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AN EXAMINATION OF THE ADVANCES IN SCIENCE AND TECHNOLOGY OF PREVENTION OF TOOTH DECAY IN YOUNG CHILDREN SINCE THE SURGEON GENERAL'S REPORT ON ORAL HEALTH

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Abstract

This paper addresses a number of areas related to how effectively science and technology have met Healthy People 2010 goals for tooth decay prevention. In every area mentioned, it appears that science and technology are falling short of these goals. Earlier assessments identified water fluoridation as one of the greatest public health accomplishments of the last century. Yet, failure to complete needed clinical and translational research has shortchanged the caries prevention agenda that incomplete at a critical juncture.

Science has firmly established the transmissible nature of tooth decay. However, there is evidence that tooth decay in young children is increasing although progress has been made in other age groups. Studies of risk assessment have not been translated into improved practice. Antiseptics, chlorhexidine varnish, and PVP-iodine may have value, but definitive trials are needed. Fluorides remain the most effective agents, but are not widely disseminated to the most needy. Fluoride varnish provides a relatively effective topical preventive for very young children, yet definitive trials have not been conducted. Silver diammine fluoride also has potential but requires study in the US. Data support effectiveness and safety of xylitol, but adoption is not widespread. Dental sealants remain a mainstay of public policy, yet after decades of research, widespread use has not occurred.

We conclude that research has established the public health burden of tooth decay, but insufficient research addresses the problems identified in the Surgeon General's Report. Transfer of technology

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from studies to implementation is needed to prevent tooth decay among children. This should involve translational research and implementation of scientific and technological advances into practice.

INTRODUCTION

Ample evidence demonstrates that the country is failing to move toward meeting *Healthy People 2010* goals to improve the oral health of preschoolers with respect to tooth decay,¹ and this problem is expanding with higher disease rates and dental workforce shortages.² The Midcourse Review for Healthy People 2010 suggested that tooth decay (caries) rates for children 2–5 years old were increasing, primarily among the poor and minorities, and most lesions are untreated, to say nothing of prevented.¹ Figure 1 is excerpted from this report. The problem likely extends to older poor and minority children as dental caries lesions are cumulative and untreated decay of primary teeth strongly predicts the same condition of secondary (permanent) teeth.^{3–8} However, older children are more likely to receive some preventive care (see Figure 2, from the National Survey of Children’s Health).

Tooth decay is attributable mostly to the infectious nature of dental caries in humans.^{9–11} Complicating this problem are workforce shortages¹², lack of access to care¹, and discrimination against populations served by Medicaid^{13–14}. This paper examines advances in science and technology associated with prevention of tooth decay in young children since the Surgeon General’s Report of 2000.

The Infectious Nature of Caries

Strategies for dental caries prevention and management can take advantage of the infectious nature of the disease or choose to view it as independent of its infectious nature. The evidence of transmission, initially from mother to child, is demonstrated not only by the correlation of maternal salivary titers of mutans streptococci (referred to hereafter as *Streptococcus mutans* or *S. mutans*) with the early colonization of her child and the early inception of caries lesions in the child, but also by the identity of *S. mutans* colonizing mother and her child, based on bacteriocin typing, endonuclease, and ribo-typing.^{11,15–18} A strong scientific basis supports evaluation of the microbial status of young mothers as predictors of the colonization of their young children’s teeth.¹¹ Interventions in the mother to suppress her *S. mutans* prolong the time to colonization of her children and prolong the time and reduce the severity of carious lesion inception.^{19–21} The notion of a discrete window of infectivity until about 26 months of age during which transmission occurs²² has been expanded following studies that showed colonization at younger ages and prior to tooth eruption. It is estimated in one study that *S. mutans* is harbored by at least 20 percent of children under 14 months of age²³ and at least 25 percent of pre-tate children in another.²⁴ The source of the *S. mutans* after 5 years of age is not known, but is likely to include siblings and caretakers, at least.

