A review of dietary fluorides for caries prevention is presented. The efficacy and safety of controlled water fluoridation has been scientifically established. Increasing public acceptance of fluoridation is placing the burden of proof on those opposing the procedure. Administration of dietary fluoride to pregnant women to control dental caries in their infants cannot presently be justified.

DIETARY FLUORIDES AND CARIES PREVENTION

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THE role of dietary fluoride in increasing the resistance of teeth to caries is thoroughly established. Since fluorides are most effective in preventing dental decay when they are included in the diet in proper amounts from early infancy, it is appropriate that a discussion of dietary fluorides and caries prevention has been included in this symposium on changes and trends in infant feeding.

As the Food and Nutrition Board of the National Academy of Sciences has pointed out, "Fluoride is present in small but widely varying amounts in practically all soils, water supplies, plants, and animals, and hence is a normal constituent of all diets."[1] In the sense that fluoride confers maximal resistance to dental caries, the board states that "fluorine is necessary to optimal health."

While the exact mechanism through which fluoride exerts its effect on the teeth is not entirely clear, this is presumably related to its replacement of hydroxyl in the hydroxyapatite, the calcium phosphate in the dental enamel and dentin and in bone. This results in an increase in hardness and a decrease in solubility of the dental enamel.

Prenatal Use of Fluoride

Since fluoride must be incorporated in the crystalline structure of dental enamel for maximal effect, the possibility of initiating the process in the fetus through the diet of the pregnant woman has been the subject of clinical, laboratory, and epidemiological investigation. Typical of the studies of placental transfer of fluoride in experimental animals are those of Maplesden and his colleagues.[2] Using rats and rabbits, they found that the fetuses of animals fed varying amounts of fluoride showed a very low level of fluoride compared to the mother. For example, the level of fluoride in the carcasses of female rats fed a basal diet supplemented with 50 ppm F was 106 ppm F, in contrast to only 1.0 ppm F in the fetal carcasses. Even at an increased fluoride intake of 200 ppm, the level of fluoride in the fetus was only 1 per cent of that of the mother.

That fluoride is incorporated in the bones and teeth of the fetus has been demonstrated by Gedalia and his coworkers,[3] but the increase in fluoride content was found to be much smaller in the teeth than in the bones of fetuses

when the drinking water of the mother contained a higher level of fluoride.

The relatively low permeability of the placenta to fluoride has been confirmed by Ericsson, in Sweden, through the use of radioactive F^{18}.[4] The radionuclide was given intravenously to four pregnant women prior to therapeutic abortion. The fetal F^{18} blood level was never higher than one-quarter of the maternal level. Similar results were obtained in rabbits approaching the end of pregnancy. In neither human beings nor experimental animals was there any indication of concentration of F^{18} in the placenta.

In another investigation, Gedalia and his colleagues[5] found that the cord blood of the fetus was lower than that of the mother and that the disproportion was greater when the maternal level was high. As this group pointed out, "It is noteworthy that similar results were obtained with fluoride intake from drinking water or from supplemental sodium fluoride tablets."

In a study of the prevalence of caries in deciduous teeth in children in relation to maternal ingestion of fluoride, by Carlos, Gittelsohn, and Haddon,[6] no significant differences were found between groups of six-year-old children, in a community with water fluoridated at a level of 1.0 and 1.2 ppm, whose mothers had lived in this community throughout the pregnancy involved, and otherwise comparable children in a community with fluoride-deficient water supplies. Similar results have been obtained in experimental animals. Stookey and his co-workers in Indiana found no reduction in dental caries in the offspring of rats exposed to drinking water containing fluoride at a level of 25 ppm.[7]

On the other hand, Blayney and Hill[8] have concluded, from a study of children in Evanston, Ill., that the prenatal consumption of fluoridated water by the mother contributes added protection to the deciduous teeth over that provided by only postnatal use by the child. However, the justification for this conclusion, on the basis of the data presented, has been questioned.[9]

On balance, then, the administration of dietary fluoride to pregnant women for the control of dental caries in their offspring cannot be justified at the present time in the light of the inadequacy and inconsistency of supporting evidence.[10]

