COMMITTEE ON NUTRITION

FLUORIDE AS A NUTRIENT

The continuation of the controversy in some areas of the country with respect to fluoridation of water and the important role that fluoride plays in dental health prompted the Committee on Nutrition to review the subject. The development of new information and a summary of the quantitative aspects of fluoride requirements were sufficient to warrant a report.

THE association of mottled enamel and dental fluorosis with community drinking water was detected before 1920 and was specifically related to the fluoride content of the water when Churchill, in 1931,[1] was able to measure trace amounts of fluoride in drinking water. Also, in areas with communal water supplies naturally containing increased amounts of fluoride, the occurrence of dental caries was lower than that seen in the general population.[2] These observations and subsequent studies[3] led to the practice of adding fluoride to communal waters, with a consequent significant reduction in the incidence of dental caries. Nearly 90 million persons in 7,500 communities[4] use water supplies containing an amount of fluoride effective in reducing the dental caries rate.

Fluoride is present in the customary diet and in most potable water sources in amounts that vary from 0.1 to 0.5 parts per million (ppm).[5] The average dietary intake of fluoride is approximately 0.5 mg daily from these two sources. In the temperate zone, fluoridated community water supplies are increased in fluoride content to a level of 1.0 ppm, thus providing, on the average, a total fluoride ingestion of 1.5 mg per day. A lesser level of fluoridation may be sufficient in warmer climates conducive to a higher water consumption. Fluoride is regarded as an essential nutrient[6] and it is now well known to be effective in the maintenance of a tooth enamel that is more resistant to decay.

Fluoride is a normal component of tooth enamel and bone. Studies *in vivo* and *in vitro* demonstrate that the calcified tissues of both enamel and bone are made up of a combination of hydroxy- and fluor-apatites of varying composition, depending on the abundance of fluoride at the site of formation. These tissues are the principal sites of deposition of fluoride. As the plasma level of fluoride increases following absorption, fluoride is rapidly deposited in bony tisssue. This process is as efficient a removal process as that of urinary excretion.[7] Fluoride appears to be deposited by exchange as well as by the development of new bone.[8] The hydroxyl ion of hydroxy-apatite exchanges with fluoride ion, and fluor-apatite crystals are thus formed at the surface of bone or enamel. In the dynamic metabolism of bone, with adequate fluoride ion present, the internal structure as well as the surfaces exhibit exchange of fluoride for hydroxyl ions. Bone develops a steady state of fluoride content if there are low or medium intakes of fluoride, and the renewal rate is equal to the deposit rate.[9] As the intake of fluoride increases, the level of steady state increases to reach a content of 0.5% of the dry weight, an amount that can be tolerated without physiologic hazard.

There appears to be an optimum fluoride intake for the growing child that allows the formation of a crystalline form of both bone and enamel apatite with low solubility, resulting, in the case of enamel, in a low susceptibility to dental decay. In the latter regard it is well demonstrated that fluoride is effective within a relatively narrow range of intake; a moderate increase above optimum causes some dental fluorosis which is not detrimental to the integrity of the enamel but may be regarded as objectionable cosmetically. While the beneficial effects noted from fluoride ingestion occur at a level of 1.5 to 2.5 mg per day, a degree of tooth mottling is observed when the ingestion exceeds 3 mg daily. An adverse effect on tooth structure may result at intake levels above 5 mg.[10]

Studies demonstrating the beneficial effect of fluoride in reducing the rate of dental caries began under the guidance of the U.S. Public Health Service about 1935 and were continued until the mid 1950's.[11] These studies demonstrated that the addition of fluoride to community drinking water at a level of 1 ppm led to a significant reduction in caries incidence. A summary of data from more than 7,000 children in 21 different cities with fluoridated water supplies demonstrated a reduction of more than 60% in the incidence of dental caries.[12]

There is no agreement on the precise manner in which fluoride effects reduction in tooth decay. Probably, it is a combination of effects, but the most significant is the assuring of a less soluble crystalline form of enamel. There is no clear evidence that fluoride exhibits either a favorable or unfavorable effect on the gingival tissues or on the development or prevention of periodontal disease.