This review focuses on the preventive strategies and technologies applicable to individual children that address goals of *Health People 2010* and if applied might mitigate the inequities identified by the Surgeon General’s Report on Oral Health (SGROH). The science and technologies to be reviewed are:

- Detection and Risk Assessment
- Interventions to Improve Prevention of Tooth Decay

DETECTION AND RISK ASSESSMENT

Early Tooth Decay Lesion Detection

Industry has developed high technology devices that allow detection of early signs of decay lesions. Early detection could increase opportunity to arrest and reverse tooth damage using a “medical” approach²⁵ and prevent the need for traditional “surgical” interventions that partially remove and reconstruct (fill) the teeth, or extract them. The devices generally have high sensitivity but inadequate specificity. Their clinical application is further limited because one method cannot be used for all tooth surfaces and under all circumstances.²⁶ Presently they appear to add little to competent visual/tactile examination.^{27–28} Moreover, these devices may be misused to justify surgical interventions and fabrication of fillings, sometimes mislabeled “minimally invasive”, instead of intensifying efforts to arrest early lesions. Devices with the best performance are expensive and cumbersome, their use time consuming, with little application in typical dental practice, community practice, or community health centers. Simpler approaches, such as fiber-optic transillumination, may be more readily adopted.²⁹

A multinational academic group has begun testing a totally visual caries lesion assessment scheme (ICDAS, International Caries Detection and Assessment System II) that focuses on early lesion detection, before cavitation has begun.^{30–31} As with the technology-based systems, the rationale is that earlier detection will increase opportunity to arrest and reverse lesions and prevent need for surgical interventions. The ICDAS has acceptable reliability and validity, but requires rigorous training, and remains in development.³²

To date there has been limited impact on training of dental students, community or health center practice adoption, although this situation could rapidly change if research demonstrated how best to achieve this aim. These methods, whether high tech or visual, rely on detection of lesions after they have occurred.

Timely Risk Assessment

As cited above, detection of carious lesions of young children is a strong risk predictor of carious lesions of older children. Also, early carious lesions (“white spots”) are strong predictors of frank cavitation of the teeth.¹¹ Dietary risk factors are also important. Risk assessment tools have been promoted to guide clinicians.^{33–34} These strategies may be helpful to primary care providers who see infants and toddlers on a regular basis. One example is the CAMBRA Caries Risk Assessment Form for Age 0 to 5 Years.³⁵ However, assessments of the children’s mothers or caretakers in terms of microbiology or caries experience, or on their infection status, may be appropriate as well.¹⁸

At the extremes, the level of colonization by *Streptococcus mutans* is an indicator and a predictor of caries activity.¹¹ High levels are typical of children with ECC.^{24,36} At lower levels of colonization the relationship is poorer; no doubt due, at least in part, to the confounding effect of fluoride exposure and the diverse testing methods used. Testing is relatively simple and cost effective if it leads to sound anticipatory guidance and prevention of disease in children. Nevertheless, bacterial testing in U.S. dental practices does not appear widespread. Research on the adoption of these technologies in both primary medicine and dentistry practice is needed.

INTERVENTIONS TO IMPROVE PREVENTION OF TOOTH DECAY

Vaccines, Bacterial Replacement, and Targeted Antimicrobial Peptides

Efforts to develop vaccines against dental caries based on both active and passive immunization continue. Secretory immune response to antigens of *S. mutans* can influence caries

pathogenesis.^{37–42} With some exceptions, most work has been done in animal models. Protection is attributable to salivary sIgA antibodies (active). Antibodies made in another host and delivered to humans (passive immunity) are also of interest. By selection of different antigens as the target for immunization, both active and passive strategies seek to inhibit a variety of functions critical to *S. mutans* in the biofilm on teeth (dental plaque). Replacement of virulent (cariogenic) *S. mutans* with non-virulent streptococci is also being investigated in experimental animals and humans.⁴³ Early *in vitro* work on specifically targeted antimicrobial peptides⁴⁴ continues but no *in vivo* validation has been reported. FDA approval of specific immunization and clinical application are still problematic because of unresolved risk-benefit questions and commercial investment required to fund extensive trials to meet regulatory requirements.

