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EFFECTIVENESS OF FLUORIDE MOUTHRINSING IN SCHOOL CHILDREN

by

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A THESIS SUBMITTED IN PARTIAL REQUIREMENT FOR THE

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SUMMARY

This thesis is purely a literature review, mainly concerned with effectiveness of fluoride mouthrinses in children. Of all the preventive programs available in dentistry, fluoridation of water supply is the most effective, practical, and feasible. Communities which cannot fluoridate their water supplies may choose a school fluoride mouthrinse program. Here again the program should be chosen on the basis of needs and resources and what is in the best interests of the target population. A school fluoride mouthrinse program may be defined as the use of a fluoride mouthrinse by children in the school setting for the prevention of dental caries, on a daily or weekly basis, depending on the resources of school or community. A major advantage of rinsing is that it is relatively inexpensive as it can be supervised by school teachers or dental assistants.

The mechanisms by which fluoride increases caries resistance may rise from both systemic and topical applications of fluoride and broadly be grouped as follows:

1. Increased enamel resistance
2. Increased rate of maturation
3. Remineralization of incipient lesions
4. Interference with microorganisms
5. Improved tooth morphology.

Sodium fluoride has been the most frequently tested fluoride compound. Acidulated phosphate fluoride has not been shown to be superior to those containing NaF. Also,

NaF is easier to formulate than APF and has practical advantages over SnF_2 as it is stable in solution and its taste is not unpleasant.

The two most common fluoride rinsing techniques combine two variables, fluoride concentration and rinsing frequency with the low potency/high frequency technique or high potency/low frequency technique. Low potency/high frequency technique is the method recommended for home use. Fluoride rinsing is indicated for patients with banded, bonded or removable appliance; and for patients with reduced salivary flow whose teeth are highly susceptible to decay. High potency/low frequency technique is the method usually used for school-based programs. This method of caries prevention is accepted as effective with a general caries inhibition of 30% to 40% after prescription for two or more years in the program. Fluoride rinsing appears effective both in the fluoride-deficient and optimally fluoridated communities.

Various combinations of self-applying fluorides may produce additive benefits, particularly those that incorporate different concentrations of fluoride, frequency of application, and methods of administration. It is well established that the percent reduction in caries following water fluoridation is greater in free smooth surfaces (buccal and lingual) and least in fissure surfaces. This pattern has also been observed in fluoride mouthrinsing trials.

A number of studies have shown that fluoride inhibits glycolysis in oral microorganisms and reduce acid

production significantly. Certain cariostatic topical fluoride procedures have been shown to permanently increase the concentration of fluoride in the outer layer of sound enamel. But the degree of protection from caries diminishes on discontinuation.

Undesirable side effects, such as soft tissue irritation or objectionable cosmetic effects, have not been observed in fluoride mouthrinse programs. Accidental swallowing of the fluoride mouthrinse does not result in acute fluoride toxicity due to the low concentration and dosage of fluoride in the mouthrinse.

Special attention must be given to the development of self-applied topical fluorides, since these do not incur the problems of insufficient and expensive professional manpower requirements. A large portion of the world's population uses a dentrifice, and many people use a mouth-rinse for oral hygiene. The incorporation of fluorides into dentrifices and mouthrinses appears a logical and practical approach to the problem of delivering fluorides to large numbers of persons. Second to water fluoridation, this approach may have the greatest public health potential.

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1. INTRODUCTION

1.1 GENERAL BACKGROUND OF FLUORIDE IN DENTISTRY

Fluoride, the most electronegative of all elements, has not only notable chemical qualities, but also physiological properties of great interest and importance to human health and well being. Research into the biology of fluorides has been very extensive during the last decades, especially after it was demonstrated in the 1930s that fluoride in very small doses has remarkable influences on the dental system; on the one hand, a strong inhibition of dental caries; on the other, and with higher doses, a disturbance of enamel formation. In fact, the discovery of the connection between excessive content of fluoride in water and endemic mottling of the enamel was one of the main starting points of research into fluorides and hard-tissue physiology and pathology.

The precise way in which fluoride exerts its protective effect against dental caries is still not fully understood. However, there is sufficient evidence to suggest that it acts in several ways both before and after tooth eruption. If fluoride is present in an optimum concentration during tooth development it results in the formation of enamel with improved crystallinity which is more resistant to acid attack. On the other hand, fluoride is also effective when applied topically to enamel after eruption.

Investigators have observed the improved appearance of the teeth in areas with adequate fluoride, and the decrease in the number of deep fissures which can be sites for later decay. This seems to be true even when tooth enamel is not

exposed to fluoride until quite late in its formation.

Many studies have confirmed the finding that fluoridation reduces the prevalence of dental caries in permanent teeth by an average of about 60%.

1.2 TOPICAL FLUORIDES AND DENTAL CARIES

Dental caries is a chronic disease which, unless its progress is interrupted by treatment, eventually leads to the loss of the affected teeth. The prevalence of the disease is not affected by treatment since restorative dentistry treats the consequences of dental caries and not the cause. The prevalence of the disease can only be reduced by prevention.

From an ecological point of view there are two major methods of preventing dental caries. The first is by increasing the resistance of tooth enamel to external attack. The second is to reduce the intensity of attacking agents. The most important factors in promoting the resistance of teeth to dental caries are the systemic and topical administration of fluoride.

In the early 1940s it was appreciated that tooth enamel could take up fluoride ions from water solutions and that this rendered the enamel more resistant to acid solution. Over the next 40 years this topical method has proved very successful in preventing dental caries, and many permutations and combinations of the concentration of fluoride in the solution, the type of fluoride compound used, and the frequency and mode of application have been studied. Concentrated fluoride solutions have to be applied by trained personnel, usually in surgery, but weak solutions may be

applied by the individuals themselves as a dentrifice or as a mouthrinse.

Previously, the rationale behind the application of fluoride topically to enamel was to increase its fluoride content and consequently its resistance to acid attack. Moreover, since it is now known that dental caries is characterized by alternating periods of demineralization or destruction and remineralization or repair, views on the mode of action of fluoride have changed. An important function of fluoride, therefore, is to tip the balance in favour of remineralization by encouraging repair or arrest of the initial lesion. In addition it is likely that fluoride exerts a direct action on cariogenic bacteria in plaque. Thus, to obtain the greatest benefit from fluoride its transient presence is required soon after the caries attack. Since there is no way of knowing exactly when this is occurring, the aim has to be regular and frequent exposure of the enamel to fluoride to arrest the early lesion.

A daily mouthrinse with a 0.05% solution of sodium fluoride reduces the incidence of caries by 30-40%. In a study in Norway, children who undertook regular fluoride mouthrinsing at school once every fortnight needed 70% fewer fillings than did controls. Fluoride compounds other than sodium fluoride, such as stannous fluoride, acidulated phosphate fluoride (APF) and amine fluoride, are effective but cost more and taste worse.

In children, regular use of fluoride tooth paste will prevent the development of half to one carious tooth surface per child per year. (A reduction of 20-30% over 3 years.)

Tooth pastes contain fluoride as sodium monofluorophosphate (NaMFP = 0.8%), stannous fluoride (SnF_2 = 0.4%), or sodium fluoride (NaF = 0.25%). Concentrations are designed to provide 1000 parts per million (ppm) fluoride. The development of improved formulations may increase the effectiveness of fluoride tooth paste without necessarily increasing the concentration of fluoride.

Topical fluoride application by dentists or hygienists as either a solution, gel or varnish has long been used in caries prevention.

Fluoride tablets or drops taken from birth can reduce caries by 75-80%. School-based studies have reported reductions in caries of 40% after 8 years of tablet use. This figure is further improved if the child slowly dissolves the tablet in the mouth before swallowing it. Fluoride drops or tablets as systemic supplements should not be prescribed when the water contains over 0.7 ppm fluoride.

Many children are given fluoride in more than one way and the benefits of combining tooth paste with mouthrinses, topical gels or solutions and with APF gels and fluoride rinses have been investigated. There was some additional reduction in caries in children receiving fluoride tooth paste plus a fluoride rinse. Benefit from combining fluoride preparations is also seen in children drinking fluoridated water. In one study such children rinsing with a 0.2% sodium fluoride solution had 40% fewer decayed surfaces than children using placebo rinse. In another study children using self applied APF gels 15 times in the first year as well as rinsing with a 0.2% sodium fluoride rinse for 3 years did

have significantly less dental caries than children who rinsed with a placebo. It seems that in general combinations of more than one fluoride agent produce greater dental health benefits than any methods used singly.

1.3 AIM OF THE THESIS

Today, as during the past 35 years, the best individual defence against dental decay remains the proper use of fluorides. The mechanisms by which fluoride prevent dental decay are thought to vary, depending upon the agent used, its route of administration, its concentration and frequency of use, and the vehicle used to deliver it. More than one mechanism may operate simultaneously and, thus, a potential for additive effects exists from the use of multiple fluoride procedures. Perhaps the most important element in producing marked cariostasis is the frequent provision of low concentrations of fluoride to teeth and dental plaque. Anticaries mouthrinses containing fluoride salts have been clinically evaluated by numerous investigators under a variety of conditions. Because of the relatively high cost of topical applications of fluoride solutions by professional personnel and the doubts about their cost-benefits, there is a growing volume of research in self administration techniques. These include:

(a) tooth brushing with prophylactic paste

(b) tooth brushing with fluoride solution, tablet or gels

(c) mouthrinsing with a fluoride solution.

The chief aim of this thesis is to review the current literature of effectiveness of fluoride mouthrinses in school children.

