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# Fluoride in oral health

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The goal organized dentistry, worldwide, is to provide a healthy, caries-free dentition It is well known that fluoride has been extremelly important in the progress made towars that goal. In fact, the use of fluoride for caries prevention has been described as one of the major public health discoveries of this century. The discovery of this property of fluoride is an interesting story (1). It all began with the search for the cause of Dental Fluorosis or "Colorado Brown Stain", as it was called in the United States. The disease is widely distributed and has been studied in many areas of the world. In its mildest state, Fluorosis appears as symetrical fine horizontal lines or patches on the enamel, but with increasing severity, areas of enamel loss can be seen (2). When this occurs it is because the enamel underlying the surface is hypomineralized to such a degree that the surface can flake off. After a period of time, the porous enemel becomes infiltrated with stain materials and the teeth become brown, thus the name "Colorado Brown Stain". From the beginning, investigators thought the disease was involved with the drinking water. In Italy they thought volcanic gases contamined the water. In several areas the drinking water connection was confirmed as the cause when the water supplies were changed to another and the ocurrence of the disease abruptly stopped.

The search for the cause of "Colorado Brown Stain" was conducted principally in the United States during the first 30 years of this century. Diet, genetics, soil and water were all studied, but the analysis of water led to the discovery that excess fluoride was the cause of the problem. Water analysis was complicate in those days by the fact that low concentractions were very difficult to detec, the method was not very sensitive and results were not very accurate. Nevertheless, by the early 1930's a relationship finally emerged that fluoride in the water caused "Colorado Brown Stain". Studies with rats where fluoride salts were added to their diet or drinking water further confirmed this finding. While all this work was going on, some investigators began noticing that although many subjects were afflicted with fluorosis, they appeared to be less prone to develop dental decay. A classical series of studies was conducted by H. Trendly Dean of the U.S Public Health Service that finally culminate in the famous twenty-one cities study (3).

Figure 1 is a graph of the twenty-one cities study findings published by Dean in 1942. You can see that when fluoride was absent from the drinking water, dental caries was very high; from 700 to 1,000 decayed teeth per 100 children. As fluoride in the drinking water increased, the caries prevalence decreased. The major effect was found at about 1.5 to 2 ppm F in the water. When a correlation was made between the effect of fluoride on caries prevalence and the degree of "Colorado Brown Stain", which by now was being called mottled enamel or dental fluorosis, it was found that when the water fluoride concentration was 1 ppm, almost all of the benefits could be obtained with none of the fluorosis effects. Because the climatic temperature effects the amount of water people drink, the optimum fluoride concentration in drinking water will be slightly higher for colder climates and slightly lower for warmer

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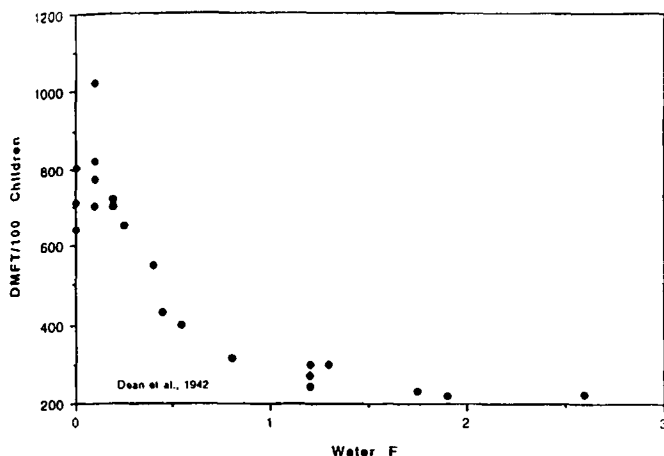


FIGURE 1

Dental caries in 12-14 year old children in 21 cities with different water fluoride levels. (DMFT = decayed, missing and filled teeth. Water F levels are parts per million).

climates (4).

Establishment of fluoride as an effective decay preventive was thus established. The story progressed rapidly after that. Starting in 1945, fluoride at the optimum level (1ppm) was introduced into the municipal water supplies of several cities (5-6). Comparing the decay rates of the fluoridated cities to the rates from non-fluorideted control cities further proved the anti-caries effect and eventually led to the fluoridation of city water supplies worldwide. In the United States nearly 50% of the people consume fluorideted water and 70% of those drinking fluoridated water benefit from fluoride intentionally added to their water.

