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# FLUORIDATION

*Morning Session*

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## Clinical dentistry and fluoride

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Rational clinical dentistry, like other therapeutic arts, depends upon the application of scientific principles; dental practice cannot be divorced from scientific knowledge and must benefit from scientific progress. This is particularly true when the prevention of dental caries by fluoride is considered. Therefore, to a dentist, it is encouraging to learn of the interest shown by The Nutrition Society, which, by organizing this Symposium, is providing a platform for the exchange of views between nutritionist and clinician. It is my task to attempt to facilitate discussion amongst students of different scientific disciplines by reviewing briefly the role of fluoride in the prevention of dental caries. In this review it is hoped to set the stage for the more detailed papers of later contributors.

Clinical dentistry is concerned with the preservation of the dental health of both the individual and the community. It is to be regretted that dental health is being maintained by the treatment of existing disease in the few, rather than by preventing dental disease in the many. Dental health depends upon the possession of a normal complement of caries-free teeth, adequately supported by healthy soft tissue and bone. Dental health is undermined by two diseases, dental caries and periodontal disease, which together are responsible for about 99% of total loss of teeth. The relative importance of these diseases depends upon age. Periodontal disease, largely a disease of adults, is not influenced by fluoride and need not concern us further. Dental caries is seen at its worst in childhood and adolescence, and it is one aspect of the prevention of dental caries that we are to discuss now.

Rational prevention depends upon a thorough knowledge of aetiology, but at the outset it must be stressed that our knowledge of the cause of dental caries is far from complete. An excellent modern review of the aetiology of caries has been published elsewhere (Sognnaes, 1962), but it would seem appropriate to outline some of the essential factors that play a part in the complex process which leads to the formation of the initial carious lesion.

Dental caries almost invariably commences at a site of food stagnation, that is in the natural pits and fissures of teeth and at the areas of contact between adjacent teeth. At these sites a glutinous and tenaciously adherent material collects to form the dental plaque. The plaque consists of bacteria, food material (notably carbohydrate), cell debris, and salivary mucin and it is the site of metabolic changes which lead to the destruction of the underlying enamel. The bacteria may have a dual role. It is possible that some organisms play an important part in attaching the plaque to a smooth tooth surface (Ennever, Robinson & Kitchen, 1951); other bacteria are capable of fermenting the locally available carbohydrate to produce simple organic acids. These acids decalcify enamel to produce the initial break in the tooth surface. This acidogenic theory of dental caries is most widely accepted, but at least two other hypotheses have been advanced; all suggested mechanisms have been reviewed by Bibby, Gustafson & Davies (1958). Subsequent penetration of the softened enamel by bacteria with both acidogenic and proteolytic properties results in an extension of the caries lesion to form a clinically obvious cavity.

This simple outline permits the consideration of several possible methods of caries prevention. In animal experiments the elimination of bacteria from caries-susceptible strains of rats, bred under germ-free conditions, has been shown to prevent caries when the rats were fed on their cariogenic diet (Orland, Blayney, Harrison, Reyniers, Trexler, Ervin, Gordon & Wagner, 1955). The removal of bacterial substrate from the mouth, by stomach-tube feeding, prevented the development of lesions in animals with an intact oral flora (Kite, Shaw & Sognnaes, 1950). Clearly, in experimental animals, both bacteria and local food factors are necessary to produce dental caries. In man the elimination of bacteria cannot be practised, but the restriction of readily fermentable carbohydrate, particularly between meals, and the removal of food debris by careful attention to oral hygiene are very important methods of reducing the incidence of dental caries (Davies & King, 1961).

If bacteria cannot be eliminated and some substrate remains, an increase in the resistance of the enamel ought to be of value. Enamel is essentially mineral, largely hydroxyapatite, with protein, 1% by weight, providing a tenuous matrix (Hodge, 1962). It is probable that fluoride combines with hydroxyapatite to form calcium fluoroapatite. This change conveys altered physical and chemical properties upon the enamel, among which are an increased micro-hardness and a reduction in acid solution rate. Fluoride probably has other important actions within the dental plaque (Jenkins, 1962).