The mammary gland does not concentrate fluorides. Ericsson, in his work with radiofluoride in rabbits, found the level of fluoride markedly lower in the mammary gland than in the blood.[4] Bercovici and his colleagues[11] found a fluoride level a little above 0.1 in the milk of lactating women who drank water containing 0.55 ppm F. The urinary level of fluoride was about three times as high as the level in milk. Breast feeding, whatever its other advantages, therefore cannot alone provide the optimal amount of fluoride for prevention of dental caries. Cow's milk, even with adjustment of its fluoride content to an optimal level, presents certain disadvantages as a medium for conveying fluoride, which will be discussed later.

Use of Controlled Fluoridation

As an American Public Health Association resolution of 1963 states, "The fluoridation of public water supplies continues to be the best public health measure for preventing dental caries.[12]

The efficacy and safety of water fluoridation have been demonstrated through scientific studies using a wide variety of approaches. Fluoridation has probably been the subject of more intensive investigation than any other public health procedure currently in use. Despite this, it has been, and continues to be, the subject of attack in every community in which its introduction is proposed. The outlook for the future of

fluoridation, however, appears brighter than ever before.

For some years, I have conceived of three phases in the natural history of fluoridation acceptance. The first phase, in the late 1940's and early 1950's, was one of relatively uncritical enthusiasm. This phase followed the initial reports on the lower prevalence of dental caries in areas served by water supplies containing fluorides at their source, coupled with preliminary reports from controlled fluoridation studies. During this period, controlled fluoridation was introduced in a number of communities with little public awareness or understanding.

This was followed by what has seemed like an endless second phase of organized reaction against fluoridation on the part of many dissident groups throughout the country. These dissident groups capitalized on the doubts of a steadily diminishing number of professional persons who urged a go-slow policy until a sufficiently large body of evidence, varying in size according to the individual's inclinations, could be accumulated. In this phase, the proponents of fluoridation have been on the defensive. Every unsupported charge of the opposition has had to be answered at length. Every quotation twisted out of context has had to be put straight an infinite number of times. All too often, the initiative has rested with the opposition, with fluoridation gains registered only after heavy investments in time and energy.

Now, I venture to suggest, we are approaching the third phase in fluoridation's troubled history, in which widespread professional and public understanding and support will place the burden of the struggle on the opposition—when it will no longer be necessary to attempt to prove the negative ad nauseam—when the overwhelming mass of evidence will be accepted as a consistent whole. There will undoubtedly be many sharp fights ahead, but these will be, hopefully, more in the nature of rearguard actions by the opposition with the passage of time.

Let me cite some of the evidence to support this assertion. The use of controlled fluoridation has grown steadily in this country. By the end of 1963, there were 2,612 communities, with a total population of more than 46,780,000, served by fluoridated water in the United States and Puerto Rico.[13] In addition, 7,580,000 persons used water with optimal levels of fluoride at their source. Also apparent is the decline in the number of communities that discontinued fluoridation after it had already been in operation, and the increase in those reinstating fluoridation after discontinuance. Contrast the three-year period of 1954-1956, when 61 communities discontinued fluoridation and only nine reinstated it, with the 1961-1963 triennium, when 16 communities stopped fluoridating and 15 started fluoridating again after previously discontinuing the procedure.

A major stride in dislodging the barriers to fluoridation was taken here in New York in December, 1963, when, after a marathon public hearing, the City Council voted to bring the benefits of fluoridation to the more than eight million persons served by the municipal water supply. Since Detroit has also approved fluoridation recently, the 12 largest cities in the United States should shortly have either controlled fluoridation or protective levels of fluoride from their supply sources. Los Angeles and Houston, both in a relatively warm climate, have 0.6 and 0.8 ppm F, respectively, in their unadjusted sources of water.

International Developments

Less than a decade age, fluoridation was almost exclusively a United States affair. By 1963, however, controlled fluoridation was in operation in 27 countries, in addition to the United States

and Puerto Rico, in every continent of the world.[14] Furthermore, the entire populations of Hong Kong and Puerto Rico served by public water supplies have fluoridated water. Chile has a national fluoridation program under which 65 per cent of the population, presumably those served by public water supplies, is said to be receiving fluoridated water. The state of Rio Grande do Sul in Brazil is implementing fluoridation on a state-wide basis.