An interesting observation was made during the early water fluoridation studies. When teeth from fluoridated water areas were analyzed, they were found to contain more fluoride than teeth from areas withouth fluoridated water. Other studies showed that powdered tooth enamel treated with concentrate sodium fluoride solutions took up fluoride and that fluoride-treated enamel was less soluble in acid. These findings led to the use of topical fluoride applications for the prevention of caries. Topical applications in this sense includes all forms of fluoride treatment given to teeth after they erupt into the oral cavity.

Before we go further, let's take a very brief look at the occurrence of fluoride in the environment and what happens when it gets into the human body.

Fluoride is found everywhere. In the earth it is present chiefly as fluorspar, fluorapatite, and cyrolite. The amount of fluoride in most foods is rather low but there are some exceptions. Tea, for example, contains high fluoride levels and some fish contain very high levels. Ocean fish often have high levels because the bones of the fish are often included, and bones concentrate fluoride. Another reason why some foods contain high concentration of fluoride is that they are prepared with fluoridated water and the fluoride may be concentrated by water evaporation during the food preparation.

The flesh of animals and their milk and most fish are low in fluoride, although with the sensitive analytical methods available to us today we can find some fluoride in everything we analyze. Typical amount of fluoride ingested by adult from food can vary from 0.9 mg per day to about 2.6 mg per day depending on whether the drinking water is fluoridated or not (8). In addition to these amounts, additional fluoride will also be ingested from drinking water. Assuming an adult will consume about one liter per day, this would provide an additional amount of 1 mg if the water is fluorideted to an optimal level of 1.0 ppm, but only 0.2 if the water contains 0.2 ppm F.

Now that we've briefly looked at the amount of fluoride taken into the body, let's briefly look at what happens to it (9). As shown in Figure 2, most of the fluoride is taken into the body by the oral route, although in some cases where there are fluoride-containing gases in the atmosphere, it can also enter by way of the lungs. (This is unusual and will only occur with some occupations). Once in the body, it enters the blood and is distributed to the bones and soft tissues. When a single high dose of fluoride is given, about 50% is taken up by the bones. Most of the remainder is eliminated within a few hours, by way of the urine, but a small amount also is eliminated in the feces and even some in the sweat. A small amount is also taken up by the teeth during their formation.

## Fate Of Ingested Fluoride

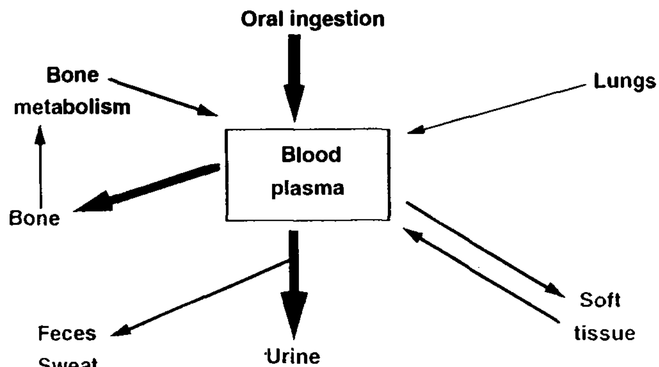


FIGURE 2

When a small amount of fluoride is consistently taken in every day, an equilibrium or steady state is reached where the amount of fluoride eliminated almost equals the amount taken in. Only a small amount is retained by the bones.

To return to dental considerations one can ask, how does this presence of fluoride in the body and in the environment of the teeth affect dental caries? As mentioned before, there are two modes of treatment; topical and systemic. This implies that there are two mechanisms. Actually, investigator have presented evidence for several mechanisms (9). These have included (1) increased enamel resistance to bacterial acids, (2) enhanced enamel maturation, (3) inhibition of plaque microorganisms, (4) improved tooth morphology and (5) the promotion of remineralization.

The first mechanism listed above is perhaps the oldest and was assumed to function because it was thought that enamel high in fluoride was more resistant to acid. When the enamel of the teeth forms in the presence of fluoride, it becomes enriched in this element in the form of fluorapatite. Most of the fluoride found in the enamel of a tooth has gotten there by the oral route during the enamel formation period, but additional fluoride can also be acquired after the tooth erupts if concentrated topical solutions or gels are applied to the teeth. If teeth are acid etched or are carious, much more fluoride is taken up by them.

The next mechanisms for the effect of fluoride is enhanced enamel maturation. When the teeth erupt into the mouth, the surfaces are still slightly deficient in mineral, particulary in certain spots called hypomineralized areas. These areas normally become fully mineralized with time by contac with saliva. But before complete mineralization, they are more susceptible to caries. When fluoride is present in the environment, the rate of mineral deposition is significantly increased. Furthermore, the mineral that is deposited in the hypomineralized areas has more fluoride, which also improves the resistance of the teeth.

