JADA LANDMARK SERIES

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Newburgh-Kingston caries-fluorine study XIV. Combined clinical and roentgenographic dental findings after ten years of fluoride experience

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Among the important questions which have to be answered when a new public health practice is considered are (1) the need for this new practice, (2) its safety, (3) its practicability and (4) its effectiveness. The literature during the past two decades has reported numerous surveys which have demonstrated the magnitude of dental caries prevalence and the yearly incidence rates.[1] The inadequate means which are available to cope

public and parochial schools in Newburgh and Kingston, N. Y. All the examinations at that time w… staff dentist using the c… ror and explorer techn… was made according … classification which pr… free teeth, untreated ca… and unerupted teeth. E… chart had some notati… status (Fig. 1).

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Pointing the way to better oral health

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In many respects, it is remarkable that this study was carried out during the 1940s. Until the late 1930s, most attention to fluoride by public health authorities centered on how to remove it from water and how to reduce fluorosis. Indeed, several leading researchers had patents on methods for removing fluoride from drinking water.[1] There was relatively little interest in using fluoride as a preventive agent. The impetus to study the possible preventive effects of fluoride arose from several sources, possibly starting in 1937.

In that year, the first reference in a large epidemiologic study that fluoride in water might be associated with reduced prevalence of tooth decay was reported by Klein and Palmer.[2] They observed, referring to the low prevalence of dental caries in Native Americans residing in the southwestern United States, “Fluorides are well known as enzyme inhibitors and it may be suggested that perhaps a measure of the responsibility for low caries attack rates in the southwestern areas may be the result of the drinking of fluoride waters … ." This suggestion resulted in increased activity exploring the relationship between fluoridated water and the prevalence of caries. In 1938, several branches of the U.S. Public Health Service conducted studies jointly[1] in Texas—in Amarillo and in Wichita Falls, both areas with elevated levels of fluoride in their water. Data confirmed the earlier observation that fluorosis was associated with low levels of tooth decay. Dean[3] subsequently carried out a series of epidemiologic studies in several areas and concluded that prevalence of caries was reduced even in areas where there were low levels of fluoride in water.

Several additional studies followed quickly, affirming the possibility that fluoride might be used to prevent dental caries. For example, sound enamel was found to harbor more fluorine than did carious enamel.[4] In addition, several investigators demonstrated that caries in rats was significantly reduced by adding fluoride to an experimental diet.[5,6] The concept had advanced to the stage at which H. Trendley Dean[7] was quoted in Time magazine (Jan. 8, 1940), "There is a possibility of partially controlling caries through the communal water supply."

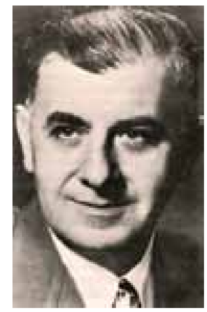
Why did it take so long to connect fluorosis with a lowered experience of caries? The prevailing dogma at the time was that damaged enamel was highly susceptible to decay. It was inconceivable that mottled enamel could possibly be more resistant to carious attack. As pointed out by Hodge and Smith,[8] "To break through a widely accepted doctrine, even with convincing evidence in hand, is a feat which few have accomplished. The history of the relation of fluoride to dental caries and to mottled enamel was no exception. The psychological set in this field was the doctrine that a perfect tooth never decays." However, this illustrates the value of combining epidemiologic data and animal-based and bench research for an effective clinical outcome.

At the time, war was raging in Europe. The Unites States entered hostilities in 1941, and the government was occupied with recruitment and building up the armed forces. It would not have been surprising if no further action on the possible public health effects of fluoride had been taken. Perhaps the deplorable state of dental health in the nation—as pointed out through the elegant work of Klein and Palmer,[2] together with the enormous number of armed forces recruits who were rejected because of appalling dental health—caught the attention of public health authorities. More than 900,000 of the 2 million called up for selective service were rejected because of physical and medical disability. Dental defects were by far the leading cause (21 percent).[9] The opportunity to improve dental health was grasped by Ast,[10] who, in a brilliant monograph, made the case to conduct a study to determine the benefits, if any, of adding fluoride to drinking water. It is noteworthy that Ast had submitted his monograph in partial fulfillment of the requirement of a Master of Public Health degree from the University of Michigan in 1942.