I cannot refrain from referring to a highly significant recent development across the Atlantic in the Republic of Ireland. In a country known for the individuality of its citizens, legislation was enacted in 1960 mandating the fluoridation of all public water supplies. The constitutionality of the act was promptly challenged on the ground, among other things, that fluoridation failed to respect bodily integrity; in other words, that it was detrimental to the health of the individual. Following the longest civil action in the history of the Irish Republic, in which I was privileged to serve as a witness for the government, the Irish High Court upheld the constitutionality of the act, and, on July 3, 1964, the Irish Supreme Court dismissed the appeal made against the High Court decision.

The judgment delivered by Justice Kenny in the High Court action is outstanding for its balanced summary of the status of water fluoridation by an unbiased nonmedical observer, based on the voluminous testimony of witnesses on both sides of the question. In his judgment Justice Kenny concluded: "Let me say then that I am satisfied beyond the slightest doubt that the fluoridation of the public water supplies in this country at a concentration of 1 p.p.m. will not cause any damage or injury to the health of anybody, young, old, healthy or sick who is living in this country and that there is no risk or prospect that it will."[15]

One of the major obstacles to the more rapid spread of fluoridation in the United States has been the resort by the opposition to use of the referendum. In the course of a referendum, the opposition plays on the groundless fears of the public with the implication that it is safer to maintain the status quo than to try something new which may have an element of danger. The opposition throws up a smoke screen and then cries, "Where there's smoke, there's fire!"

A recent action suggests that the promotion of water fluoridation may be starting to move from the community to the state level. The Connecticut State Public Health Council recently voted to publish a notice of intent to adopt a resolution requiring fluoridation of all water supplies serving populations of 10,000 or more over a period of time prior to July 1, 1967.[16] That any such action will undoubtedly be vigorously contested through the courts does not detract from the significance of the proposed approach.

Increased resistance to dental caries is the most obvious benefit of drinking water containing the optimal level of fluoride for the particular geographic area. Measured in terms of the number of decayed, missing, or filled permanent teeth, the incidence of dental caries has been found to be from 48 to 70 per cent less among groups of 12-14-year-old children in various communities on fluoridated water from birth than among children of the same ages on fluoride-deficient water.[17] Of even greater significance is the decrease in the number of missing teeth, the decrease ranging from 65 to 89 per cent among children in the same age group on fluoridated versus nonfluoridated water. These benefits are known to be carried over well into adult life.[18]

A less obvious benefit of fluoridation is the reduction in dental malocclusion. In Newburgh, for example, 35 per cent

of a group of children on fluoridated water from birth had normal occlusion, in contrast to only 12 per cent in Kingston, where the water was deficient in fluoride.[17] The economic benefits of fluoridation have been studied by Ast, Cons, Carlos, and Maiwald.[19] Their preliminary findings indicate that the costs of initial dental care in a group of five- to six-year-old children are more than twice as much in a nonfluoridated community than in a community with fluoridated water.

Dietary Fluoride Supplements

While fluoridation is the method of choice, "Dietary fluoride supplements," as the 1964 APHA resolution puts it, "although not as practical, economical, or as effective as a public health measure, are being utilized where fluoridation is not available. Rational provision of such fluoride supplements is dependent upon accurate and current determinations of fluoride levels in both public and private drinking water services."[12]

There is no reason, on theoretical grounds, that fluoride prescribed in tablet, lozenge, or liquid form in proper dosage in well-controlled situations should not be as effective for individual children as fluoridated water at the optimal concentration.[20] One of the problems is the uncertainty of translating literally to individual use the experience gained from water fluoridation, with the exception of fluoridation of water supplies for the use of individuals or single households.

