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Fluorides and Dental Health: A Review

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ABSTRACT

Background: Traditional management of dental caries has focused primarily on treatment via the excision of diseased tissues and sub-sequent restoration of the defect. Mechanical tooth preparation is a destructive and irreversible method of removing the natural dental tissues, and while dental materials have improved significantly in recent decades (in many cases, with properties that closely resemble those of natural dental tissues), they are artificial. Dental restorations and even implants cannot replace natural teeth completely. A comprehensive treatment plan for dental caries should include eliminating cariogenic bacteria, reducing plaque acidogenicity, enhancing tooth remineralization, and repairing the damaged teeth. Contemporary caries management includes dietary analysis and advice, oral hygiene instruction, placement of fissure sealants, and the use of fluoride therapy, xylitol chewing gum, and antimicrobial agents such as chlorhexidine. Various forms of fluoride therapy are used to prevent and sometimes to arrest caries, although the effects of fluoride therapy are related to the chemical composition of the fluoride product and the method used to apply the material to the tooth surface.

Keywords: Dental Caries, Fluoride, Fluoride Rinses, Salt Fluoridation, School Water Fluoridation.

INTRODUCTION

Fluorine, a trace element, is a halogen like chlorine, bromine, and iodine. Fluoride is found everywhere throughout nature. The major source of ingested fluoride is water, particularly from deep artesian wells. It is found in soils rich in fluorspar (calcium fluoride), cryolite (sodium aluminum fluoride), and other minerals. It is also found in plants, foodstuffs, and body tissues. In humans, fluoride is found mainly in the calcified structures like teeth and the skeleton.

Fluoride is a nutrient beneficial to dental health and it is included in the 1980 recommended dietary Allowances, which emphasizes its importance in nutrition.[1] Fluoride is a mineral that occurs naturally in many foods and water. Every day, minerals are added to and lost from a tooth's enamel layer through two processes, demineralization and remineralization. Minerals are lost (demineralization) from a tooth's enamel layer when acids formed from plaque, bacteria and sugars in the mouth which attack the enamel. Minerals such as fluoride, calcium, and phosphate are redeposited (remineralization) to the enamel layer from the foods and waters consumed. Too much demineralization without enough remineralization to repair the enamel layer leads to tooth decay. Fluoride helps prevent tooth decay by making the tooth more resistant to acid attacks from plaque bacteria and sugars in the mouth. It also reverses early decay. In children under 6 years of age, fluoride becomes incorporated into the development of permanent teeth, making it difficult

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for acids to demineralize the teeth. Fluoride also helps speed remineralization as well as disrupts acid production in already erupted teeth of both children and adults.[2]

FLUORIDE

All foods contain at least traces of fluoride, waterborne fluorides are generally the most important source for humans. Modern diets are becoming increasingly important as a source of fluoride because of the increased use of fluoridated water in the preparation of processed food and beverages. For temperate climates the optimal fluoride level in water supplies for reduction of dental caries without undesirable mottling is 1 ppm (part per million). Based on infants' and young children's normal intake of between 2 and 4 glasses of water or the equivalent per day, this level of 1 ppm would provide a total daily intake of 0.5 to 1 mg of fluoride per day. For older children, adolescents, and adults, the intake from water would be equivalent to 1.5 to 2 mg of fluoride per day because they may drink between 6 and 8 glasses of water or the equivalent (1500 ml) per day.

In low fluoride areas, the daily diet furnishes only 0.3 mg. in high fluoride areas, the daily intake from food is about 3.1 mg. Fruits, vegetables, and cereals contain very small amounts of fluoride The rich sources of fluoride are sea foods, especially fish with small bones such as sardines and salmon, which tend to take up fluoride readily. The amount of fluoride in fresh fish may be about 1.6 ppm, whereas in canned salmon, sardines, and mackerel it may be as high as 7 to 12 ppm.

On a dry weight basis, one of the richest sources of fluoride is tea; the leaves contain from 75 to 110 ppm. However, the average cup of tea may contain only 0.5 to 1.5 ppm because most of the fluoride is extracted when the tea is steeped in hot water. Milk products taken along with sodium fluoride can reduce fluoride's availability to bones and teeth by 50 to 79%.