2. DENTAL CARIES

ETIOLOGY OF CARIES

Dental caries is a localized multifactorial disease in which there is an interplay of three principal factors: the host (primarily the saliva and teeth), the microflora, and the substrate, or diet. In addition, a fourth factor - time, must be considered in any discussion of the etiology of caries. Diagrammatically, these factors can be portrayed as four overlapping circles (Fig. 1). For caries to occur, conditions within each of these factors must be favourable. In other words caries requires a susceptible host, a cariogenic oral flora, and a suitable substrate which must be present for sufficient length of time. Conversely, caries prevention is based upon attempts to (1) increase the resistance of the host (fluoride therapy, occlusal sealants, immunization), (2) lower the numbers of microorganisms in contact with the tooth (plaque control), (3) modify the substrate by selecting noncariogenic foodstuffs, and (4) reduce the time that the substrate is in the mouth by limiting the frequency of intake.

HOST FACTORS: SALIVA

Saliva is a mixture of secretions from the three pairs of major salivary glands with contributions from numerous minor mucous glands. The secretion of each type of gland has a unique composition. For example, the secretion of the submandibular glands contain 50% more calcium (6.8 mg calcium/100 ml) than that of the parotid glands (Newbrun,

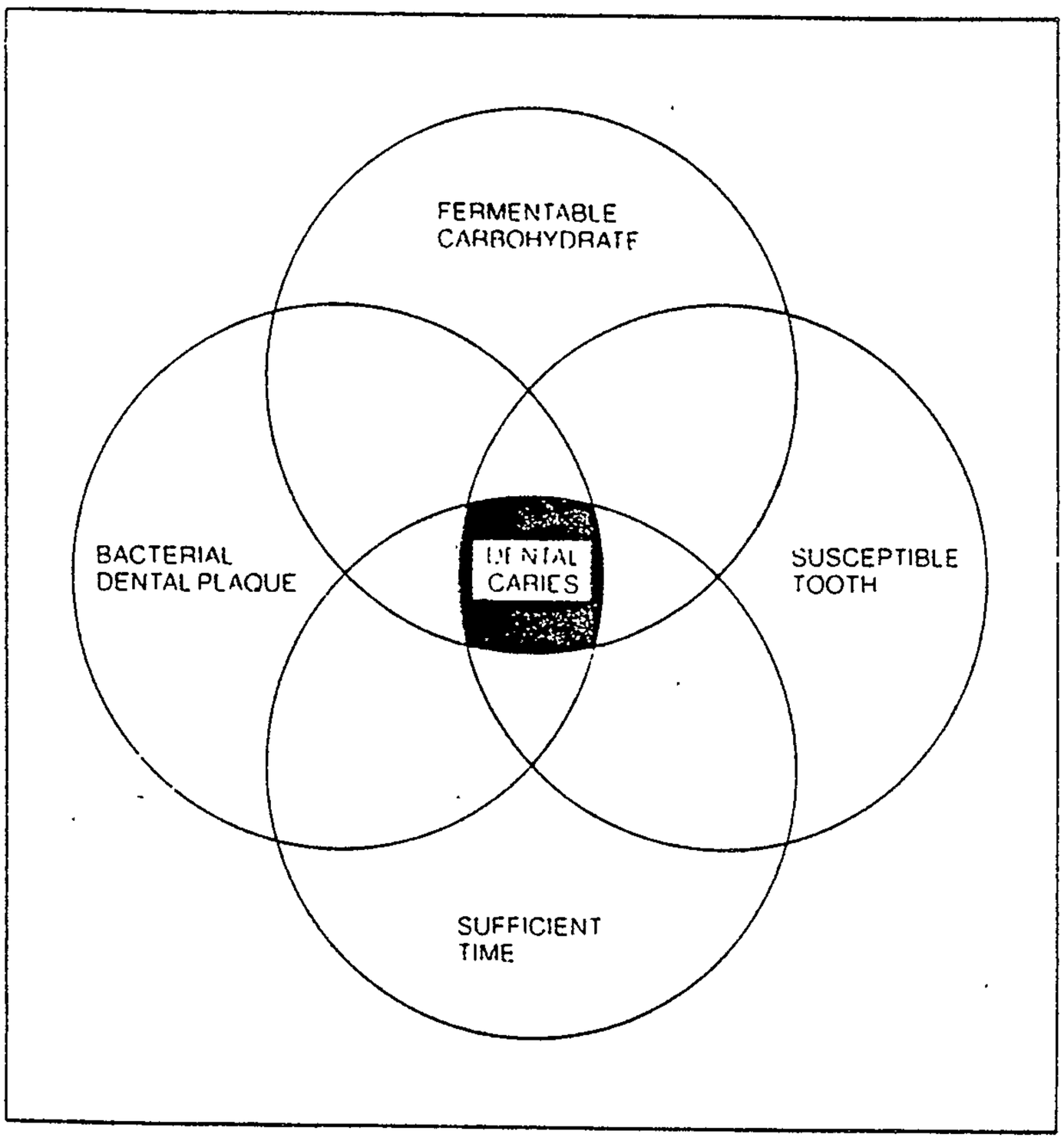

Fig. 1. The four circles diagrammatically represent the parameters involved in the carious process.

All four factors must be acting concurrently (overlapping of the circles) for caries to occur.

Source: Newbrun, 1983.

1961). Such regional differences may, in part, account for the observed relative immunity of the lower anterior teeth to caries and the higher frequency of calculus deposits.

Currently, no consistent relationship has been established between dental caries prevalence and salivary amylase, ammonia, urea, calcium, phosphate, pH or viscosity. An inverse relationship between salivary flow rate and caries may exist, but the literature is in conflict on this point. The flow rate itself influences the salivary Na^+/ HCO_3^- ratio; at higher flow rates there is an increased buffer capacity and tendency to have less caries.

HOST FACTORS - IMMUNIZATION

The mouth is provided with both humoral and cellular arms of the immune system, both of which could influence the composition of the microbial communities in the oral cavity (Fig. 2). Theoretically, antibodies could control populations of cariogenic bacteria in either of two ways: (1) they could inhibit colonization, by reacting with bacterial surface receptors or by inhibiting glucosyltransferase and thereby blocking glucan-induced irreversible adherence, or (2) they could opsonize bacteria, permitting phagocytosis by polymorphonuclear leukocytes or possibly macrophages. But the practicality of caries prevention by specific immunization has not yet been resolved from the point of view of safety. Much additional experimental work and human trials will be required before a caries vaccine can be applied to clinical practice. Immunization may supplement the established caries prevention obtained by fluoride (systemic and/or topical) but not replace it.

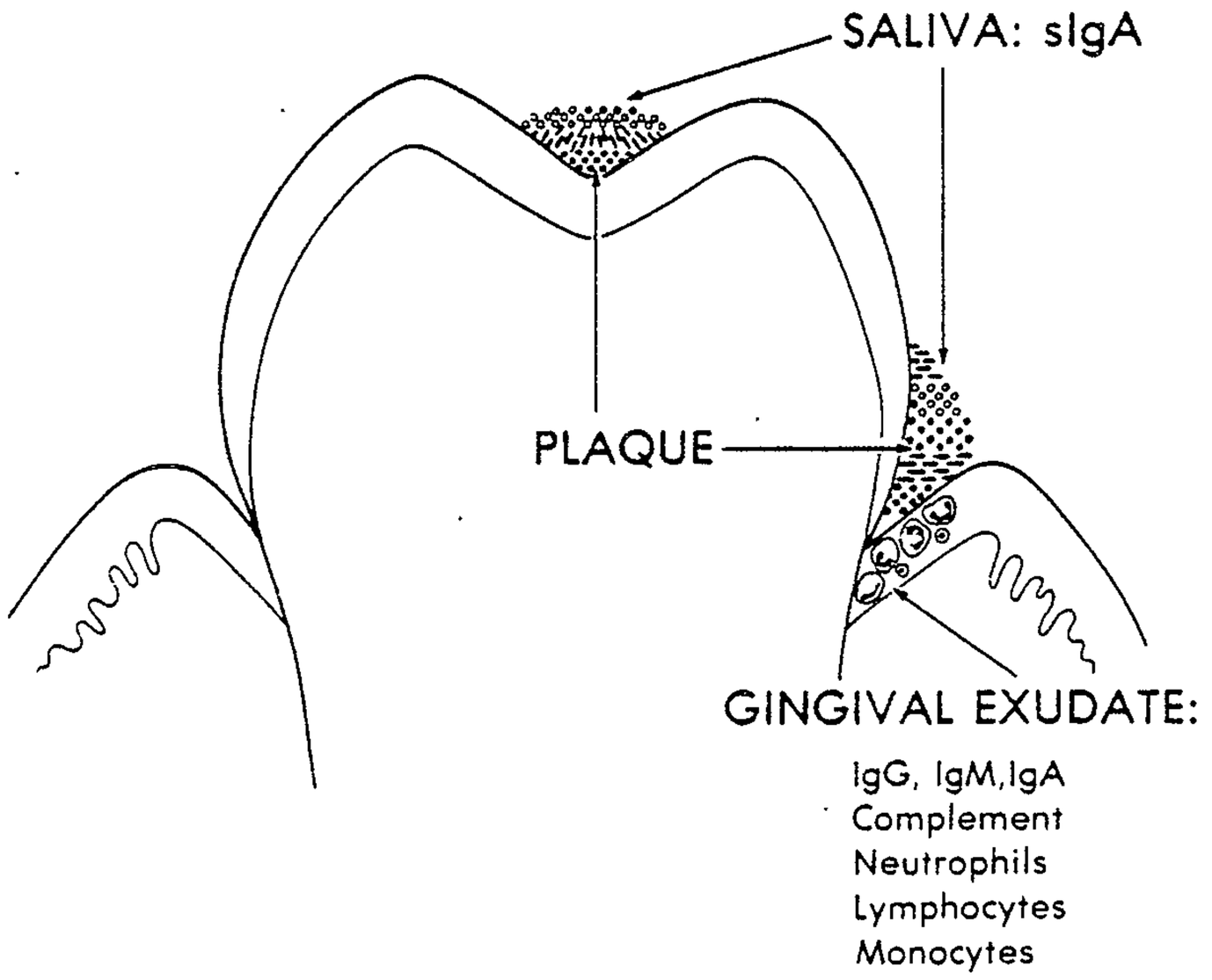

Fig. 2. Humoral and cellular factors at the plaque-tooth interface. Saliva provides secretory IgA. which can reach plaque both at the gingiva and at occlusal fissures. Gingival exudate provides both humoral (IgG. IgM. and IgA) antibodies and cellular components (neutrophils. lymphocytes). but only to plaque in the gingival region.

