FLUORINE AND DENTAL CARIES*

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One of the most fertile fields of dental research has been the study of the role played by fluorine in dental health. No brief summary can pretend to cover the field exhaustively.

Fluorine in Tooth Enamel

The presence of fluorine in human tooth enamel was reported as early as 1805 by Gay-Lussac and Berthollet (31). Crichton-Browne (20) in 1892 thought "it well worthy of consideration whether the reintroduction into our diet . . . of a supply of fluorine in some suitable natural form . . . might not do something to fortify the teeth. . . ."

Such early references were, perhaps, prophetic, but cannot be credited as originating the current scientific consideration.

The current knowledge of the action of fluorine stems from a study of mottled tooth enamel, a disfiguring dental defect.

Recognition of fluorine as the agent in production of mottling of enamel sprang, in 1931, from the work of Churchill (17) and of Smith, Lantz, and Smith (52).

Later studies proved that mottled enamel is endemic in nature, and directly related to the concentration of fluorine in the drinking water consumed by children during tooth-formation years. Dean (22) has shown that fluorine at 1 ppm. in the drinking water produces mottled enamel of the mildest form in about 10 per cent of children, while 4 ppm. produces more definite mottling in 90 per cent of cases.

Black and McKay (11) had reported, as early as 1916, that the incidence of caries was less in mottled teeth than in normal teeth. Cox (18) was apparently the first, specifically, to suggest (in 1937) a beneficial role for fluorine in preventing caries. Within limits, there appears to be a distinct relationship between fluorosis and caries, and in areas of edemic fluorosis there is an inverse relationship, caries decreasing as fluorosis increases.

This evidence is supported by reports that the fluorine content of sound teeth is higher than that of carious teeth (3).

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Some contrary opinions have been expressed. Bunting in 1928 reported (13) his finding that the frequency of caries was the same although the extent and activity of caries was less in fluoride areas.

Applebaum in 1936 reported (2) that he found a lack of correlation between the severity of mottling and the number of carious areas.

M. C. Smith (53) warned that the favorable results might be misleading. Smith reported that in St. David, Ariz., where the drinking water contained from 1.6 to 4.0 ppm. of fluorine, children of 12–14 years did show a definite reduction in caries but that residents aged 21–41 showed excessive caries.

Weaver (58) also stated that fluorine had a postponing action, but did not prevent caries, the delay not exceeding five years.

Fluoride Added to Diet

In spite of the few contrary opinions, and in spite of possible dangers which will be discussed later, there have been numerous proposals to add fluoride intentionally to the diet (usually to the drinking water) in order to reduce caries.

Tests are at present being conducted in Evanston, Ill., Grand Rapids, Mich., and Newburgh, N. Y., in which fluorine is being purposely added in low concentration to the drinking water of these test towns, while neighboring control towns are continuing to use fluoride-free water. The results of these tests, over a sufficiently long period, should be convincing.

Such results presumably cannot be entirely conclusive, however, until continued for the entire life span of the generation born after the experiments started.

The earlier studies, both on animals and on humans, indicated that the caries-inhibiting and fluorosis-producing action of fluoride-containing drinking water were both found when the water was consumed during the tooth formative age (1). It was naturally assumed that the tooth enamel contained fluorine, which, as a result, and depending upon the amount of fluorine laid down in the enamel, showed an increased caries resistance and fluorosis or mottling.

Continued observation has indicated that the consumption of fluorine-containing water may still have a caries inhibiting effect on fully erupted teeth (25, 39).

Since it is unlikely that ingested fluorine can be deposited by metabolic processes in the enamel of erupted teeth, these observations have suggested that fluorine may find its way directly from drinking water into the tooth structure.

Volker, in 1939, showed (56) that tooth enamel would pick up fluoride on contact with fluoride solution.

Topical Application of Fluoride Solutions

There have been numerous reports of the use of fluoride solutions by topical application, recognized by a recent editorial in the *Journal*

of the American Dental Association (1) which recognizes the probable effectiveness of such procedure but warns of potential dangers.

Armstrong was reported in a newspaper article in November, 1940, as believing that topical application of fluoride would prevent caries.