At the fluoride levels used in water fluoridation, the *maximum* number of persons receive the desired dental benefits without danger of systemic effects to *any* individuals in the community. Children drink varying amounts of fluids and varying proportions of tap water in total fluid. Walker and his coworkers[21] found that breast-fed infants, for example, drank an average of only 19 ml of tap water daily in contrast to about 300 ml in bottle-fed infants. This hardly provides a solid basis for individual dosage of fluorides.

In a study by Arnold, McClure, and White, a group of 221 children of professional persons were given tablets containing 1 mg F (corresponding to 1 liter of water with 1 ppm F) daily for periods up to 15 years.[22] The rates of decayed, missing, and filled teeth corresponded to those found among children drinking water at 1 ppm F for comparable periods of time.

Community programs for the administration of fluoride to individual children as a substitute for water fluoridation have been beset by difficulties. Apart from the greatly increased cost and personnel time needed, these programs have not been met with enough community interest and cooperation, especially among the population groups with the greatest need for dental care, to justify their continuance. This is readily understood when we reflect on the problems encountered in maintaining children who have a history of rheumatic fever on prophylactic drugs over a period of time even though, in rheumatic fever, we are dealing with a systemic disease carrying a major threat to the individual.

In properly motivated families, individual dosage of fluoride-containing tablets or liquids can be prescribed for individual children who are denied the benefits of fluoridation. A daily dosage of 1 mg (0.5 mg F) of sodium fluoride is generally recommended for children under three years of age. For children of this age, sodium fluoride, in solution as drops or as a dilute solution in preparing formulas or other foods, is the most convenient form of administration. For children who have reached their third birthday, the sodium fluoride dosage is doubled to 2 mg daily, and tablets may be substituted for liquid preparations if desired.

The administration of fluoride-vitamin combinations to children is not justified by any scientific rationale. The use of inflexible combinations of nutrients makes it all but impossible to adjust the fluoride intake to the needs of the individual in relation to the fluoride level in the community water supply. Certainly, multiple vitamin preparations are being widely abused, and the addition of fluoride to these preparations only multiplies the abuse. The increased expense of fluoride supplementation when linked with vitamins and other nutrients further increases the difficulty in fluoride use in poorly motivated families. In other families with presumably stronger educational backgrounds, multiple vitamins are rarely needed because the family diet would tend to be adequate in the first instance.

Fluoride is probably absorbed from milk almost as well as from water. Here again, apart from the problem of excessive cost, the administrative difficulties all but preclude serious consideration of this medium for fluoride. Control would be needed of the many dairies supplying milk, and some mechanism would have to be found for supplying varying levels of fluoride, since a particular dairy serves households with different water supplies. In addition, consumption of milk is far more variable than that of water.

Brief mention should be made of the various approaches to the application of fluoride to the teeth. The topical application of fluoride compounds such as a 2 per cent sodium fluoride solution or 8 per cent stannous fluoride solution has a significant caries-inhibiting effect, but considerably less than that from community water fluoridation. The use of a stannous fluoride dentifrice is another, but less effective, method of topical application.[23,24]

An exciting new development now being field-tested is the topical application of acidulated fluoride solution with phosphate. Early results suggest a high order of caries protection.[25]

Summary

The efficacy and safety of dietary fluoride, especially in the form of fluoride at a concentration of 1 ppm in drinking water, has been thoroughly established.

The administration of dietary fluoride to pregnant women for the control of dental caries in their offspring cannot be justified at the present time on the basis of available evidence.

Acceptance of water fluoridation appears to be entering a new phase in which broad professional and public understanding will place the burden of the struggle on the opposition.

More than 54 million persons in the United States are in communities served by water with optimal levels of fluoride, and the 12 largest cities in the country should shortly have either controlled fluoridation or protective levels of fluoride from their supply sources. Controlled fluoridation is in operation in 28 countries, in every continent.

Water fluoridation reduces the prevalence of dental malocclusion as well as of dental caries, and reduces the costs of dental care for children.

Fluoride in the form of tablets, lozenges, or liquid may be used when fluoridated water is not available. The use of fluoride-vitamin combinations in children, however, has no scientific rationale.

Topical application of fluoride solutions is also of value in the prevention of dental caries in the absence of water fluoridation.

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