Source: Newbrun, 1983

HOST FACTORS: TOOTH

TOOTH MORPHOLOGY AND ARCH FORM

A susceptible host is one of the factors required for caries to occur. On the basis of clinical observations, it is known that the pit and fissure areas of the posterior teeth are highly susceptible to caries. Food debris and microorganisms readily impact in the fissures. Investigations have shown a relationship between caries susceptibility and the depth of the fissure.

Certain surfaces of a tooth are more prone to decay, whereas other surfaces rarely show decay. For example, in lower first molars the likelihood of decay in descending order is occlusal, buccal, mesial, distal, and lingual, whereas in upper first molars the order is occlusal, mesial, lingual (palatal), buccal and distal. On upper lateral incisors, the lingual (palatal) surface is more susceptible to caries than the buccal surface. These differences in decay rates of various surfaces on the same tooth are in part due to morphology, e.g. buccal pit on lower molars, lingual groove of upper molars, and lingual cingulum of upper incisors. An intraoral variation exists in susceptibility to caries between different tooth types. The most susceptible permanent teeth are the lower first molars, closely followed by the upper first molars and the upper and lower second molars. The second bicuspids, upper incisors, and first bicuspids are the next in sequence, whereas the lower incisors and cuspids are the least likely to develop lesions (Fig. 3). Irregularities in arch form, crowding and overlapping of the teeth

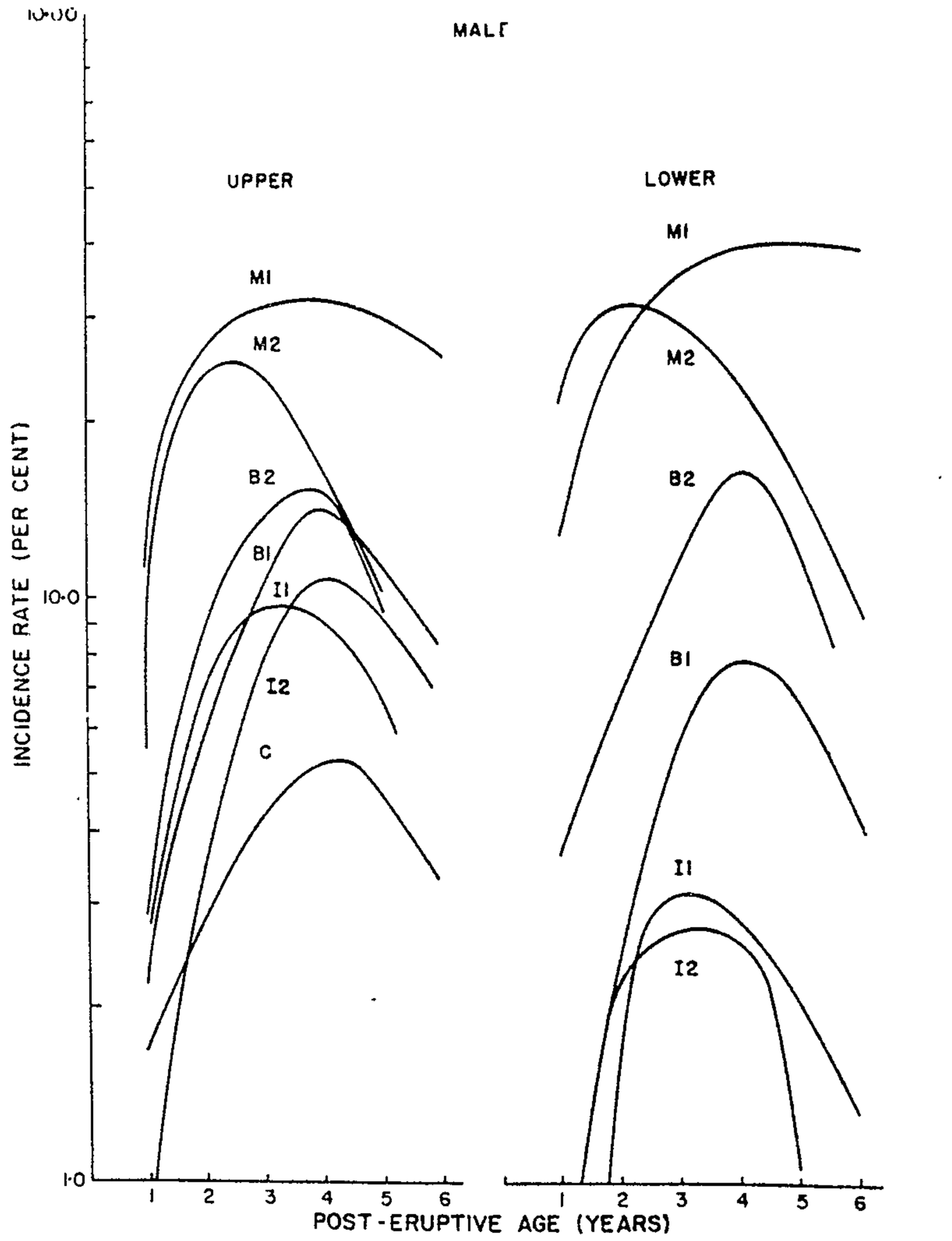

Fig. 3 Curves showing annual probability of caries attack of the permanent teeth of male children in Kingston, New York. Semilogarithmic scale. *M2*, second molars; *M1*, first molars; *B2*, second premolars; *B1*, first premolars; C, canines; *I2*, lateral incisors; *I1*, central incisors. (Courtesy of Carlos and Gittelsohn.[5])

Source: Newbrun, 1983

also favour the development of carious lesions.

TOOTH COMPOSITION

There is good evidence to indicate that the enamel surface is more caries-resistant than the subsurface. Microradiographs of initial carious lesions frequently reveal marked demineralization of the subsurface enamel beneath an outermost layer which is only slightly affected (Fig. 4).

Fig. 4. Microradiograph of white spot lesion of enamel.

Compare the extensive demineralization of the subsurface enamel with better mineralized surface layer (original magnification x 100).

Source: Newbrun, 1983

Surface enamel is harder than the underlying enamel. These differences are likely to be related to the many differences between the composition of surface and that of the rest of the enamel. The surface enamel has more minerals and more organic matter, but has relatively less water. In addition certain elements, including fluoride, chloride, zinc, lead, and iron, accumulate in the enamel surface, while other constituents, such as carbonate and magnesium, are sparse in surface as compared with subsurface enamel. Changes of enamel, such as decrease in density and permeability and an increase in nitrogen and fluoride content, occur with age. These alterations are part of the posteruptive 'maturation' process whereby teeth become more resistant to caries with time. The concentration of fluoride of the surface layer of enamel increases as the fluoride concentration of the drinking water increases, and such enamel is less soluble in acids. Furthermore, the higher the fluoride concentration of the water supply, the lower the prevalence of caries. The addition of fluoride ions to the surface above the carious lesion favours remineralization, and so helps maintain the integrity of the lesion. This in turn will act as a 'brake' on the progress of the lesion.

MICROBIAL AGENTS

The mouth has a diverse resident microbial flora. The humidity and temperature of the mouth and the passage of all nutrients needed by many types of microorganisms through it several times each day provide ideal circumstances for microbial colonization of various stable and relatively

stable surfaces within the mouth. The environment within the mouth varies widely as such different ecological niches of the enamel surfaces of the teeth, the root surfaces, deep carious lesions, the tongue, the gingival crevice between the gingiva and the tooth, and saliva. As a result, wide variations in the species and distribution of microorganisms are observed from one niche to another.

The high hydrogen ion concentrations (low pH values) in carious lesions favour colonization and growth of aciduric organisms such as the lactobacilli. Likewise, the strict anaerobic conditions of the gingival crevice favour the bacteroides species and veillonella species. While numerous hypotheses have been formulated about the actual chemical reactions that destroy tooth substance, including proteolysis and chelation, the consensus is that the primary reaction is the slow and intermittent dissolution of hydroxyapatite by acid. The tiny percentage of organic matter in enamel, even though minutely dispersed throughout the structure in a membranous network, does not appear to pose any barrier to the dissolution of mineral in an acidic environment. As a carious lesion progresses into the dentin with its much higher organic concentration, primarily collagen, dissolution of hydroxyapatite by acid and proteolysis go hand in hand to produce the typical deep carious lesion.

Two species of microorganisms have received special attention as potential caries producing agents. L. acidophilus for many years was considered the most likely caries producing microorganism. More recently, Streptococcus mutans has received special attention for various reasons. This

microorganism is either not present in the human oral cavity before teeth erupt or at least is not present in sufficient concentration to be detected by currently available methods. However, soon after the primary teeth erupt S. mutans can be detected on tooth crowns.

Long before the animal studies on dental caries implicated streptococci, lactobacilli were in vogue as the major cause of dental caries, and the lactobacilli count was initiated nearly fifty years ago. Bowen's studies (1967) on dental caries in monkeys showed lactobacilli, particularly L. casei, to be the prime cause of dentinal caries. The environment of the deep dentinal lesion is conducive to the growth of lactobacilli as they are more readily retained and flourish under acidic conditions where streptococci would not grow. The observed fact that lactobacilli occur in relatively small numbers in dental plaque indicates that they may not be a major aetiological agent in the initiation of enamel caries. However, where microcolonies of lactobacilli in the initiation of caries in man cannot be stated with any certainty at present. Almost certainly they play an important part in the destruction of dentine in established lesions (Silverstone et al., 1983).