Absorption:

The major site of absorption of fluoride in human appears to be the stomach, although studies with experimental animals suggest that intestinal absorption also occurs. The soluble fluoride in drinking water is almost completely absorbed, whereas approximately 50 to 80% of the fluoride that naturally occurs in foods is absorbed.

Distribution:

When compared with all other tissues and structures, the teeth and skeleton have the highest concentrations of fluoride because of the affinity of fluoride for calcium. In descending order, the highest levels are found in cementum, bone, dentin, and enamel. The fluoride content of teeth and bones increases rapidly during the early mineralization periods and continues to increase with age, but at a slower rate. Once deposited, it is firmly bound to the tooth mineral for life.

Fluoride is found in both extracellular and intracellular fluids of soft tissues but at very low concentrations. Fluoride is also found in saliva at about 0.01 ppm. When fluoride is ingested, the salivary fluoride level increases after 5 to 15 minutes, reaches a maximum after about 30 minutes, and then decreases to normal levels in about I hour. This salivary level may play a part in the maintenance of the fluoride concentrations in the outer layer of the tooth enamel. The principal route of excretion of fluoride is the urine (90 to 95%). The remainder (5 to 10%) is found in the feces. Sweat may also be a route of excretion of a minute amount of fluoride.

The relatively low efficiency of the human kidney in the reabsorption of fluoride and the high affinity of the bones and teeth for fluoride are effective mechanisms for maintaining low concentrations of fluoride in the soft tissues and plasma. The amount of fluoride in urine is directly related to the degree of active bone growth. Fluoride excretion is lower when a child is growing rapidly and is actively depositing bone mineral than in adults with a mature bone structure and fully mineralized teeth.

Storage:

Fluoride tends to be deposited in calcified structures such as bones and teeth when they are in the active stage of mineralization. Bone fluoride concentration increases steadily with water fluoride levels up to 4 ppm, but shows lower increases at 8

ppm. The factors that attract fluoride to bones include (1) the presence of an active growth area at the ends of the long bones, (2) the small size of the bone crystals, and (3) the close contact between bones and the blood supply.

In the case of teeth, fluoride is deposited in the enamel via the systemic (affecting the body as a whole) route when the lattice is developing and maturing because mature adult tooth enamel has no cells, it is not affected directly by systemic fluoride. Rather, there is a local effect: fluoride in the mouth penetrates the enamel surface by diffusion through the minute spaces between the enamel crystals and through remineralization of the tooth surface. This local effect is increased when the crown is newly erupted into the mouth. Fluoride is continuously added to the enamel surface, but to a much lesser extent as the tooth ages and practically not at all when it is completely mineralized. The concentration of fluoride in the tooth enamel of individuals who regularly drink water containing 1 ppm of fluoride can reach 800 to 900 ppm in the outer layers.[3] In the developing enamel fluoride is deposited within the body of the crystal, whereas in the fully formed enamel fluoride is mainly deposited in the surface layer of the tooth.

Fluoride will also penetrate partly demineralized enamel, dentin, or cementum of new carious lesions. In fact, carious enamel may take up 10 times more fluoride than adjacent healthy enamel and thus help inhibit the expansion of the carious lesion.

FLUORIDE AND PREVENTION OF DENTAL CARIES

The salivary fluoride level is derived from systemic fluoride and exerts a topical effect on the tooth during the early post eruptive period when the enamel surface can be altered by the chemistry of the oral environment. Eating or drinking might speed up the clearance of fluoride from the mouth, and therefore should be postponed as much as possible after consumption or after topical application of fluoride. In this way, high levels of fluoride in saliva can be achieved for extended periods.

The enamel undergoes calcification starting as early as 12 to 16 weeks in- utero for the first tooth that erupts, the deciduous central incisor. The calcification continues on until the last deciduous tooth erupts, namely, the second molar. This makes it possible for fluoride to affect the mineralization of the deciduous teeth if given early enough, that is, at birth in fluoride free communities.