Studies have been directed to the prenatal effect of fluoride ingestion during pregnancy and the development of caries resistance in infants. Studies using radioactive fluoride have shown that there is limited transfer of fluoride across the human placenta. When the fluoride intake was low, as with drinking water approximating 0.1 ppm, fluoride content of placental tissue was lower than that of maternal or of fetal blood. With a fluoride intake from water containing 1.0 ppm of fluoride, the maternal blood fluoride of the placenta was higher than that of fetal blood.[13] Thus, the placenta allows fluoride to reach the fetal circulation to a small extent, but not in sufficient amounts to affect favorably the structure of bone and enamel. Furthermore, the placenta appears to act as a collecting organ, assuring safe levels to the fetus even with high levels of maternal ingestion of fluoride. There is no consensus that prenatal fluoride ingestion is significant in reducing dental caries in deciduous teeth.[14]

The addition of fluoride to drinking water is an effective means of assuring a relatively uniform intake and provides beneficial oral and systemic effects. However, some 40 million persons in this country do not have access to central water supplies. The main source of fluoride intake in areas with a low fluoride content in the drinking water is food. Fluoride is ubiquitous and present in all foods, but its content is exceedingly small in most foods. However, it is contained in relatively large amounts in some foods that are common to most diets.[15] Seafoods are highest in fluoride value, some ranging from 6 to 12 mg per kilogram. Meats and chicken provide amounts in the range of 1 to 2 mg per kilogram. Cereals, in general, provide 0.5 to 1.0 mg per kilogram, and fruits and vegetables contain a similar amount. Milk, both human and cow, contains 0.1 to 0.2 mg per liter. This is a level that is closely related to the fluoride content of blood plasma in both species. The main dietary item providing unusual amounts of fluoride is tea. Dry tea leaves contain 30 to 60 mg per kilogram, and the fluoride level in tea as customarily prepared is approximately the same as that in fluoridated water, 1.0 ppm. Further attention must be given to the availability of fluoride from food sources. It has been shown, for example, that the fluoride of fish protein concentrate, contained mostly in the bone fraction, is less than 50% available. There is no evidence that fluoride intake from dietary sources consistently exceeds 0.5 ppm. Thus, diet alone does not allow for a level of fluoride intake that consistently inhibits the occurrence of dental caries. However, with the use of fluoridated water, intake reaches 1.5 mg per day on the average, which is an effective level.

McClure[3] estimated the total daily intake of fluoride by children 1 to 12 years of age from water containing 1 ppm and from food containing from 0.1 to 1.0 ppm of fluoride based on the dry weight of the food. The maximum levels of daily intake of children in four age groups—1 to 3 years, 4 to 6 years, 7 to 9 years, and 10 to 12 years—

were approximately 0.83 mg, 1.11 mg, 1.38 mg, and 1.73 mg.

Alternative methods of providing fluoride in areas with no access to fluoridated water have been studied. These methods include the addition of fluoride to foods or to salt, the use of fluoride tablets for daily ingestion, and reliance on topical treatment of teeth, as well as the use of fluoride-containing dentifrice preparations. Fluoridation of salt has been practiced, particularly in Switzerland where the early results were not favorable, mostly because of the low level of fluoride provided. More recent studies indicate that, even though intake of salt is variable, there is a significant caries reduction among children of families using fluoridated salt containing 200 mg of sodium fluoride in 1 kg.[16] Home fluoridation of water has been proposed with the development of devices that will inject the fluoride solution into the home water system.[17] This method is not entirely satisfactory because of the need for occasional fluoride analysis and possible adjustment of the equipment. It has also been suggested that school water supplies be fluoridated to provide a higher level of fluoride, 3.0 to 5.0 ppm, when children use this water during only part of the day.[18] Some experience indicates a significant caries reduction under these conditions. Again, the system requires continual attention to avoid excessive intakes of fluoride.