Antiseptics

There are several studies of the utility of antiseptic agents to inhibit caries in older, self-compliant individuals.^{19,45} With regard to preschoolers, some are strong advocates for combining fluorides with various antimicrobials, especially for those with disparities and whose families are mobile, because topical fluorides do not provide complete protection against tooth decay.⁴⁶ Two topical antimicrobials have been investigated to some extent: chlorhexidine di-gluconate (CH) and polyvinylpyrrolidone iodine (PVP-I).

Chlorhexidine

Chlorhexidine (CH) rinses, available in the U.S., are sold by prescription but are lower in concentration (to reduce staining of teeth) than products sold in other countries. Approved by the FDA for gingivitis control, no formulation has FDA approved for caries control in children. Research, particularly in Europe and China, has examined the effectiveness of a CH varnish coating for the teeth, with mixed results. A recent systematic review of 14 publications of controlled clinical trials concluded there was a moderate caries reducing effect when the varnish was applied every three to four months.⁴⁷ The variability in CH varnish formulations may have strongly influenced bioavailability and thus effect of CH. While CH varnish and other CH-containing vehicles may have value in caries prevention for very young children, the evidence is inconclusive; no child-products are available in the U.S., and none can be recommended.

I₂/KI and PVP Iodine

The *in vitro* and *in vivo* iodine antiseptic literature on dental caries of three decades ago was promising, but most human studies were very small.^{48–49} Pilot and small scale clinical studies of utility of PVP-I in young children, some with established active ECC, show strongly encouraging data.^{50–53} Larger scale evaluations are warranted and timely.

Topical Fluorides

The benefits of fluoride delivery via professional in-office applications, home-use mouthrinses, gels and toothpastes are well established. These strategies have had limited impact on populations with little access to the dentist. Community water fluoridation is highly effective but depends upon public water supplies and political approval of their fluoridation. Mouth rinses, gels and toothpastes are individual compliance-dependent, and dependent on economic and access feasibility. In the late 1990s, manufacturers gained approval from the FDA to market topical sodium fluoride varnishes first available in Europe in the 1960s. Although indicated formally for tooth sensitivity reduction primarily in adults, they are being used for decay prevention and arrest in children, and good data suggest that they are more effective than the older technologies.^{54–55} The varnishes are safe for infants and toddlers.

Manufacturers have not sought, however, an indication for prevention of decay, perhaps because they see the market as small and return on investment not large. The formulation of the varnishes is largely unregulated, and manufacturers have produced various forms of varnish that alter their properties. No data show that these competing products are equivalent.

The varnishes are important because they provide an easy to use, safe, and cheap fluoride vehicle for preschoolers, our most vulnerable population. While the varnishes are being adopted in public health practice, use in private dental practice lags. There has been movement for physicians and nurses to apply varnish, and in some states Medicaid reimburses these primary care practitioners in addition to dentists and dental hygienists for this service.⁵⁶ The Preventive Services Task Force, Centers for Disease Control and Prevention (CDC), American Dental Association (ADA) and American Academy of Pediatrics (AAP) have not endorsed topical fluoride treatment for primary prevention in children before 24 months of age and AAP guidelines specifically note the lack of a definitive trial.⁵⁷ Thus, a multi-center clinical trial is needed to demonstrate the effectiveness of fluoride varnish delivered during well-baby visits by primary care physicians and nurses.

New studies on the adoption of this technology in practice are needed. There have been almost no attempts to study ways to spread adoption.⁵⁸

Diammine silver fluoride

Research outside the U.S. has highlighted the value of diammine silver fluoride to both arrest and prevent recurrences of ECC. This product has been available in Japan and several other countries for years but was never brought to the U.S. Evidence suggests that it is at least twice as effective as sodium fluoride varnish.^{59–60} One drawback, staining of the cavity/tooth after treatment, appears preventable.⁶¹ Research is needed to learn about how this compound works. NIH is just beginning to sponsor research regarding this potentially helpful approach but lack of FDA approval is a barrier.