Another mechanism by which fluoride might inhibit caries is its effect on the growth and metabolism of plaque bacteria. At very high fluoride concentration bacteria are killed, but of the concentration normally used in the mouth, fluoride has been thought to reduce the amount of acid formed by the bacteria.

Fluoride has also been thought to improve the morphology of the teeth when they are formed in the presence of optimun fluoride concentrations. The molars have been shown to have shallower and wider fissures that do not allow the accumulation of plaque as much as deeper fissures.

And finally, fluoride is involved in remineralization of early carious lesions (10-11). This mechanism is thought to be the most important of all the mechanism, at least for those products that are used on a daily or weekly basis, such as dentifrices or mouthrinses.

A definition of remineralization can be given as "the redeposition of mineral into incipient caries lesions". To understand remineralization we must first look at an early carious lesion. The initial visible stage of a carious lesion is called a "white spot". White spot are areas of the teeth where acids from the bacterial plaque have produced subsurface demineralization. Because of still poorly understood reasons, the surface of the white spot remains relatively sound, losing only 5-10% of its mineral content whereas the area below the surface zone may have lost 50% of its mineral. White spots may be as shallow as 100 µm (0.1 mm) or so deep that they penetrate the entire enamel thickness.

What we would like to do is replace the mineral that was lost from this subsurface area, and there is good evidence that this can be done. In fact, there is evidence that this is a natural occurrence. For example, it has been shown that many natural white spots disappear with time. In one study 72 white spots in a group of children, age nine years old, were identified (12). Examination of the same white spot six years later showed that over 50% of then had disappeared. About 36% of then did not change, and only 12% progressed to open carious lesions. It appears that half of these early lesions had completely remineralized.

Now that we have briefly looked at some of the mechanisms by which fluoride inhibits caries formation, lets now look at how it is used in the mouth.

As was stated earlier, fluoride can function both systemically and topically. Although the relative importance of these two routes is still being debated evidence is available to suggest that if fluoride is ingested during the period of tooth formation, the teeth will be more resistant to decay. The recommended amount of fluoride for systemic administration is shown in Table 1 which also shows the adjustment to make for fluoride present in the drinking water (13). From birth to age 2 years, children living in low water fluoride areas should receive 0.25 mg fluoride per day. This increases to 0.50 mg at age 2 year and to 1.00 mg at age 3 years and this amount should be continued to age 13 years for maximun effect. When the drinking water fluoride concentration is moderate, but still below optimun, the dosages are cut in half, and when drinking water fluoride is above 0.7 ppm F no supplements are recommended.

As indicated earlier, if excessive fluoride is ingested, dental fluorosis may result. Therefore it should be the responsibility of both the dentist and the children's parents to be sure that an excess is not taken inadvertently because of exposure to multiple sources such as fluoride tablets plus fluoride mouthrinses plus fluoridated drinking water. Also,

TABLE 1
FLUORIDE SUPPLEMENT SCHEDULE

| AGE | Drinking Water Fluoride Concentration < 0.3 PPM | 0.3- 0.7 PPM | > 0.7 PPM |
|---|---|---|---|
| Birth-2yrs | 0.25 mg | 0 | 0 |
| 2 yrs-3yrs | 0.50 mg | 0.25 mg | 0 |
| 3yrs-13yrs | 1.00 mg | 0.50 mg | 0 |

because small children may swallow much of the toothpaste applied to their brush, only a pea size amount should be applied to the brush. In regard to fluorosis, it should be recognized that fluorosis can only develop in teeth prior to their eruption and it has been shown that the critical time for fluorosis risk is between the ages eleven months and six years.

Systemic fluoride can be taken in a number of forms. The amount of fluoride administered can easily be adjusted using liquid drops, but tablets and lozenges are also usually available at different dose levels. Rinse supplements are intented to provide both systemic and topical benefits as are lozenges which can be chewed and swished in the mouth before swallowing.

Fluoridated table salt is not usually considered a supplement although technically it is, since it provides a systemic benefit. Actually fluoridate salt is intended as a substitute for water fluoridation.

The second major category fluoride product are those applied topically. Topical applications of fluoride were developed because teeth from areas with fluoridated water were found to contain higher fluoride levels and it was thought that these high levels were responsible for the increased resistance to dental caries. It was also found that fluoride levels in teeth could be increased by topical application. Usually the teeth were treated with solutions containing 1-2% (10,000 - 20,000 ppm) fluoride ion.