The first permanent tooth in which the enamel and dentin matrix is formed is the first molar. Some trace of mineralization occurs in this tooth as early as 28 weeks in- utero. However, by 2½ to 3 years of age the enamel is usually completely formed. Therefore, fluoride ingestion must start some time before age 2, preferably at birth, in order to have the maximal benefit on the mineralization of the enamel. The uptake of fluoride by enamel depends on the amount of fluoride ingested and on the age of the tooth at the time of fluoride exposure. The rate of uptake is very rapid during the first years and then tapers off. Also the higher the fluoride level in the water, the greater is the initial rate of deposition during tooth mineralization.

The ability of fluoride to be a cariostatic agent depends on genetic and environmental factors operating in the mouth (e.g., the degree of caries challenge by the amount of sugar-sweetened snacks and condition of the enamel). Thus great individual variation may be seen in the efficacy of fluoride in reducing the incidence of caries. DePaola have shown a large disparity between fluoride concentration in enamel of individuals and caries experience.[4] Keene et al., have shown that caries-free subjects tend to have a higher fluoride level on the surface enamel and to live in fluoridated communities.[5]

Mechanism of Anticarious Action of Fluoride:

For the last 4 decades, the element fluoride has been established as both the most used anticaries agent and the most useful agent in preventive dentistry. Since 1946, when Bibby first investigated the use of fluoride as a rinse, it has been incorporated in a number of vehicles ranging from water to the more complex one, dentifrice.

There are three mechanisms by which fluoride inhibits caries, and usually more than one is involved. These mechanisms are (1) an increase in the enamel's resistance to acid solubility as a result

of a high concentration of fluoride in the outer enamel surface (2) the ability of fluoride to remineralize demineralized or hypomineralized enamel and (3) fluoride's antibacterial effects on plaque growth, glycolysis, glycogen synthesis; acid production, production of extracellular polysaccharides necessary for plaque adhesion to tooth surface, and solubility of calcium phosphate deposits within plaque.

Decrease in acid solubility

It has been shown that enamel formed in the presence of fluoride has more perfect and larger crystals, is less soluble in acid and less likely to develop caries. This happens because fluoride favors the formation of fluorapatite, a more acid resistant apatite. The hydroxyl is replace by the fluoride ion in the apatite lattice, making it more stable and less soluble. It also remove the voids seen in hydroxyapatite.

Remineralization

Caries is essentially a result of demineralization of enamel following ingestion of carbohydrate rich food. During the interval between meals, the Ph rises, this results in some amount of remineralization. Small amount of fluoride enhances remineralization and reduces the amount of calcium and phosphate dissolution.[6] The greater the concentration of fluoride released from the dissolved enamel or already present in the plaque, more remineralization will be favored and carious process will be slowed. **Pigman W, Cueto H and Kolourides, Fiegan F et al.** have shown that fluoride level as low as 1 ppm enhances remineralization.[7,8]

Also studies have shown that remineralization in the presence of fluoride and saliva is more resistant to decay. A short term use of topical fluoride is used to raise the fluoride level of tooth surface. The fluoride level is maintained using fluoride toothpaste daily.

Antibacterial action

Fluoride may have a bactericidal or antiplaque action. From a bactericidal stand point, fluoride will inhibit many enzymes essential to cell metabolism and growth such as enolase, an enzyme needed for carbohydrate metabolism. It also has an inhibitory effect on glycolysis. From an antiplaque standpoint, fluoride can lower the surface energy of the tooth, thereby making bacterial attachment and plaque formation difficult.[9] It can also desorb bacteria from hydroxyapatite because it can bind more effectively to positively charged areas on the apatite crystal than can bacteria.

Historical review

A landmark epidemiological finding in public health dentistry was achieved when it was reported that when dental fluorosis increased, the incidence of dental caries decreased.[10] Indirectly related to this major discovery in preventive dentistry are a number of preliminary scientific observations dealing with fluorides and dental structures from the beginning of the nineteenth century. For example, in the early 1800s fluoride had been found to be one of the chemical constituents of teeth and bone by the reputable chemists Morichini, Gay-Lussac, and Berzelius. In 1878, the Great French investigator Magitot wrote in his treatise on dental caries that the resistance of enamel to acid decalcification was due in part "to the minute quantity of fluoride it (enamel) contains.