Two important events occurred that certainly facilitated the JADA clinical study of Ast and colleagues.[11] The first was the development by Churchill[12] of a relatively simple and highly accurate method to measure the level of fluoride in water, which led to proof that enamel mottling is associated with the levels of fluoride in water.

Secondly, until 1937 there was no agreed-upon, consistent method to report either the incidence or prevalence of carious teeth. The term "DMF" (decayed, missing or filled) was derived by Klein and Palmer[2] to describe caries experience in permanent teeth using data from their study.

Dr. David Ast



Dr. Henry Klein

Dr. H. Trendley Dean

SYSTEMIC VERSUS LOCAL TOPICAL EFFECT

Even before the clinical trials commenced, controversy erupted over whether fluoride had to be ingested to exert its protective effect or could be applied topically for the same effect. Understandably, the prevailing opinion for well more than a decade was that the benefit of fluoride was solely due to its systemic effect because of its mottling. There were many who demonstrated experimentally that fluoride interacts with erupted enamel and also that systemic administration of fluoride was not essential for some protection.[5,13,14]

Table 2 • DMF[1] teeth per 100 children ages 6–16, based on clinical and roentgenographic examinations, Newburgh[2] and Kingston, N.Y., 1954–1955

Age[3]	Number of children with permanent teeth		Number of DMF teeth		DMF teeth per 100 children with permanent teeth[4]		
	Newburgh	Kingston	Newburgh	Kingston	Newburgh	Kingston	Per cent difference K-N
6–9[5]	708	913	672	2,134	98.4	233.7	−57.9
10–12	521	640	1,711	4,471	328.1	698.6	−53.0
13–14	263	441	1,579	5,161	610.1	1,170.3	−47.9
16	109	119	1,063	1,962	975.2	1,648.7	−40.9

1. DMF includes permanent teeth decayed, missing (lost subsequent to eruption), or filled.
2. Sodium fluoride added to Newburgh's water supply beginning May 2, 1945.
3. Age (last birthday) at time of examination.
4. Adjusted to age distribution of children examined in Kingston who had permanent teeth in the 1954-1955 examination.
5. Newburgh children of this age group exposed to fluoridated water from time of birth.

Figure. Table 2 from the original 1956 JADA article by Ast and colleagues.[11]

Eventually, the science supported the topical-only effect.[15] The available evidence—clinical[16] and from animal models—reveals that for the optimum effect, fluoride should be present during tooth development and continuously posteruption.[17]

It is surprising that so much controversy continued over whether the protective action of fluoride resulted from a systemic effect or topically. The data revealed in the article demonstrate explicitly that children exposed to fluoride during mineralization of enamel displayed much more protection than those whose teeth were not exposed to fluoride before eruption (Figure).[11] It is noteworthy that children in Newburgh had five times more caries-free primary teeth than did children in Kingston. Nevertheless, the controversy continued.

EFFECT ON PRACTICE AND COST BENEFIT

The mark of a profession is that it works toward eliminating the need for its services. Nowhere was this dictum better illustrated than in a 1945 hearing on public water fluoridation before the city commissioners of Grand Rapids, Mich. The Grand Rapids mayor inquired whether there was any concern on the part of the dental profession that fluoridation would affect their incomes adversely. The president of the local dental society responded that the dental profession's concern was the "treatment and prevention of dental disease, and it was very anxious to reduce the impact of dental caries in any way that was possible."[18] It is to our profession's credit that the American Dental Association has been unstinting in its support of fluoridation over the decades.

It is clear that Ast and colleagues[11] were concerned about the effects of water fluoridation on dental practice. Breaking out the F component of DMF, they noted that the rate for filled first molars in the two cities did not differ among all age groups, except for 16-year-olds. However, the proportion of first molars with untreated caries was three times as great, and the proportion of first molars missing was eight times as great in Kingston compared with Newburgh. Ast and colleagues[19,20] continued their interest in the cost/benefits of water fluoridation and published articles on the topic in 1965 and 1970.