S. mutans is also of interest because it has the ability to form from sucrose an extracellular polymer of glucose, mutans, which aids the microorganisms in adhering to the enamel surface and in establishing a stable relationship there. This microorganism does not form a comparable polymer from other monosaccharides or disaccharides. This microorganism is also identifiable, although often at low

concentrations, in most carious lesions that clinically appear to be active. Since sucrose, table sugar, is the most common sugar in the human diet, the S. mutans-sucrose-mutans polymer relationship results in an appealing hypothesis that sucrose and S. mutans are the villains in human caries (Newbrun, 1983).

Adherence of bacteria to the pellicle coated tooth surface is an important feature of smooth surface caries but would be of lesser importance in pits and fissures where the organisms could be more readily retained. Although originally considered of prime importance in the adherence of bacteria, particularly S. mutans, to the tooth surface, such adherence is now believed to involve specific interactions between bacterial surface proteins and components of pellicle. The role of glucans, in this model (Fig. 5), is to serve as bridges between the organisms and this contributes to the build-up of plaque (Staat and Langley, 1980).

Studies on several populations in the USA, South America and the Netherlands have shown a correlation between the numbers or isolation frequency of S. mutans and the DMF caries index, whereas no such relationship has been reported with other streptococci species (Littleton et al., 1970; Shklair et al., 1972; Rogers, 1973; Hoerman et al., 1972).

The results of further longitudinal studies on human caries are awaited with great interest. If it can be shown that human caries is caused specifically by infection with S. mutans, this provides the basis for specific prophylaxis and treatment of the disease directed against that organism. The evidence from human studies concerning the role of

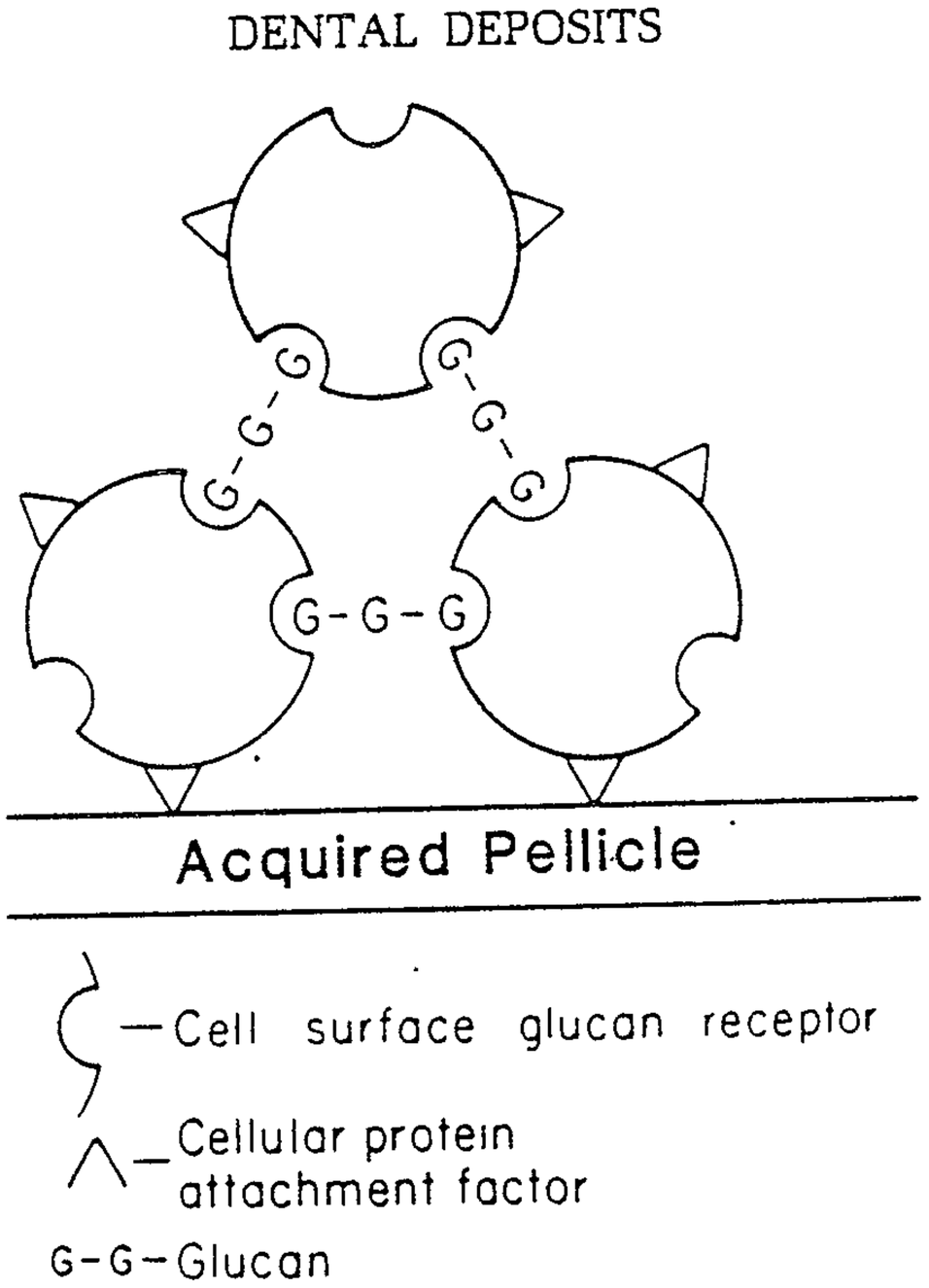

Fig. 5. Schematic diagram of proposed model of S. *mutans* adherence which illustrates 1) the interaction between bacterial surface proteins and acquired pellicle (sucrose-independent, weak), and 2) the glucan-mediated cell-cell accumulation (sucrose-dependent, strong). (Courtesy of R.H. Staat et al.) .

Source: Staat, Langley and Doyle, 1980

organisms other than streptococci or lactobacilli in dental caries is limited. In theory any acid-producing organism present in plaque may contribute towards the carious process. Certain Actinomyces species appear to be able to produce a particular type of caries experimentally, and there is some evidence that these organisms may be involved in root surface caries in man. This type of caries occurs in older subjects than the more common enamel caries of childhood and adolescence, and attacks exposed cementum. Caries at these sites was shown by Dr. R.G. Schamschula (1977) to be particularly prevalent in New Guinea natives, and to be associated with high incidence of Actinomyces. Currently, in 'western' communities it is more common in older subjects but these could be an increase in the prevalence of root surface caries (and also periodontal disease) as fewer teeth are lost due to coronal caries - thus there would be 'a change in the pattern of disease', a phenomenon which has been observed in other fields of medicine (Bowen, 1981).

DIET

It is the carbohydrate component of the diet that is associated with the formation of dental caries. Fats and protein either do not affect cariogenicity or are generally considered to be cariostatic (Pigman, 1970). Three factors influence the cariogenic potential of carbohydrates: (1) the type of carbohydrate, (2) the oral clearance of the carbohydrate or, conversely, its persistence on tooth surfaces, and (3) the frequency of consumption.

Type of Carbohydrate

Sucrose, common table sugar, is believed to be the major cariogenic food factor in the human diet (Newbrun, 1969; Shannon, 1977). While glucose, fructose, galactose, lactose, maltose, dextrose, and starch have all been shown to form caries in experimental animals, sucrose invariably results in the greatest tooth destruction.

Sucrose is utilized by oral microorganisms both in the formation of plaque matrix, which adheres the microorganisms to the tooth and in the production of acids that dissolve the tooth. Bacterial enzymes hydrolyze sucrose, a disaccharide, yielding glucose and fructose. These monosaccharides can be utilized as immediate sources of energy, yielding lactic and other organic acids that can dissolve the mineral of the tooth. Conversely, through the action of the enzymes dextran sucrase and levan sucrase, sucrose can be converted into long chain polymers of glucose, called dextran (polyglucan), or of fructose, called levan (polyfructan). Dextran promotes the adhesion of plaque bacteria to each other and of the plaque itself to the surface of the tooth. Both dextran and levan also serve as extracellular substrates within the plaque that can be subsequently metabolized to their respective moieties with the further production of organic acids. The metabolic pathways of sucrose utilization by the plaque microorganisms is diagrammed (Fig. 6).

Because sucrose is utilized both in the formation of plaque matrix and in the production of acids that dissolve the tooth, its cariogenic potential is greatly enhanced