In 1916 Black and Mckay noted the teeth of children raised in the Colorado Springs area were stained brown (thus named Colorado brown stain). They suggested the term mottled enamel for this condition. Furthermore, Mckay reported that children with mottled enamel had a "curious absence of decay" and that certainly the incidence of caries in mottled enamel was no greater than that in normal enamel. In 1933 Dean began an extensive study of the relation of fluorides in community drinking water to tooth mottling or, as he termed it, "endemic dental fluorosis".[11] The results of these studies and others not only proved this relationship but also provided the first scientific evidence that fluoride at an optimal level of 1 ppm in communal water supplies was a significantly effective caries-preventive nutrient.

Fluorides can be added to individuals daily intake in the following forms:

Communal Water Fluoridation

It is interesting that Hong Kong, which has the lowest caries incidence and DMFT for 12-year-

old persons, has had its water supply 100% fluoridated for more than 20 years. Conversely, Brazil, whose water supply had the lowest percentage of fluoridation, did not experience the decrease in caries seen globally. Brazil has now started fluoridating 45% of its water supply.

The World Health Organization suggested that the rapid spread of fluoride availability underlies the 30 to 50% decrease in the caries rate experienced by many children in highly industrialized countries during the past 20 years. Other factors contributing to this decline in caries were (1) greater dental health awareness, (2) expansion of dental resources, and (3) application of preventive dentistry including nutrition counseling, use of antibiotics, and herd (group) immunity.[12,13]

School Water Fluoridation

In areas that lack central water systems. Therefore, part-time availability of fluoridated water (i.e., in schools) has been suggested. School water supplies have been fluoridated with levels of three-times **(Horowitz HS and Heifetz SB 1965)[14],** 4½ times **(Horowitz HS 1972)[15]**, and seven times **(Heifetz SB 1978)[16]** the optimum for communal water fluoridation (1 ppm), resulting in a significant reduction in caries incidence. The caries reduction at each of these respective levels of fluoridation was 22, 40, and 40%. It is projected that after 12 years of school water fluoridation one might expect a 40% reduction in caries.

Fluoridated Table Salt

Because table salt has been such an effective vehicle (carrier) for the addition of iodine to the diet, it was suggested that it be used for fluoride. There have been several studies with fluoridated table salt, but certain questions about the following have arisen: (1) determining the optimal concentration of fluoride in salt as related to the level of natural fluoride in water supplies; and (2) determining the amount of table salt that has to be ingested each day to produce a significant reduction in caries. It has been suggested that 200 to 300 mg of fluoride should be added to a kilogram of salt.[17,18] The daily requirement for salt has not yet been determined, but the average adult consumers about 6 g.

When the effect of fluoridated salt on caries reduction was compared with that of fluoridated water, the salt was found to be about two-thirds as effective as the water.[19] Studies in Latin America show that a 30 to 40% caries reduction was achieved when 90 mg of fluoride per kilogram of salt was used.[20]

Fluoridated Milk

There have been studies in which milk has been used as a vehicle for fluoride administration. In one study, 1 mg of fluoride as sodium fluoride was added to a half pint of milk daily. The 80 children who drank this fluoridated milk for 4½ years had 80% less decay than did a control group.[21] In another study, fluoridated milk was found to be as effective as fluoridated water in reducing dental caries.

Dietary Supplements of Fluoride Tablets

Most studies reported a caries reduction in deciduous teeth of approximately 50 to 80% when fluoride administration was begun before about 2 years of age and was continued for a minimum of 3 to 4 years. After the use of fluoride tablets for 2 to 4 years, caries reduction in the permanent teeth of children aged 9 to 13 years was appro3ximately 20 to 40%. This means that when fluoride tablets are ingested daily beginning at around age 5 to 9 years (age during primary school), the permanent teeth can still be significantly protected from caries.[22]

A lozenge that is allowed to dissolve slowly in the mouth is preferred to a tablet or drops, because it can produce both topical and systematic effects. Fluoride tablets have an important advantage in that a specific and precise dose can be delivered. However, there are a number of disadvantages with fluoride lozenge or tablet usage when compared with water fluoridation. The assurance of continuous daily ingestion is much less and the cost is greater. Furthermore, fluorides taken once a day are excreted relatively rapidly. Thus it is difficult to maintain as constant a systemic and local fluoride level as when drinking fluoridated water several times a day.