Xylitol

Xylitol is a sugar substitute that is “generally regarded as safe” by FDA. In teens and young adults, it is not only non-cariogenic but also anti-cariogenic. Its use is limited, like that of other sugar alcohols, by its limited absorbability from the gut. Its benefit cannot be attributed merely to a salivation stimulatory effect of chewing gum use.⁶² Xylitol is a safe and effective tooth decay preventive agent when incorporated into chewing gum or other confections used habitually.^{63–65} Its use, like that of fluoride, is associated with promotion of remineralization of white spots and established lesions. Considerable evidence indicates that it inhibits the metabolism of *S. mutans*.^{66–67} The American Academy of Pediatric Dentistry supports use of xylitol chewing gum as a caries inhibitor, but recommends further research. It emphasizes the need for proper labeling of xylitol products so that parents and professionals can make appropriate choices.⁶⁸ Nevertheless, application has been limited by absence of formulations that demand minimal adherence and are acceptable in a greater variety of settings, such as in preschools/schools. A minimum of five to six grams and three exposures per day from chewing gum or candies are needed for clinical effect in adults.⁶⁹ A recent study found that xylitol oral syrup administered topically two or three times per day at a total dose of 8 g was effective in preventing early childhood caries.⁷⁰

A landmark study showed that when mothers of preschoolers chewed high content xylitol chewing gum habitually, their preschoolers had delayed colonization and lower levels of *S. mutans*, and similarly delayed and much reduced caries experience.^{71–72} In spite of the large body of data supporting the effectiveness and safety of xylitol and a growing number of products, its adoption—particularly in the period immediately post-partum, is not widespread.

The cost of xylitol-sugar free products for daily use is relatively high by comparison with other sugar-free products, but modest by comparison with the cost of filling of carious lesions.

Occlusal Sealants

While there were convincing data at the time of the SGROH for the application of sealants as a key objective of *Healthy People 2010*, the actual adoption of sealants by dentists has not been achieved.¹ Sealants are designed to be placed when the permanent molars erupt (around 7–8 and 13–14 years old). Data up to 2004 suggests no more than 32 percent of children receive this service, up from 23 percent during 1988–94. The equivalent rate for age 14 is 21 percent.⁷³ In part, this is because up to one-third of permanent molars are cavitated by the time the teeth erupt enough to be sealed, depending on the risk group, and most dentists will not seal caries lesions in spite of evidence that this strategy can be effective in arresting them.^{74–75}

The only innovation since the SGROH has been the development and marketing of glass ionomer sealants. The argument for this strategy is that glass ionomers can be placed on partially erupted permanent teeth where they release small amounts of fluoride, putatively inhibiting local lesion development. However, only limited pilot studies of these materials exist and their potential remains unexplored. Retention rates of the glass ionomer cement sealants are lower than current generation of conventional resin-based sealants. The limited literature on sealing primary molars is not encouraging.⁷⁶ Definitive studies are needed.

Non-fluoride remineralization strategies

There has been considerable interest in developing novel remineralizing agents that complement or substitute for the clinical effectiveness of fluoride. Studies largely sponsored by industry have been conducted to promote products claiming to remineralize early caries lesions.^{77–79} These products are formulated as professionally applied pastes, toothpastes and gums. Conceptually, the work is interesting. Nevertheless, the work is not focused on control of early lesions of ECC and claims of effectiveness are not well substantiated. Little has been done to establish how such products would be used to benefit children.

CONCLUSIONS

This review has focused on the role of science and technology in achieving the goals of *Healthy People 2010*. Tooth decay is a serious and growing problem for very young children. It impacts quality of life. It especially affects the poor, ethnic minorities, Native Americans and Alaska Native populations.