A number of form of topical applications have been used. Fluoride can be applied professionally in the dentist's office either as a solution or gel or by means of a fluoridated prophylaxis pastes. In general, prophylaxis pastes do not deposit as much fluoride into enamel as topical solution or gels. This is due to the thickness of the pastes, the presence of little or no water in the pastes and the fact that many of the abrasives are incompatible with fluoride. A form of topical applications that can be very effective when properly used, is self-applied APF gels (Acidulated-Phosphate-Fluoride). In this method of treatment, children are given custom-fitted plastic mouthtrays into which they place a small amount of APF gel, which is about half as concentrated as the gel used for professional applications. The trays are held in the mouth for about 5 minutes, five days per week. Treatment can be continued for an extended period of time.

Although use of relatively highly concentrated fluoride applications are quite effective, the more frequently applied topical forms of fluoride applications familiar to most people are mouthrinses and dentifrices.

In contrast to systemic supplements, where sodium fluoride is almost always used as the fluoride source, a number of different types of fluoride have been used in topically applied products. In the past, sodium fluoride was widely used for professional applications but in many cases it has now been replaced by other agents. Sodium fluoride, however, is still widely used in mouthrinses and dentifrices and in some prophylaxys pastes. Stannous fluoride (2-2.5% F) is used for professional applications and also in some prophylaxis pastes. The most popular topical agent for professional applications is APF (1.2% F) because it deposits large amounts of fluoride in the teeth and is more stable than stannous fluoride, which has to be made up fresh before each use. APF is prepared from sodium fluoride dissolved in phosphate buffer at pH 3.2. APF has also been used in prophylaxis paste. Amine fluoride is used in some parts of Europe but doesn't seem to offer any advantages over the other fluoride agents.

A review of the findings from numerous clinical studies of topical applications produced the data shown in Table 2 (Mellberg and Ripa, 1983). 9 Although there was wide variation in the findings, professional topical applications resulted in about 29% reduction in new decay. Use fluoride prophylaxis pastes produced about 18% less decay. Self-applied gel was effective, providing 70% less decay.

Mouthrinses and dentifrices are probaly the most widely used fluoride applications. Mouthrinses contain sodium fluoride at 200-250 ppm F when intended for daily use and 900 ppm F when intended for use once per week. Dentifrices are prepared with sodium fluoride, stannous fluoride or sodium monofluorophosphate, and usually contain 1000 - 1100 ppm F but 1500 ppm F also been used.

For maximum efficacy of a fluoride dentifrice, the abrasive must be carefully selected so that it is compatible with the fluoride agent. Sodium monofluorophosphate is compatible with a wide variety of abrasives which has made

TABLE 2
CLINICAL EFFICACY OF TOPICAL FLUORIDE APPLICATIONS

| Product | Mean Caries Inhibition |
|---|---|
| Topical solutions/gels<br>more than 40 studies (1947-1976)<br>NaF, APF, $SnF_2$ equivalent | 29% |
| Prophylaxis pastes<br>5 studies (1964-1980)<br>$SnF_2$, APF equivalent | 18% |
| Self-applied gels<br>1 study - school days<br>NaF, APF equivalent | 70% |

TABLE 3
CLINICAL EFFICACY OF MOUTHRINSES AND DENTIFRICES

| Product | Mean Caries Inhibition |
|---|---|
| Mouthrinse (daily)<br>7 studies (1965-1975)<br>NaF, APF equivalent | 29% |
| Dentifrices<br>More than 50 studies (1955-1979)<br>NaF, MFP, $SnF_2$ equivalent | 24% |

it widely used throughout the world. The development of special silica abrasives in recent years has increased the use of sodium fluoride in dentifrice formulations.

Table 3 shows the average caries inhibition found in clinical trials of mouthrinses and dentifrices (9). Overall, rinses gave about 29% fewer caries and dentifries about 24%. There was no clear difference among the various fluoride agents used in dentifrices but it would be expected that not all formulations were equally effective.

There are many topics related to fluoride and oral health and it is impossible to address them in the short space available, but it can be stated that throughout the fifty year history of fluoride in oral health, no other agent has proven itself more effective than fluoride in preventing dental caries. When properly used, it is capable of almost entirely preventing decay. The future undoubtedly will see improved fluoride-containing products. For example, antiplaque and anticalculus agents are being added to fluoride dentifrices (14) and new ways to boost the effectiveness of fluoride agents are being investigated. Perhaps in a few years dental caries can truely be a disease of the past.

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