Bibby (10) reports on a new technique by which dental prophylaxis is conducted with 1 per cent NaF, H_2O_2, and pumice, and he claims that two prophylaxes will reduce caries by 25 per cent while three prophylaxes will reduce caries by 43 per cent.

Cheyne (15, 16) found that topical applications of solutions of from 500 to 60,000 ppm. of fluorine were useful in reducing carious activity in existing lesions and decreased the formation of new lesions.

Jordan (38) and Knutson (40, 41, 42) reported that a solution of 2 per cent NaF, applied topically, would prevent new carious areas, but would not stop the carious process if previously initiated.

An editorial in the *British Medical Journal* (29) and a review by Hodge (34) both acknowledge the effectiveness of topical application, while further work by several other workers verifies the effectiveness of local application.

These results all lead to a conclusion that the topical application of fluoride has some action in preventing caries. This conclusion cannot be recorded at this point, however, without adding that in the writer's opinion, all the positive evidence indicates that repeated applications of preparations of very high fluoride content are required, and that there is, as yet, no convincing evidence that any significant value can be expected from the addition of reasonably low fluoride concentrations to dentifrices.

Before entering upon a further discussion of the mechanism of fluoride action it is necessary to outline, as a working hypothesis, a mechanism of caries itself.

Caries is regarded as a condition attacking the tooth from an outside surface.

The original attack of caries upon tooth structure is regarded by many as a simple chemical attack by acids. In order for the acids to produce the typical localized attack it is assumed that they form, and are concentrated within a dental plaque—an adhering, discrete surface deposit or a food particle wedged into a narrow space such as a crevice or an interproximal space, which holds the acids *in situ* in spite of rinsing of the surface by water or saliva.

The acids are presumably formed by living organisms acting within the plaque or particle on carbohydrates originating in foods.

The organisms are acidogenic in nature and comprise one or more of the group of Bacillus acidolphilus, acidogenic Streptococci, yeasts, and molds.

The carbohydrate substrate is typified by sugar, but other substances may also be involved.

The reactions leading to carious attack can be represented as requiring *all* of the following contributing factors:

1. Fermentable carbohydrate.
2. Acidogenic organism.
3. Plaque or static particle.
4. Susceptible tooth surface.

Thus, if the chain of reactions were *completely* broken at any one point, caries could be prevented. It is practically impossible, of course, completely to avoid any one of the four contributing factors. There is, however, tenable evidence that caries can be reduced by at least four methods:

1. Reducing fermentable carbohydrate in diet.
2. Reducing the organisms in the mouth, as by the use of germicidal agents or other agents inhibiting the fermenting reaction.
3. Cleaning the teeth thoroughly to remove all food particles or plaques.
4. Increasing the resistance of the tooth surface to acid attack.

Atkins (6), Dean (24), Jay (36, 37) and Miller (49) have reported that fluorine action is associated with low oral bacterial counts.

Lipman (44) has stated that low concentrations of fluorine do interfere with fermentation of carbohydrate and Bibby (7) has found that fluorine in concentration of less than 1 ppm. reduces acid production by acidogenic bacteria. Atkins (6), Hodge (33) and McClure (47) have suggested that fluorine may decrease caries by interfering with the acidogenic process.

In so far as fluorine may act within the mouth rather than by becoming an integral part of the tooth structure, its action could have little claim to specificity or natural physiological significance. Many other substances have been shown to influence caries by such action in the oral cavity, including penicillin, vitamin K, oxalate, ammonia, iodoacetic acid, and various germicides.

The deposition of fluorine in tooth structure by the pre-eruptive consumption of fluoride-containing water can be accepted as fully established. Evidence that this is the important mechanism of fluoride caries prevention has been offered by Armstrong (4), Cox (18), Dean (23) and Irving (35).

Of course, many workers who have claimed results from the post-eruptive topical application visualize the mechanism as absorption of fluorine by the tooth.

The effect of fluorine in increasing the caries resistance of teeth appears to most workers to be accomplished by means of increasing the resistance of such enamel to attack by acids.

Thus it has been reported that the enamel of fluorosed teeth is less acid soluble than that of normal teeth (33, 56).

The treatment of ground enamel by topical application of fluoride

reduces its solubility in acids (8, 9, 14).