Dental caries is an infectious disease yet the application of this concept in practice is limited. Accordingly, antimicrobial approaches, directed at both mothers and at young children, have an important place in tooth decay prevention and control. Antiseptics, chlorhexidine varnish and PVP-iodine, as well as xylitol chewing gum used by mothers, have been shown to be effective in inhibiting carious lesion incidence, but definitive trials are needed.

Fluorides remain the most effective agents but are not widely disseminated to the neediest. Fluoride varnish provides a relatively effective topical preventive for very young children, yet definitive trials of its application in primary care practice have not been conducted. Scientific advances outside the U.S. have suggested the potential of silver diammine fluoride, but it is not FDA approved and no research has been carried out in the U.S. Data support effectiveness and safety of xylitol, but adoption is not widespread and additional research is needed on formulations and vehicles to increase access. Dental sealants are of unquestioned benefit and remain a mainstay of public policy yet, after decades of research, widespread use has not occurred. Definitive trials are needed of new materials that can be used on erupting teeth.

The research in the U.S. to address the growing level of tooth decay in our youngest children is too limited. Research and adoption have not kept pace with the problems identified in the Surgeon General's Report on Oral Health. Transfer of technology from studies to implementation lags.

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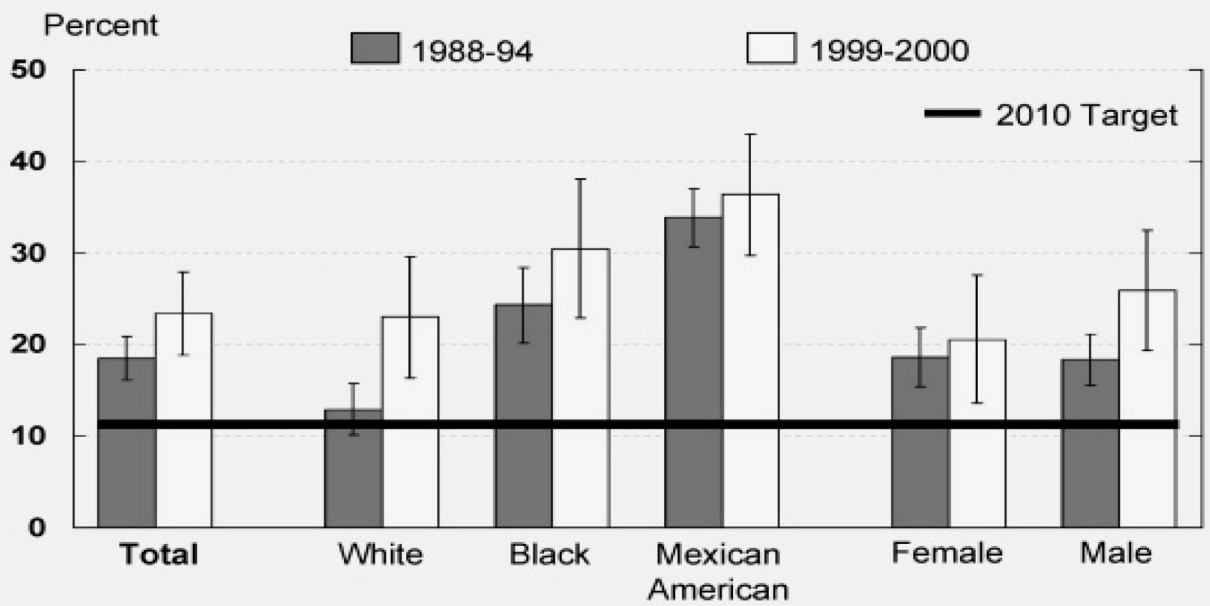
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Children 2-4 Years Who Have Ever Had Caries in Primary Teeth, 1988-94 and 1999-2000



Note: Black and white exclude persons of Hispanic origin. Persons of Mexican-American origin may be any race.
 Source: National Health and Nutrition Examination Survey, NCHS, CDC.

Obj. 21-1a

Figure 1.