A brief examination of the history of fluoride in relation to dental caries shows that at the close of the nineteenth century the affinity of fluoride for calcium was known, the uptake of fluoride by bone had been demonstrated and the presence of fluoride in enamel had been suspected. In the early years of this century a relationship between hypoplastic mottling of the enamel and the fluoride content of drinking water was considered likely, but remained unproven, largely because of the difficulties in detecting low concentrations of fluoride in water. In spite of the observations of Black & McKay (1916) that mottled teeth had a limited susceptibility to caries, attention was focused upon the possible toxic effects of fluoride. Dental investigators were concerned not so much with caries reduction as with enamel mottling, which later became known as enamel fluorosis. Dean, Arnold & Elvove (1942) reported the relationship between the incidence of dental caries and mottled enamel and the concentration of fluoride in the water supplies of the towns where the subjects lived. This study demonstrated a direct relationship between high fluoride concentration in water and tooth mottling and an inverse relationship between fluoride concentration and caries incidence. A later study (Dean, 1946) showed that children aged from 12 to 14 years, living in Galesburg and Monmouth, USA, each with a fluoride concentration in their water supplies of about 1·8 p.p.m., had a lower incidence of caries than children in control towns with low fluoride levels. A further important finding in this study was that only half the protected children in Galesburg had mottled teeth, yet there was no significant difference between the DMF index (number of decayed, missing and filled teeth, an index of the severity of caries attack) of children with mottled teeth and the DMF index of children without mottling. From this observation it was inferred that fluoride could reduce the incidence of dental caries irrespective of the presence of mottling. It was then but a short step to the realization that the fluoride concentration of a water supply could be adjusted to avoid objectionable enamel fluorosis without decreasing the preventive effect of the fluoride.

The relationship between DMF, mottling and fluoride concentration in drinking water in the United Kingdom has been studied by Forrest (1956). She demonstrated that caries incidence was minimal at the level of about 2 p.p.m. fluoride and that mottling was least objectionable at about 1 p.p.m. fluoride. A slight reduction in mottling was observed with an increase in fluoride concentration in the water from 0·1 p.p.m. to 1·0 p.p.m. Therefore the optimal level for both low caries and relative freedom from mottling appears to be about 1 p.p.m. fluoride. If the concentration of fluoride is increased above this level mottling becomes a problem and there is little gain in preventive effect. The observation that a fluoride concentration of 1 p.p.m. reduces the incidence of mottling which would otherwise be found in a low-fluoride area, suggests that fluoride may be necessary for the formation of enamel free from the so-called idiopathic hypoplasia. Thus the systemic administration of fluoride to children during the period of tooth formation may provide a double benefit.

Objectionable enamel fluorosis has been mentioned, and this condition will now be examined in a little more detail. The severity of enamel fluorosis depends upon the concentration of fluoride in the water supply (Dean, 1942). The earliest change is a small white spot beneath a normally glazed enamel surface. As the concentration of fluoride rises such spots become larger, brown in colour and eventually the tooth surface becomes pitted. Pl. 1 shows a moderate degree of fluorosis which might be seen in a subject whose teeth had developed in the presence of a water supply containing about 6 p.p.m. of fluoride. There is considerable individual variation in the degree of enamel fluorosis produced by water of a given fluoride content, but at the level of 1 p.p.m., minute white spots, often symmetrically distributed on premolar teeth, are found in only some of the subjects at risk. Disfiguring mottling has not been reported at this concentration.

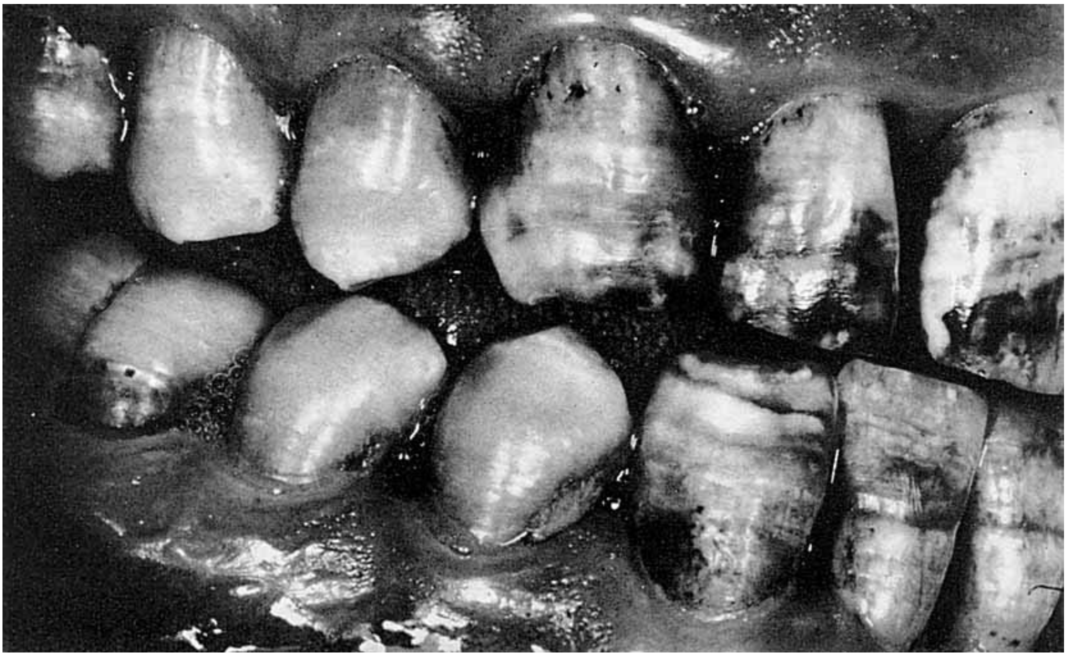
In passing, it is important to note that there are many causes of mottled and pitted teeth other than fluorosis (Jackson, 1961). A solitary hypoplastic spot on one tooth may result from the spread of infection from a deciduous predecessor. Measles or other childhood fever, occurring at an age when the affected parts of the teeth were calcifying, may cause enamel hypoplasia. Discoloration of teeth occurs in some inherited defects of dentine formation (Rushton, 1954). These are but a few of the many causes of hypoplasia and discoloration which should be eliminated when statistics on enamel fluorosis are compiled.