Toxic Effects of Fluorine Use

There are many warnings in the literature that there are possible toxic or harmful results from the use of fluorine. An editorial in the *Journal of the American Dental Association* (27) stated in 1940 "Although it has been fairly well established that fluorine has a slightly retarding influence on the progress of dental caries . . . (the) deleterious influence . . . is too serious to be counterbalanced by questionable caries retarding influence."

On the other hand, Cox and Levin (19) in 1942 stated "We believe that when all of the facts are known, the toxic effects of fluorine will be far outweighed by the beneficial effects in the prevention of dental caries."

These two contrary opinions cannot, today, be evaluated, since all of the facts are not yet known.

It can be argued with considerable justification that public health control of the fluorine in drinking water can achieve a desirable fluorine level by adding fluorine up to 1 ppm. or by removing excess fluorine to this level. The safety of this procedure is not our immediate concern, although Arnim (5), Box (12), and Dean (22) did report that even at the low 1 ppm. fluorine level there was some mild mottling.

Phillips and Lamb (51) found that fluoride consumption by rats produced pathologic changes in kidneys, testes, and thyroid.

Wilson (60) reports that there appears to be a relationship, geographically, between endemic fluorosis and endemic goitre.

Morgareidge (50) found that fluorine interfered with the vitamin D healing of rat rickets.

The systemic toxicity of fluorine has been reviewed by Machle and his associates (45, 46), who found some fluorine in the urine of people living in areas with fluorine-free water. They also report that fluorine ingested at low levels appears to be completely excreted in urine and feces, while at higher levels there is retention.

McClure (48) has reasoned that since fluorine is excreted, its toxicity may not be as great as would have been expected.

R. R. Smith (54) reports that twice the usual fatal dose of fluorine can be fed to guinea pigs if calcium carbonate or magnesium oxide are also administered. Smith reasons, therefore, that the inclusion of fluorine in a dentifrice may not be unsafe.

The form in which fluorine is ingested, however, also influences its effects upon teeth. Greenwood (32) found that pups developed dental fluorosis when fed sodium fluoride, while the same level of fluorine fed as bone meal did not produce fluorosis. Lawrenz (43) reported that a high calcium content in the diet depressed the sensitivity to the deposit of fluorine in the teeth.

While the literature does not offer satisfactory evidence as to the comparative topical effectiveness of fluorine in various forms, it would seem reasonable that the caries-reducing effectiveness of fluorine might be reduced as much as its toxicity by admixture with other products which lower its absorbability.

With more specific reference to the possible deleterious effects of the topical application of fluorine DeEds (26) reported on the use of ammonium fluoride to produce a rapid bleaching of teeth, and stated that there was a danger of producing mottled enamel. An editorial in the *Journal of the American Medical Association* (28) warned that the topical use of fluorine would produce mottling, although this was vigorously denied by Visscher (55) and Wilbur (59).

While it may be improbable that the topical application of fluorine would produce mottling, it does not seem impossible that whatever shell of enamel was affected sufficiently to alter the caries process might also be rendered brittle just as fluorosed enamel has been reported to be fragile by Applebaum (2) and Smith (52).

If it is assumed that as a result of topical application fluoride is to be held in contact with the teeth in a sufficiently strong solution for a sufficiently long time to permit adsorption on enamel, there may also be adsorption on root areas which might exaggerate the hardness of any calculus deposits present, and stimulate the further formation of calculus.

An editorial in the *Journal of the Canadian Dental Association* (30) advises against the addition of fluorine to drinking water, citing among the reasons the observations of Gottlieb that fluorine is bad for the tooth root, leading to more peridontal disease and loss of teeth.

Dean (21) has also observed that fluorine in drinking water as high as 4 ppm. seems to predispose to gingivitis.

Conclusion

Opinions as to the justification for the addition of fluoride to dentifrices range from a conviction that such a step would be useless if not positively dangerous, to the opinion of one author that the incorporation of fluoride in dentifrices should be made compulsory.

It is the writer's present judgment that the effectiveness of adding minor amounts of fluoride to a dentifrice for lay use is not established, that the potential dangers of adding fluorine to a dentifrice are not to be ignored, and that, for the present, the use of fluorides should be limited to applications which are under strict clinical supervision.

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