Percent of Children Receiving Preventive Dental Care in Past Year, by Age

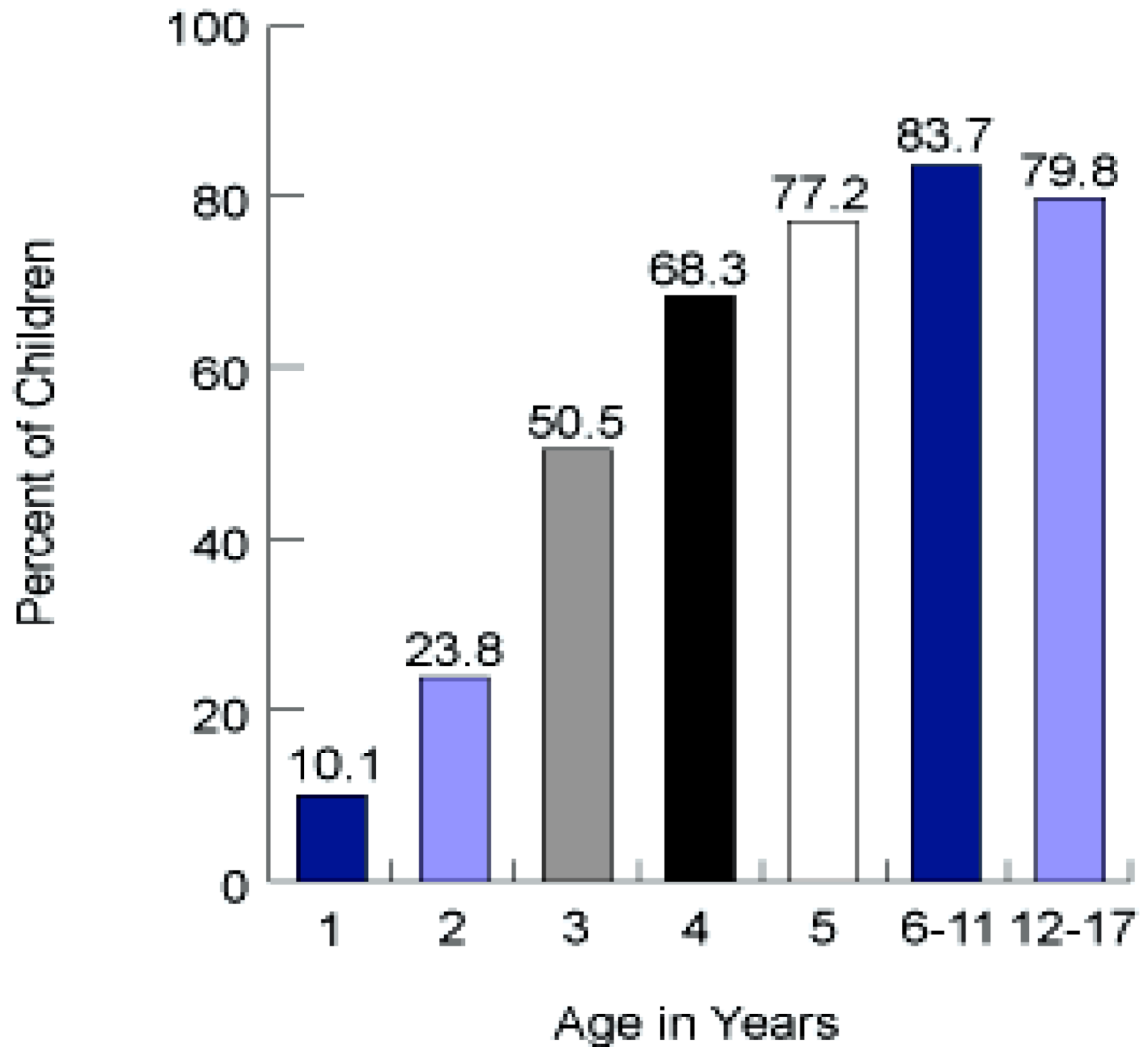


Figure 2.