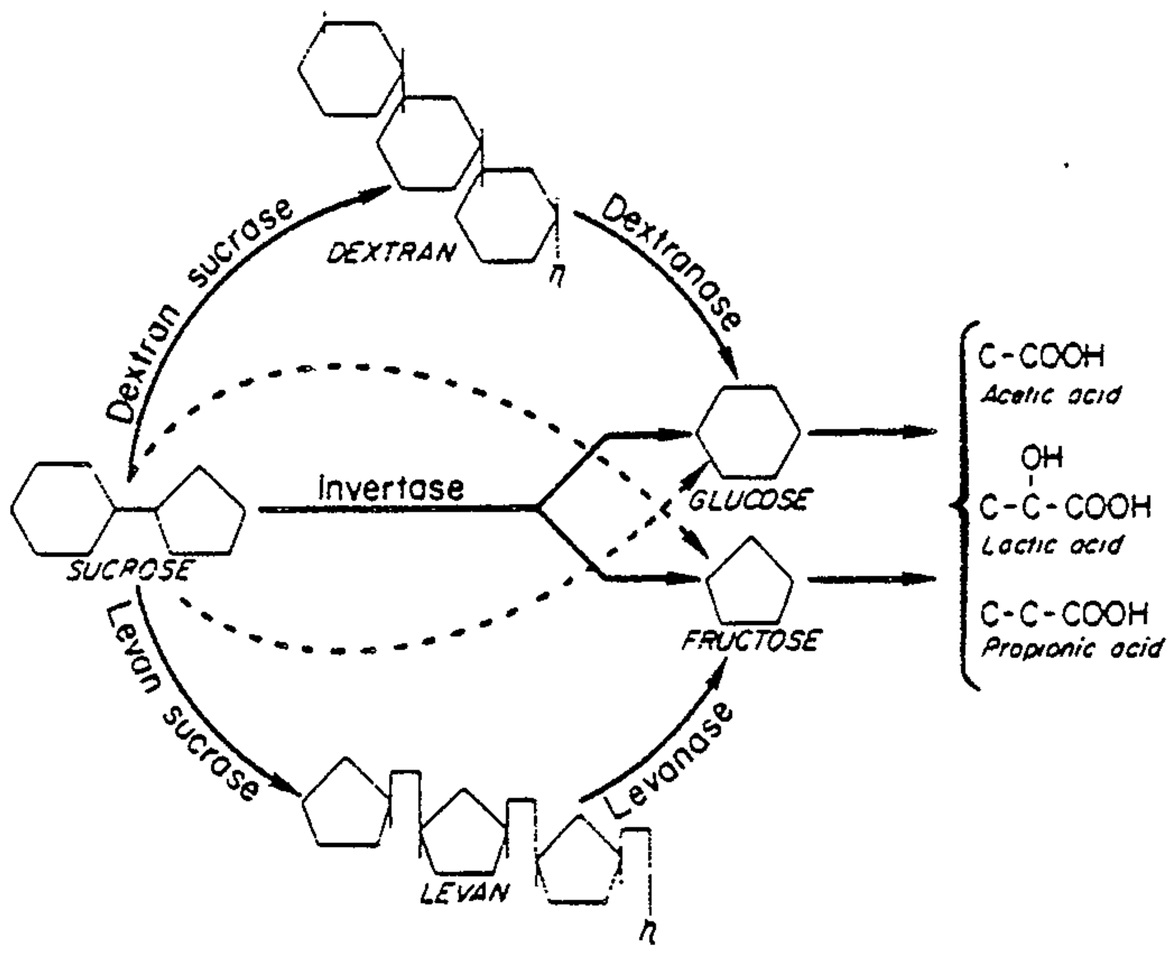

Fig. 6. Sucrose, a disaccharide consisting of glucose and fructose, is metabolized by plaque microorganisms to simple organic acids capable of dissolving the tooth and to complex polysaccharides that promote adhesion of the plaque or serve as future metabolites.

Source: Mellberg and Ripa, 1983

above that of other sugars. For instance, while the amount of dental plaque is greatest when sucrose is the ingested carbohydrate, large quantities of plaque can also be formed in association with the ingestion of other carbohydrates such as sorbitol. The cariogenicity of these plaques, however, is less than that formed in association with sucrose.

The adhesion produced by the polyglucans is especially important for the initiation of caries on smooth tooth surfaces where, in the absence of plaque, the saliva may be expected to wash away the microorganisms. The aggregation of Streptococcus mutans, Streptococcus sanguis, and Actinomyces viscosus is all mediated by polyglucans. It has been demonstrated in both animals and humans that drastic reductions in the level of dietary sucrose can result in a decrease in the oral population of extracellular polysaccharide-forming streptococci (Bowen, 1967; Van Houte, 1964).

Because sucrose is a disaccharide, it is small enough to readily diffuse into the bacterial plaque. As long as it is a dietary constituent, therefore, it can continue to function as a precursor of the plaque matrix, as a direct source of acid that causes demineralization of the tooth, and as a raw material for plaque storage products, which can later be degraded to acids.

Oral Clearance

An important dietary factor in the formation of caries is the duration of time the carbohydrate remains in the mouth and is capable of interacting with dental plaque.

The duration is partly dependent upon the stickiness or retentiveness, of the food consumed.

The physical form of the carbohydrate determines its retentiveness, and thus appears to be a major factor in determining the cariogenicity of the diet. In the famous Vipeholm study, Swedish investigators rated the oral clearance of several sucrose-containing foods. They then selectively added them to the diet of institutionalized individuals and studied their caries activity for five years (Gustafsson et al., 1954). When the inmates' standard diet was supplemented with sugar in solution, which has a low retention quality, there was a minimal caries increase. When sticky candies such as toffee and caramel were added to the diet, the subjects experienced a marked increase in caries activity. Sugar supplements with intermediate oral clearance were associated with moderate levels of caries increase.

Frequency of Eating

The third factor associated with the cariogenicity of foods is the frequency with which they are consumed. A quantity of carbohydrate consumed during several snacking sessions is potentially more cariogenic than if the same amount were consumed at a single session. This is believed to be related to the change in plaque pH that accompanies ingestion of fermentable carbohydrates.

The pH of dental plaque is normally close to neutrality. When a fermentable carbohydrate is ingested, there is a rapid drop in pH to approximately 5.0 at which time acid dissolution of the tooth can occur (Stephan, 1940).

The pH remains at this level for approximately 20 minutes and then gradually returns to its preingestion level. Frequent snacking results in repetitive drops of the plaque pH and, therefore multiple attacks at the plaque-tooth surface interface.

The interaction between plaque and ingested carbohydrate is demonstrated in Fig. 7. The resting pH of the plaque on the left and right maxillary incisors was measured. Rinsing with a 10% solution of glucose produced an immediate drop in pH followed by a gradual return to baseline levels. The left tooth was then brushed, removing most of the plaque, and the patient again rinsed. There was a minimal fall in pH on the tooth in which the plaque had been dispersed, whereas a low acid pH was again recorded for the plaque on the unbrushed tooth (Kleinberg, 1970).

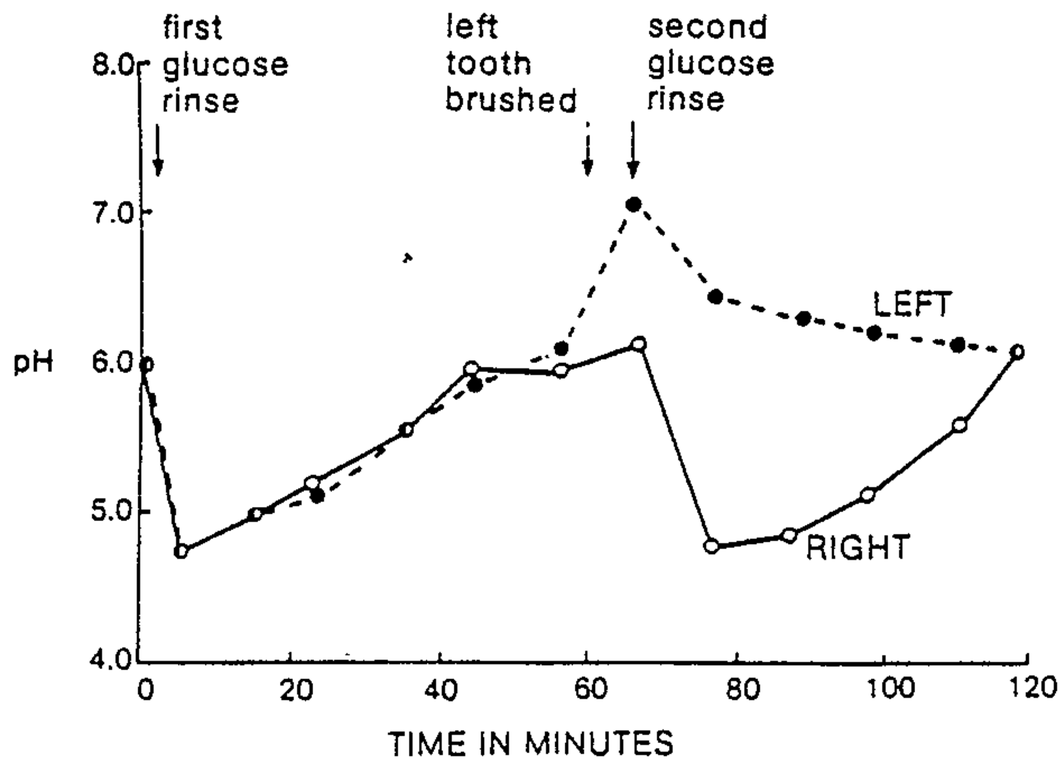

Fig. 7. Changes in pH of the dental plaque following rinsing with a 10% solution of glucose. The dispersal of plaque by brushing alters the pH curve.
(Modified from *Kleinberg*, 1970)

3. ANTICARIES MECHANISMS OF FLUORIDE

The mechanisms by which fluoride increases caries resistance may rise from both systemic and topical applications of fluoride and can broadly be grouped as follows:

1. Increased enamel resistance
2. Increased rate of maturation
3. Remineralization of incipient lesions
4. Interference with microorganisms
5. Improved tooth morphology.

1. INCREASED ENAMEL RESISTANCE

Physio-chemical Basis

Dental caries is a disease involving dissolution of enamel by acids from bacterial plaque and that dissolution is inhibited by the presence of fluoride. Because fluoride forms fluorapatite, a less soluble mineral, it has long been thought that the anticaries effect of fluoride is the result of reduced solubility and that a greater amount of fluorapatite results in a greater solubility reduction.

When enamel is exposed to a pH of about 5.5 or lower it will dissolve according to the following equation:

$$Ca_{10}(PO_4)_6(OH)_2 + 8H^+ \rightarrow 10Ca^{++} + 6HPO_4^{=} + 2H_2O$$

Because dissolution ordinarily occurs beneath a bacterial plaque, the concentration of calcium, phosphate, and other ions in the solution will increase. When the plaque stops producing acid (H^+), the pH rises and the amount of dissolved

mineral the solution can hold will diminish. This results in the precipitation of some of the mineral. Calcium, phosphate, and other ions originally present in the plaque will add to those dissolved from the enamel and affect the pH at which precipitation begins and also the types of compounds formed. Thus, carious dissolution of enamel can be seen as a cyclic phenomenon consisting of phases of demineralization and reprecipitation that are determined by changes in the pH and ionic concentrations within the plaque and the lesion.