Sodium fluoride tablets containing 1 mg fluoride have been distributed in rural sections of Germany, resulting, as subsequent studies[19] showed, in a substantial reduction in caries incidence. It has been found that, if use is begun at the age of 6 months, the dose should provide 0.5 mg daily until age 3 years, and 1.0 mg daily thereafter.[20] To assure significant results, it is necessary to provide such a program through school or other social organizations to maintain care and continued interest in daily use. In the United States, fluoride has been provided in vitamin preparations in drop form containing 0.5 mg fluoride per dose for infants up to age 3 years and in tablets containing 1.0 mg fluoride for children over 3 years.

Hamberg recently reported the results of a controlled study in Swedish children[21] of fluoride in vitamin drops for prevention of caries. Up to 6 years of age the mean number of decayed teeth in the fluoride group was about half that of the control group.

Dental experience indicates that frequent topical application of fluoride solutions to the tooth surface is an effective means of caries reduction and is important, particularly in children who are caries prone. The preferred preparations for topical application are stannous fluoride (10%) or an acidulated sodium fluoride in 1.0 M orthophosphoric acid.

With the variety of sources of fluoride available, the question arises as to safety if several of these sources are used simultaneously. There is no need to utilize other sources of fluoride if the drinking water is fluoridated. For example, the amount of fluoride absorbed from dentifrice is a small percentage of the fluoride content of the dentifrice. However, even though simultaneous use does occur, the safety margin is such that the urinary excretion and the bone deposition systems prevent harmful excess of fluoride deposition.

The saving in cost of dental care resulting from the fluoridation of drinking water has been estimated from studies such as the Newburg-Kingston fluoridation study in New York.[22] During this 3-year study, the mean annual cost of dental care for a child residing in Newburg consuming drinking water with added fluoride (1.0 ppm) was approximately one-half that of a child living in Kingston, drinking water with a low fluoride content. This difference, applied to children in 7,500 communities now using fluoridated water, results in a significant reduction in dental care costs.

The principal demonstrations of the beneficial effect of fluoride in the reduction of dental caries are with children, although the study done by Englander and Wallace[23] in Aurora and Rockford, Illinois, strongly suggested that the use of controlled fluoridated water provides caries prevention continuing into adult life. In addition to the evidence of improvement in dental health, there is evidence that the integrity of the bony structure of the body is affected when fluoride intake is favorable. However, there is need for further studies of older age groups. It has been suggested that the storage in bone of the less soluble fluor-apatite instead of hydroxy-apatite may be beneficial to older people with osteoporosis.

In a low fluoride area of North Dakota, with drinking water containing less than 0.3 ppm fluoride,[24] the incidence of osteoporosis, reduced bone density, and collapsed vertebrae was substantially higher, especially in women, than in a nearby area with drinking water containing 5.5 ppm. Also, visible calcification of the aorta was significantly higher in the low fluoride area, particularly in men. Dietary sources of calcium for the two areas were comparable, suggesting that the effect was directly related to fluoride intake.

Detrimental effects of fluoride ingestion do not appear with intakes of 5 mg or less daily. There was no significant total body retention of fluoride in studies of young men 19 to 27 years of age maintained under controlled conditions. Fecal excretions of fluoride were between 10 and 30% of intake, and urinary excretions were from 20 to 70% of intake. Perspiration accounted for smaller amounts. Under these conditions there appeared to be no excessive fluoride deposition in bone tissue. However, bone is an accumulator of excess fluoride when ingestion exceeds 5 mg daily. Skeletal fluorosis has been reported[25] with ingestions of 10 to 15 mg daily, particularly under conditions of high industrial fluoride contamination.

Nutritional surveys continue to find dental caries to be the most prevalent disease for all age groups beyond infancy. The administration of fluoride is an effective means of reducing the incidence of dental caries. Physicians caring for infants and children in regions of the country where community waters are not fluoridated and the natural water contains a low level of fluoride ($<$ 0.5 ppm) should see that sufficient fluoride is prescribed to provide an intake of 0.5 mg per day for children up to 3 years of age and 1.0 mg per day after age 3 years.

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