; dmft, Decayed, missing, or filled primary teeth; NA, not applicable; NF, not fluoridated; NR, not reported; ppm, parts per million; perm, permanent teeth; prim, primary teeth; SC, social class; U.K., United Kingdom; yrs, years

Appendix Continued

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Appendix C: Potential Adverse Effects of Community Water Fluoridation—Summary of Findings from the National Health Service York Review

The main conclusions of the systematic review of public water fluoridation conducted by the National Health Service Centre for Reviews and Dissemination, University of York, England (the NHS York review),[1,2] are as follows:

- All but one of 88 included studies of dental fluorosis and enamel opacities not caused by fluoride were defined by the reviewers to be of low quality. The researchers used regression analysis of data from the 88 studies to predict a significant dose–response relationship between water fluoride level and the prevalence of dental fluorosis. The regression equation predicted that among people exposed to a water fluoride level of 1.0 ppm, the prevalence of dental fluorosis would be 48% (95% CI, 40% to 57%) for fluorosis of any level of severity and 12.5% (95% CI, 7.0% to 21.5%) for fluorosis of esthetic concern, respectively. (The level of severity of fluorosis includes a "questionable" classification in which a definite diagnosis of the mildest form of fluorosis is not warranted and a classification of "normal" is not justified.[3] Fluorosis of aesthetic concern includes fluorosis that involves more than 25% of the tooth surface and corresponds to "mild" or worse in Dean's Fluorosis Index.[3])
- Overall, the findings of 29 studies of bone fracture effects showed small variations around the "no-effect" mark. A meta-regression of bone fracture studies also found no association with water fluoridation.
- Overall, 26 studies showed no clear association between water fluoridation and incidence or mortality of bone cancers, thyroid cancer, or all cancers.
- Overall, the 33 studies examining other possible negative effects provide insufficient evidence on any particular outcome to permit confident conclusions.

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