The presence of fluoride in the dissolution medium effectively reduces the solubility of the enamel by promoting the precipitation of hydroxyapatite and by preventing the formation of more soluble calcium phosphate minerals. In addition to fluorapatite already present in the enamel, more fluorapatite may also form.

$$\underset{\text{hydroxyapatite}}{Ca_{10}(PO_4)_6(OH)_2} + 2F^- \rightarrow \underset{\text{fluorapatite}}{Ca_{10}(PO_4)_6F_2} + 2OH^-$$

It is claimed that the initial rate of dissolution of hydroxyapatite is the same as fluorapatite (Gray et al., 1962). However, the subsequent formation of secondary precipitates (such as calcium fluoride) on the surface of the enamel crystals reduces the rate of diffusion of hydrogen ions and of undissociated acid to the crystals, thus reducing their rate of solution.

$$Ca_3(PO_4)_2(OH)_2 + \underset{2\%}{NaF} \rightarrow CaF_2 + Na_3PO_4 + H_2O + NaOH$$

In a study by Masayuki et al. (1983) synthetic hydroxyapatite pellets were agitated in 0.5 M acetate buffer solutions containing various concentrations of fluoride at pH 4.0 and at 25°C to examine the behaviour of CaF_2 formation. This dissolution experiment found that the most sensitive information on CaF_2 formation could be obtained at 200 ppm F. X-ray diffraction and SEM analysis showed that the numbers of CaF_2 particles were increasing with the agitation time. Microradiography and electron microprobe analysis as a depth profile showed that after 3 hr agitation the apatite pellet surface was completely covered with CaF_2 particles, and the double layers of CaF_2 were formed.

Larsen et al. (1977) showed that the fluoride concentration curve, which was obtained from the experiment with the enamel apatite dissolved in the acidic solution containing fluoride, could be divided into three parts, and that the CaF_2 formed during the initial period was redissolved in the second period, and fluorapatite was formed during the second and third part of the investigation, while hydroxyapatite dissolved during the entire experiment. Thus, during longer incubations, it can be reasonable to consider that CaF_2 acts as a provider of fluoride ions.

Caries Resistance Related to Reduced Enamel Solubility

Fluoride can affect the solubility of enamel not only when it is acquired during enamel formation but also when it is given as a topical application. However, because the mode of acquisition is different, the effect may be different. For example, a high level of fluoride acquired

prior to eruption is more effective in slowing enamel dissolution in vitro than the same level acquired topically (Nicholson and Mellberg, 1969).

It has been shown that a small amount of fluoride in an acid solution can have a pronounced effect on hydroxyapatite (enamel) solubility. This can be explained by the finding that when hydroxyapatite is exposed to low fluoride concentrations (about 1 ppm), a layer of fluorapatite forms on the hydroxyapatite crystals. This thin layer causes the hydroxyapatite to act as though it were all fluorapatite governing the rate of dissolution (Brown et al., 1977).

Both of the hydroxyl groups in hydroxyapatite need not be replaced by fluoride for the hydroxyapatite to have a lower solubility. Moreno et al. (1974) found that the lowest solubility was attained when only 58% of the hydroxyl groups were replaced by fluoride.

Caries Resistance Related to Enamel Fluoride

A positive correlation of high enamel fluoride with caries resistance is also suggested by the caries history of subjects whose teeth were formed under the influence of fluoridated drinking water but who later moved to non-fluoridated areas. Deatherage (1943) found that subjects who moved from fluoridated water areas maintained some protection for as long as 20 years. Investigation of the residual anticaries effects of topical fluoride application has been carried out in only a few cases.

The deposition of fluoride in enamel from topical fluoride treatments varies considerably with the type of

fluoride and procedure, evaluation of the residual effects of those treatments expected to deposit a small amount of fluoride in enamel should be considered separately from those expected to deposit a large amount. Treatments not expected to deposit significant fluoride in sound enamel include dilute neutral fluoride, such as that used in mouth-rinses, and infrequent applications of more concentrated neutral sodium fluoride.

Post-treatment caries increments from several studies of this type have been reported. Knutson and Armstrong (1946) reported a positive residual effect, which appeared to increase with time up to three years after a short series of 2% NaF applications. Conversely, Sundvall-Hagland et al. (1959) found no residual effect from 2% NaF applications and, in fact, the treatment group had an increased caries rate after the first year. Bibby and Turesky (1947) applied 0.1% NaF to a very small group of subjects and reported that most of the protection was maintained for three years following the applications. Koch (1969, 1970) found no residual effect from a 0.5% NaF mouthrinse given once every two weeks for three years in school, but did find residual benefits after three years of daily use of a 0.1% dentrifice.

In contrast to the above studies, where the treatments were not likely to deposit much fluoride in sound enamel, several studies with acidic fluoride preparations, which deposit more fluoride in enamel, have demonstrated positive residual benefits. Englander et al. (1969) found that most of the benefit of a daily ApF gel (0.5% F) applied with custom fitted mouth trays was maintained for at least

two years. In the same study, they also used a neutral gel that was shown to deposit a relatively large amount of fluoride and found a large residual benefit. Horowitz and Kau (1974) used ApF solution and gel (1.2% F) once or twice per year for nine years and found some residual effect during the following five years. In contrast to these studies, Melberg et al. (1978) found no residual protection after a short series of ApF gel (1.2% F) applications in an area with fluoridated drinking water.

Value of Deeply Located Fluoride

In many areas on teeth the thickness of enamel may be 1,000 μ (1 mm) or more, but high fluoride concentrations are found only in the outer 30 to 50 μ. This is the case both when the teeth are formed in an area of optimal water fluoride or when the fluoride is acquired topically after eruption. The fact that high levels of fluoride in sound enamel normally are restricted to the outer region may be related to the extent of its protective effect. Yet it is at depth below 30 to 50 μ that the major initial loss of mineral occurs during caries formation. This is not to imply that fluoride in surface enamel has no effect on caries resistance, for it has been shown that the outer, relatively sound layer of enamel over the incipient lesion is thicker when fluoride concentrations are high.

Effect of Fluoride in Altered Enamel

Unsound enamel can acquire fluoride topically and thereby be made more resistant to acid. There are two types

of unsound enamel that fluoride can affect: developmental hypomineralised and acid demineralised. Developmental hypomineralised enamel are seen as small, opaque white areas of greater caries susceptibility. They are specific areas on the teeth that are less than fully mineralised upon eruption and therefore will acquire somewhat larger amounts of fluoride from topical exposure. Acid demineralised enamel also takes up more fluoride than sound enamel. Increased fluoride levels have been found in enamel defects, caries lesions, and under plaque where it is presumed that the plaque periodically provides an acid environment for the enamel.

2. INCREASED RATE OF MATURATION

It is common clinical experience that the resistance of teeth to caries appears to increase posteruptively with age and it is axiomatic that greater benefits are obtained by topical fluoride when it is administered shortly after eruption of the teeth. It has been thought that this is because newly erupted enamel is able to acquire more fluoride than older enamel and thus can be made more resistant to further caries attack. Also newly erupted enamel has areas where mineral deposition is not entirely complete. These hypomineralised areas may become fully mineralised within only a few months after eruption. In addition, hypomineralized areas that mature in the presence of fluoride should contain more fluoride than enamel that was fully mineralized upon eruption. These areas will therefore be made more resistant to acid.

3. REMINERALIZATION OF INCIPIENT LESION

Incipient lesions of enamel, generally known as white spots, have long been recognized as an early clinical stage of dental caries. G.V. Black, the father of modern dentistry, has been credited with saying, 'He who understands the white spot of enamel understands dental caries'. Studies on remineralization were done as early as 1912 by Head and 1921 by Andresen, but modern research began in the 1960s with the work of Koulouride and Pigman, Van der Fehr, Backer-Dirks, and others.

Essentially it was stated that incipient lesions (white spots) were opaque, white areas on the enamel having a relatively sound surface but with substantial mineral loss 30 to 50 μ below the surface. When the environment of the lesion was cariogenic, as under appropriate plaque, the demineralization continued until a cavity formed. However, if the environment was changed to allow free access to saliva, the lesion often became arrested or actually disappeared because of redeposition of mineral within the lesion (Remineralization). A brown colour, resulting from the presence of organic material, is usually associated with an arrested lesion.

Fluoride or calcium phosphate mouthwashes were used by several investigators to arrest or remineralize white spot lesions. Muhler (1960) pointed out that a reversal rate of 2 to 3% occurred after topical application of water, but the rate was 22 to 25% after application of stannous fluoride. He stated that areas of teeth previously considered carious had changed from chalky white and soft to pigmented

and hard and furthermore had not increased in size.

Effect of Fluoride on Remineralization

Fluoride enhances the rate of remineralization from calcium phosphate solution. Even in minute amounts it increases the rate of precipitation of hydroxyapatite where the formation of the more soluble octacalcium phosphate would otherwise be favoured. Remineralization of etched surfaces is accelerated by as much as four to five times by only 1 ppm F, and remineralization of white spots may be increased twofold. Fluoride has been shown to increase mineral deposition in sound enamel, and remineralization was increased by topical fluoride applications to etched enamel prior to exposure to calcium solutions or to the environment.

Weatherell et al. (1972) found that fluoride in the gingival area of the enamel increased with age whereas in other areas there was no such increase. He suggested that this was due to acid attack followed by remineralization in areas frequently covered by fluoride rich plaque.

Effect of Plaque on Remineralization

The plaque acts as a barrier to the treatment contacting the teeth, and it can act as a reservoir for acid and calcium phosphate dissolved from the enamel. It also can act as a reservoir for remineralizing agents, concentrating them near the lesion surface. The plaque may inactivate the agents, for example, by complexing or reacting. In the case of fluoride, bacteria may actually take the fluoride into

cell-faster under acidic conditions, when it is needed most for countering cariogenic demineralization. As a reservoir plaque usually contains much higher concentrations of fluoride, calcium and phosphate than saliva.