So far attention has been confined to discussing some of the effects of fluoridation of public water supplies. Mention must now be made of other methods of systemic fluoride administration. Sodium fluoride tablets are being used to provide an individual child with a daily intake of about 1 mg of fluoride. If it is to be fully effective the procedure must be maintained for at least 10 years, but such a programme makes great demands upon parental co-operation. Following the example of goitre prevention by the addition of sodium iodide to table salt, Wespi (1961) in Switzerland has added sodium fluoride to salt. Individual variation in the consumption of table salt and the fact that salt may not be given to infants make this method difficult to control. Theoretically the ingestion of sodium fluoride in any form should be effective in reducing the incidence of dental caries but there is little clinical evidence to support the use of these methods.

In an attempt to reduce caries incidence, local applications of fluoride solutions to the enamel surface have been tested. The original stimulus for this procedure came probably from the work of Volker (1939), who showed in in vitro experiments that enamel treated with a fluoride solution was less readily soluble in acid than untreated enamel. That it is possible to build up the fluoride content of the enamel, from the surface, has been shown by Jackson & Weidmann (1959). They related the fluoride content of pooled enamel samples of teeth from low-, medium- and high-fluoride areas to the age of the subjects. They found that the enamel fluoride content continued to rise long after the completion of enamel formation, when it was virtually beyond the influence of systemic metabolic processes. From this study it would appear that fluoride is taken up by the enamel surface as fluoride-containing fluids pass through the mouth.

In clinical trials topically applied fluorides have caused reductions in the DMF index of from 10 to 40% (Slack, 1956; Jordon, Snyder & Wilson, 1959). This wide range of effect is probably a reflection of many variables which include the cation of the fluoride salt, the fluoride concentration, the pH of the solution, the number of applications, the age of the patient and the technique of the individual operator. Although a useful effect has been demonstrated by some workers, it should be remembered that topical applications are impracticable for whole populations. There are far too few dentists to carry out the repeated applications that are necessary.

Recently, special interest has been attached to stannous fluoride and the use of this agent has been reviewed by Beck (1961). In experiments to test the effect upon enamel solution rate of treating enamel with solutions of many different fluoride salts, Muhler, Boyd & van Huyson (1950) found that stannous fluoride was the most effective compound. Therefore it was suggested that the stannous ion plays some part in this enhanced effect. Experiments such as these have led to the use, as a topically applied prophylactic agent, of an 8% solution of stannous fluoride and to the development of the much more controversial vehicle for fluoride application, a toothpaste containing stannous fluoride.



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There are difficult chemical incompatibilities that have to be surmounted during the development of a satisfactory stannous fluoride toothpaste. It has been shown that the soluble or available fluoride of a paste falls during storage and further that saliva under in vitro conditions reacts with a fluoridated paste to reduce the amount of fluoride available to the tooth (Duckworth, 1962). A similar study by Manly (1961) has also shown that the availability of the stannous ion decreases even more rapidly with the age of the paste. These are just two reasons why a fluoride-containing toothpaste may not have the expected effect. Indeed, as judged by the results of clinical trials the pioneer American fluoride toothpaste has not been universally successful in combating dental caries (Kyes, Overton & McKean, 1961). At the present time at least four fluoride toothpastes are being, or are about to be, tested in this country, but results of these clinical trials will not be available for at least 2 years.

To conclude this brief review it may not be out of place to remind ourselves of the requirements of the practising dentist and, above all, of the requirements of his patient, of any agent used in the prevention of dental caries. They are effectiveness, combined with ease of application to the population as a whole, and freedom from side effects. The available evidence indicates that these requirements are met by the addition of fluoride to domestic water supplies in a concentration of about 1 p.p.m. Other measures mentioned in this review must be regarded as of secondary importance in the prevention of dental caries by fluoride.

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## EXPLANATION OF PLATE 1

Fluorosis of dental enamel in which there is brown staining without pitting of the enamel surface.