Several investigators have explored the effect of water fluoridation on the use of dental services under various settings. Maupome and colleagues[21] (echoing Grembowski and colleagues[22]) noted that in general, "Community water fluoridation was associated with reduced total and restorative costs … but the magnitude and direction of the effect varied with locale and age, and the effects were generally small." More recent studies in public health settings confirm again the extraordinary cost-effectiveness of water fluoridation,[23,24] providing eloquent testimony for continuing community water fluoridation.

MECHANISM OF ACTION

As soon as the caries-preventive effect of fluoride was recognized clinically, it was suggested that because fluoride is an enzyme poison, it must affect the metabolism of oral bacteria.[2] Fluoride, even in low concentrations, affects the ability of microorganisms to produce acid and to withstand its adverse effects.[25-29] Fluoride affects resting pH values[30,31] and also influences the enzymes associated with plaque formation.[32,33] Although the levels of fluoride in saliva are low (0.04 parts per million) even in a fluoridated area, fluoride is concentrated within dental plaque and may be as much as 100 times higher than that in surrounding saliva.[27]

From the earliest observations on the cariostatic effects of fluoride, it was noted that fluoride could interact with enamel[13,14,33] (an observation that ran contrary to the view that enamel was inert). The alleged "inertness" of enamel led to the belief that fluoride could only be effective when given systemically. Elegant studies by Cheyne (such as one he published in 1940[14]) revealed that fluoride also could be effective when administered topically. Many investigators were extremely cautious in recommending topical applications of fluoride[8] because of toxic effects of fluoride in elevated concentrations. Nevertheless, Bibby[34] explored the effect of including fluoride in a chalk-based toothpaste; this was an unfortunate effort, as the fluoride combined with the chalk (calcium carbonate) and was inactivated. The first commercially successful toothpaste (Fluoristan-Crest) was introduced in 1954. Crest, which originally contained stannous fluoride,[35] utilized the antibacterial effects of the stannous ion and the caries-protective effect of fluoride. More than 95 percent of all toothpastes sold in the United States today contain fluoride.

Two major observations seemed to advance our understanding of the topical effect of fluoride. Backer Dirks and colleagues[36] noted the extraordinary number of white spots in enamel or arrested caries in children from two Dutch communities—Tiel (fluoridated) and Culemborg (nonfluoridated). It was subsequently suggested that the white spots arose from early carious lesions remineralizing. That early carious enamel lesions can remineralize was elegantly demonstrated later.[37,38] These observations have led to a plethora of demineralization and remineralization studies exploring the effects of fluoride applied in various formulations and regimens,[39] and have given an extraordinary impetus to exploring novel formulations of toothpaste and other vehicles. Two important and clinically relevant observations arise from those investigations of fluoride: first, that it is possible to repair or reharden white spot lesions and, second, that it is not always necessary to restore teeth with early carious lesions surgically. It is also important to note that repeated exposure to small doses of fluoride is more effective in preventing and remineralizing lesions than are single applications of high concentrations of fluoride.

U.S. Surgeon General Leonard Scheele (1950) and the American Dental Association endorsed the addition of fluoride to drinking water on the basis of data from preliminary results and did not wait for a final clinical outcome.[40]

FLUORIDE: THE FULL POTENTIAL

Over the years, despite the available scientific evidence, the philosophy of "more is better" has prevailed. As more and more sources of fluoride are entering the food chain, the inevitable has begun to surface: an increasing prevalence of fluorosis,[41] which, unfortunately, is leading to cries to eliminate water fluoridation or reduce the recommended levels of fluoride in water. The ambient levels of fluoride present in the mouth are critical to optimum and maximum effect.

The use of devices to release fluoride steadily into the mouth has illustrated the dramatic preventive effects of low levels of fluoride.[42,43] Surely, with modern technology, it is possible to attain comparable effects by reformulating conventional vehicles of fluoride delivery. The optimum use of fluoride in prevention of dental caries remains an elusive goal.[43]

POSTSCRIPT

The Centers for Disease Control and Prevention has recognized water fluoridation as one of 10 great public health achievements of the 20th century.[44]

David Ast died Feb. 3, 2007, at the age of 104. He has left a legacy in the annals of public health that is extraordinary by any standard. Today, 204 million Americans drink fluoridated water, and millions more have avoided the adverse health and economic consequences of tooth decay thanks to the pioneering efforts of dedicated public servants such as David Ast. Our profession should be proud and grateful. ■

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