4. INTERFERENCE WITH MICROORGANISMS

Fluoride can affect microorganisms in several ways. At low fluoride concentrations it inhibits acid formation. At higher concentrations it can affect growth and metabolism; and at very high concentrations it is lethal. Jenkins (1959) found that the inhibition of bacterial acid production by microorganisms is greater at low pH. This is fortunate, since the fluoride will be most active when the conditions are most cariogenic.

Inhibition of bacterial growth and metabolism is related, at least in part, to the effect of fluoride on enzymes. The enzyme most sensitive to fluoride during the formation of acid is enolase. It also has been suggested that the primary fluoride activity is the inhibition of glucose transfer across the cell wall.

In vivo evidence for an effect of fluoride on salivary organisms has also been obtained. The formation of lactic acid from sugar was reduced for 10 to 20 minutes following rinses with 0.1% to 0.5% NaF (Ericsson and Hellstrom) and the number of viable microorganisms in whole saliva diminished for several hours after rinsing with 0.1% to 0.5% SnF_2. Brushing with monofluorophosphate dentrifice (0.1% F) reduced the number of salivary streptococci in the mouth, and topical 1% sodium fluoride applications decrease the lactobacillus

count to one-sixth of pretreatment levels, an effect that persisted to some degree for as long as 24 days.

Fluoride Concentrations in Plaque

Wide variations of fluoride concentrations in plaque have been reported. However most of the recent studies report concentrations in dried samples to be within the range of 25 to 50 ppm F. The distribution of fluoride in plaque apparently is not uniform since its concentration is related to the thickness of deposit. Thick or heavy plaques usually have a lower fluoride concentration than thin plaques (Birkland et al., 1971). This may be related to the rate of plaque growth or slow rate of fluoride diffusion from the surface inwards. Whatever the reason, it suggests that the concentration may be lower near the enamel surface where its presence would be most beneficial during a caries attack.

The concentration of fluoride in plaque from communities with fluoridated drinking water is about twice as high as in non fluoride communities. After use of fluoride mouthrinses or dentrifices, it can reach 100 ppm for periods of minutes, although it may remain elevated for several hours or more.

Taken as a whole, these findings indicate that the concentration of fluoride in plaque is not sufficient to render it totally non pathogenic, but that it may contribute to the anticaries activity of the agent. Because of the nature of antibacterial effects, fluoride will be more effective as its concentration and frequency of use are increased.

5. IMPROVED TOOTH MORPHOLOGY

The areas of the teeth most susceptible to dental caries are the occlusal surfaces, and those with deep fissures are considered to be the most prone to caries. Studies of the effect of water fluoridation on tooth size and shape have suggested that fluoride tended to make the teeth slightly smaller (Cooper and Ludwig, 1965) and more important to give them shallower fissures (Lovius and Goose, 1969). The reduction in fissure size associated with water fluoridation is modest; consequently, the effect on dental caries by this mechanism is questionable. However, a study of the use of systemic fluoride supplements indicated an anticaries effect due to altered tooth morpholody, although the assessment of the fissures was subjective.

Delay of eruption has been demonstrated in man, but at fairly high concentrations of 2.5 ppm F (Short, 1944; Adler, 1951). However at 1 ppm differences in eruption patterns are smaller or insignificant both in the permanent dentition (Kunzel, 1971; or Binder, 1972) and in the deciduous dentition (Tank and Storwick, 1974; Castaldi et al., 1969).

An increase in enamel fluoride level may occur when fluoride is made available shortly before eruption, but an effect on fissure morphology probably requires fluoride exposure during an earlier stage of crown formation. A summary of the anticaries mechanisms provided by the different treatment forms is given in Table 1.

Table 1 Possible anticaries mechanisms of fluoride therapy forms

Mechanism	Supplement	Dentifrice	Rinse	Frequent topical	Annual topical	Prophylaxis paste
Increased enamel resistance	+	O	O	+	+	+
Remineralization	+*	+	+	+	O	O
Antibacterial	+*	+	+	+		
Improved morphology	+					

+ Significant effect possible. O Effect possible on incipient lesions * From F tablets if chewed and swished.

Source: Mellberg and Ripa, 1983

4. FLUORIDE MOUTHRINSES

4.1 BACKGROUND OF FLUORIDE MOUTHRINSES

A mouthrinse may be defined simply as a substance that is swished around the oral cavity and then expectorated in order to freshen the mouth and breath. Thus, its purpose is primarily cosmetic. The most popular form is a liquid, although mouth rinse troches, lozenges, concentrates, and sprays are also available. In the case of the liquid mouth rinses, the material may be introduced into the oral cavity in either a full strength or a diluted form.

The basic ingredients in a liquid mouth rinse formulation are water, alcohol, flavouring oils, and colouring materials. Other components may include humectants, astringents, emulsifiers, antimicrobial agents, sweeteners, and therapeutic substances.

A therapeutic mouth rinse can be defined as a formulation containing a drug substance and used to transfer this drug substance to the hard and soft tissues of the oral cavity. This drug substance then imparts a chemical, physiologic or pharmacologic action that is manifested clinically as a reduction in the incidence of plaque, caries, calculus or gingival disease.

The idea of using fluoride in a mouth rinse is not new. In the 1940s, only a few years after the first controlled community water fluoridation studies began, Bibby and others conducted a clinical trial in which dental students rinsed with an acidified sodium fluoride solution. Although

use of the rinse failed to have an effect on caries, possibly because of the low concentration of fluoride, the concept of a fluoride containing therapeutic mouth rinse was born. Further reports of fluoride rinsing, however did not appear in the American literature for more than a decade. In 1960, Weisz, a practising paedodontist, reported success with a sodium fluoride mouth rinse that was used by his patients at home. However the amount of fluoride used in the rinse was considered by the American Dental Association to be too high and, therefore, unsafe for home use.

In 1965, Torell and Ericsson reported the results of a large clinical trial in which several groups of school children were exposed to different topical fluoride treatments. Two groups used fluoride mouth rinses. One rinsed daily at home, without strict supervision, using a 0.05% sodium fluoride solution. The other rinsed once every two weeks at school, under supervision, with a 0.2% sodium fluoride solution. The caries reduction after two years of rinsing was considered statistically significant for both groups of children when compared with the caries activity of children who received no fluoride treatment. This study became a classic in the field. Although many other clinical mouth rinsing trials have been conducted, especially in the Scandinavian countries and United States, the rinsing regimens that have been adopted and the concentration of fluoride in the rinse solutions have usually been similar or identical to those tested by Torell and Ericsson. A summary of some of these clinical studies is presented in Table 2.

TABLE 2 CLINICAL INVESTIGATIONS CONDUCTED WITH MOUTH RINSES CONTAINING FLUORIDES

INVESTIGATOR(S)	MATERIAL UTILIZED*	CONCLUSIONS
McCormick and Koulourides, 1965	NaF (3–40 ppm F^-) plus calcium and phosphate	Daily rinsing for one year produced significantly less interproximal caries in Grade 1 and 2 children
Torell and Ericsson, 1965A	NaF (226 ppm F^-)	Daily rinsing for two years produced a 50% DMFS caries reduction in 10-year-old children
	NaF (904 ppm F^-)	Rinsing every two weeks for two years produced a 21% DMFS caries reduction in 10-year-old children
Kasakura, 1966	NaF (452 ppm F^-)	Daily rinsing for two years produced a 60% DMFT caries reduction in Grade 4 children
Koch, 1967	NaF (2260 ppm F^-)	Rinsing every two weeks for three years produced a 23% DMFS caries reduction in 10-year-old children
Torell, 1969	NaF (904 ppm F^-) plus $CaCO_3$ 0.8% sodium monofluorophosphate dentifrice used daily at home	Rinsing every two weeks for 2½ years in conjunction with daily use of the fluoride dentifrice produced significantly less caries than use of the fluoride rinse alone
Gerdin and Torell, 1969	0.2% KF + $MnCl_2$ 0.2% NaF + $MnCl_2$ 0.2% NaF	Weekly rinsing for four years indicated that the KF + $MnCl_2$ rinse produced significantly less caries than the other two rinses in 9- to 13-year-old children
Swerdloff and Shannon, 1967	0.1% SnF_2 (250 ppm F^-)	Daily rinsing for five months established the feasibility of using this rinse and produced a non-significant DMFT caries reduction in school children
Horowitz, Creighton, and McClendon, 1971	NaF (904 ppm F^-)	Weekly rinsing for 20 months produced a 44% DMFS caries reduction in Grade 5 children and a 16% reduction in Grade 1 children
Frankl, Fleisch, and Diodati, 1972	NaF (200 ppm F^-) pH 4.0	Daily rinsing for two years produced a 25% DMFS caries reduction in 14-year-old children
Aasenden, DePaola, and Brudevold, 1972	NaF (200 ppm F^-) NaF (200 ppm F^-) pH 4.0	Daily rinsing for three years produced a 27% DMFS caries reduction (neutral rinse) and a 30% reduction (acidulated rinse) in 8- to 10-year-old children
Brandt, Slack, and Waller, 1972	NaF (904 ppm F^-)	Twice weekly rinsing for two years produced a 36% DMFS caries reduction in 11-year-old children
Moreira and Tumang, 1972	NaF (452 ppm F^-)	Weekly rinsing for two years produced a 35% DMFS caries reduction and three times weekly rinsing produced a 36% reduction in 7-year-old children
Radike, Gish, Peterson, King, and Segreto, 1973	0.1% SnF_2 (250 ppm F^-) Fluoridated Water	Daily rinsing for two years produced a 33-43% DMFS caries reduction in 8- to 13-year-old children
Rugg-Gunn, Holloway, and Davies, 1973	NaF (226 ppm F^-)	Daily rinsing for three years produced a 35% DMFS caries reduction in 11- to 12-year-old children
Gallagher, Glassgow, and Caldwell, 1973	NaF (1808 ppm F^-)	Weekly rinsing for two years produced a 27% DMFT caries reduction in 11- to 13-year-old children
Heifetz, Driscoll, and Creighton, 1973	NaF (0.3% F^-) NaF (0.3% F^-) pH 4.0	Weekly rinsing for two years produced a 38% DMFS caries reduction (neutral rinse) and a 27% reduction (acidulated rinse) in Grade 7 and 9 children
Forsman, 1974	NaF (113 ppm F^-) NaF (904 ppm F^-)	Weekly rinsing for two years produced significant caries reductions for both rinse groups, with the lower level of fluoride providing a somewhat better effect

*All rinses are essentially neutral, unless otherwise indicated.