Prenatal Fluoride Supplement

On the basis of knowledge of the chemistry of tooth maturation and mineralization, fluoride

supplements are not recommended for adults, including pregnant women, for reducing dental caries. Most investigators agree that fluoride ingested by the pregnant woman passes through the placenta and is incorporated into the developing bones and teeth of the fetus. However, the concentration of fluoride that actually reaches the fetus is generally lower than that in the maternal blood.[23] Fluoride uptake greatly increases in developing enamel with a small change in fluoride concentration in fetal extracellular fluids. Infants exposed prenatally will have higher plasma, skeletal, and developing enamel fluoride levels than those not exposed to prenatal fluoride **(Drinkard CR 1986[24], Parker PR and Bawden JH 1986[25])** However, any dental health benefits that might result would affect the deciduous teeth only. Studies show that more proof of anticaries protection for the children is needed before fluoride supplements can be recommended for the pregnant woman.[26,27]

Fluoride Supplements for Infants and Children

Daily administration of individualized dietary supplements of sodium fluoride is desirable for young children who live in areas where community or school water fluoridation is not practiced. There has been some controversy about giving fluoride supplements to infants younger than 6 months of age, even when there is practically no fluoride in the water supplies. Because Aasenden and Peebles reported some mid dental fluorosis in children given 0.5 -mg fluoride supplements from birth, and because there is a wide range in the fluoride content of milk-based formulas, which more than 60% of infants drink, Adair and Wei recommended that no fluoride supplements be given to infants less than 6 months of age (with exception of breast-fed infants, who should be given 0.25 mg daily).[28] Singer and Ophaug stated that, in view of the wide range of fluoride intake in infants up to 6 months of age, only infants consuming breast milk or cow's milk and not milk-based formulas should be given 0.025-mg fluoride supplements if they live in nonfluoridated areas.[29] On the other hand, Driscoll and Horowitz suggested that in fluoride-free areas 0.25 mg (or 2 to 3 drops) of fluoride in solution be given daily from birth and continued until 2 years of age; then a 0.5-mg lozenge be given until the child is 3 years of age, up to 13. (If the infant can manage a lozenge it should be prescribed).

Fluoride Rinses

Mouth rinses can be swished in the mouth and swallowed. In such a way they have both a systemic and topical effect on caries reduction. Ripa have shown that 3 years is necessary to achieve the maximum benefit from a rinse program for children.[30] This agrees with most other studies conducted. An additional year of rinsing did not reduce the caries rate further. Horowitz and Heifetz have reviewed the results of several studies showing caries reduction of 21 to 44%.[31] They concluded that the more frequent the use, the greater the inhabitation of caries. DePaola found that ammonium fluoride reduces caries by 54%. The lower incidence of caries on newly erupted teeth may have been due to a special effect of the fluoride ion.[32] A number of studies involving rinses once a week with high concentrations of fluoride (0.2%) showed caries reductions between 11 and 47%. Repeated use of 0.25% sodium fluoride twice daily or 0.5% fluoride gel daily over extended periods gave an 80% reduction. This level of fluoride is not recommended on a daily basis for a prolonged period because it may be toxic.

Bawden (1980)[2] found that fluoride mouth rinses were more effective in children with a higher caries baseline (normal level) than a low caries baseline. The lower the incidence of caries, the more limited the effect of each preventive measure.

Ripa et al. **(1980)**[30] found that combining 0.2% sodium fluoride rinses on a weekly basis with pit and fissure sealants increased the number of caries-free children and that the effects were cumulative.

CONCLUSION

In recent years, there have been modest decreases in caries in certain segments of the population. Nonetheless, caries remains a common disease, with disadvantaged segments of the population disproportionately suffering caries. Fluoride has been used to prevent caries for more than 30 years. Several studies have demonstrated fluoride's ability to control caries. There are variety

of fluoride products in different forms are available for use by dental professionals and patients and are safe and effective when used appropriately. Since multiple sources of fluoride exposure exist, a coordinated approach to fluoride delivery is essential.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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