Source: Stallard, 1982

The data indicates that mouth rinses containing sodium fluoride (at various concentrations and frequencies of use) are safe and effective with regard to reducing the incidence of caries. These trials have been sufficiently favourable for dental public health officials to adopt fluoride mouth rinsing as the main alternative to water fluoridation in community prevention in many areas of the world, e.g. Sweden, Norway, Denmark, Cuba and Eire.

4.1.I Self-Applied Fluoride Programs in Schools

For the past two decades, considerable research has been conducted on the use of fluoride tablets or fluoride mouth rinses in schools. Because children attend school regularly and therefore are readily available and because schools operate on a more rigid schedule than do individual families, schools are a logical place for administering self-applied fluoride to children. Self-applied fluoride programs in schools have the following advantages:

1. The procedures have been proved effective in reducing tooth decay.
2. They involve little time.
3. The techniques of rinsing or using tablets are easy to learn.
4. Few materials and supplies are required; thus, these programs are inexpensive.
5. Non-dental personnel with minimal training can easily supervise the procedures.
6. The procedures can be administered easily with minimal interruptions of a school's academic program.

Outline for determining the appropriate self-applied fluoride program for use in schools is described in Table 3.

An important step in initiating a self-applied fluoride program is to obtain necessary local support for the program from such sources as the school board, superintendent of schools, the board of health, local dental society, principals, teachers and the local health officer. It is also useful to have the support of other local health societies such as medical, nursing, dental hygiene, dental assisting, pharmacy and parent/teacher groups. A consent form or permission slip signed by a parent or guardian must be received before a child can be enrolled in a self-applied fluoride program.

Rinsing should begin in kindergarten and extend to the highest grade level within the school system. While the participation and cooperation of children in the lower grades is usually excellent, De Paola and Soparker have emphasized that a rinsing program at the high school level is frequently fraught with logical problems, poor participation, and indifference on the part of many of the students.

The rinse itself may be purchased already prepared, as a concentrate to which tap water is added, or as pre-measured packet of powder that must be mixed with the appropriate volume of tap water. Other materials needed for rinsing are bottle equipped with pumps calibrated to dispense 5 or 10 ml of solution, disposal bags, and a paper cup and napkin for each participant.

TABLE 3

OUTLINE FOR DETERMINING THE APPROPRIATE SELF-APPLIED FLUORIDE PROGRAM FOR USE IN SCHOOLS *

Level of fluoride in water supply	Recommended Procedure		Comments
	Tablets (Daily)	Mouthrinse ** (Weekly)	
0.0 - 0.39 ppm	√ 1 mg. fluoride	√	Children who live in areas with insufficient levels of fluoride in water should receive dietary supplements (tablets) in grades K-8 and fluoride mouthrinses in grades 9-12 or, if a tablet program is not feasible, fluoride mouthrinses for all grades, K-12.
0.4 - 0.69 ppm	√ 0.5 mg. fluoride	√	See above. If fluoride level is 0.7 and above, dietary supplements (tablets) should not be provided.
Optimally fluoridated, but not for sufficient time to provide adequate protection to all children		√	Children who have not had optimally fluoridated water since birth should receive protection of fluoride rinses.
Optimally fluoridated, but schools have a high proportion of students who either have transferred from fluoride-deficient areas or who currently reside where only trace levels of fluoride exist		√	Many communities with mobile populations have initiated a fluoride rinse program to provide protection for students who have moved from non-fluoridated areas. Continuous residents are likely to benefit as well (see below).
Optimally fluoridated		?	Limited research suggests that students may benefit from the added protection of a fluoride mouthrinse.

* General guide only, the ultimate decision must be determined by a knowledgeable dentist or physician based upon local needs.
** 0.2 percent neutral sodium fluoride solution.

Source: U.S. Public Health Service
Reference: DHEW Publication No. (NIH) 77-1196 (1977)

If a prepared rinse in unavailable, the fluoride solution must be mixed. A 0.2% NaF solution is prepared by combining 3 g NaF with 1,500 ml of tap water. If stored in a plastic, rather than a glass container, the fluoride will not become chemically inactivated. However, storage of a fluoride solution prepared from tap water gives it a stale or 'flat' taste that is less acceptable to the rinsing participants and more likely to induce nausea. In addition, non pathogenic air-born fungus can settle in the bottles and pumps when the rinse is alternatively stored and reused. It is advisable, therefore, to prepare a fresh solution on each morning that rinsing is scheduled.

The mixed NaF solution can be dispensed into disposable paper cups and taken on carts to the individual classrooms, or one dispensing bottle can be brought to each classroom and the cups filled there. In each classroom, the names of the children whose parents have provided written consent to participate are called. Each child receives 10 ml of fluoride rinse and a paper napkin. Kindergarten children receive 5 ml solution. Rinsing is timed for 60 seconds, usually by the classroom teacher. The children do not brush their teeth prior to rinsing. During rinsing, the teacher reminds the children to swish the solution vigorously between their teeth and not to swallow it. After 60 seconds, the children expectorate back into the paper cups, wipe their mouth with the napkins, and stuff them into the paper cups to absorb the solution and saliva. The cups and napkins are then collected in a disposal bag that is deposited in the classroom waste basket. The total time for classroom rinse

is approximately 5 minutes. Children are asked not to eat, drink, or rinse for one-half hour. After rinsing, the materials are collected and stored in a locked area of the school. Considering such factors as vacations, holidays, and time to initially locate the children in their new classrooms at the beginning of the school year, approximately 30 weekly rinses can be accomplished during an academic year.

However, the use of dental service personnel for a supervisory role in rinsing and fluoride tablet programs would definitely mean higher costs in terms of transport to supervise the procedure if the program is to reach every primary school on each island in the country.

4.2 DIFFERENT METHODS OF FLUORIDE MOUTHRINSING

Self-application of fluoride by rinsing has gained popularity as a relatively easy method of providing frequent topical fluoride contact to the teeth. The two principal fluoride rinsing methods, low potency/high frequency and high potency/low frequency, are described.

Rinsing can be recommended as part of a home-based individual caries prevention program or as a school based group preventive program. The fluoride concentration and the frequency of rinsing are often different for these two types of programs. There are several marketed rinses available. Most are meant to be swished and expectorated, but some can be swished and swallowed. Summary of fluoride rinse and expectorate techniques are given in Table 4.

TABLE 4. Summary of fluoride rinse and expectorate techniques

Rinsing method	Program	Fluoride concentration			Type of fluoride*	Rinse frequency	Usual dose	
		% NaF	% F	ppm F			Volume	F
Low potency/ high frequency	Individual home-based	.044	.0198	198	APF	daily	5 ml (1 tsp)	1 mg
		.05	.0225	225	NaF	daily	5 ml (1 tsp)	1 mg
High potency/ low frequency	Group school-based	.2	.0900	900	NaF	weekly	10 ml (2 tsp)	9 mg

* APF indicates acidulated phosphate fluoride; NaF indicates sodium fluoride.

Source: Ripa, 1981

Concentration and Frequency

More than a dozen fluoride concentrations have been clinically tested. The range is wide, from a low of 45 ppm F (0.01% NaF) to a high of approximately 3,000 ppm F (0.66% NaF). Rinse concentrations of 250 ppm F or less have been arbitrarily designated low potency rinses; greater concentrations are called high potency rinses. The most commonly used low potency neutral sodium fluoride has a 0.05% NaF concentration (225 ppm F) and the low potency acidulated phosphate fluoride rinse has a 0.044% NaF concentration (198 ppm F). Conversely, the most commonly used high potency rinse has a 0.2% NaF concentration (900 ppm F). For comparison, the standard acidulated phosphate fluoride solution or gel used for professional topical fluoride application in the dental office has a concentration of 12,000 ppm F.

The frequency of rinsing also varies widely, from three to four times a year to twice a day. However, the two most common frequencies are once a day, designated a high frequency rinsing program, and either once a week or once every two weeks, called a low frequency rinsing program.

The two most common fluoride rinsing techniques combine the two variables, fluoride concentration and rinsing frequency with the low potency/high frequency technique or high potency/low frequency technique. A neutral 0.2% NaF is used in these programs. Table 5 shows the composition of the fluoride solution used for the rinses.

TABLE 5. Composition of the fluoride solution used for the rinses

	mg per litre
Sodium fluoride	2,000.0
Gum arabic	4.7
Oil of peppermint	3.1
Alcohol	1.6
Methyl paraoxybenzoate	< 0.1

Source: Poulsen, Gadegaard and Birte Mortensen, 1981

Low Potency/High Frequency Technique

This is the method recommended for home use. Fluoride rinsing is indicated for patients who are caries active; for orthodontic patients with banded, bonded or removable appliances; and for patients with reduced salivary flow whose teeth are highly susceptible to decay. Patients living in either fluoride-deficient or optimally fluoridated communities can take part in this program.

This technique uses either a neutral 0.05% NaF rinse or an acidulated phosphate fluoride (0.044% NaF) rinse. The patient is directed to use the solution once a day, usually before bed time. Either 1 or 2 teaspoons (5-10 ml) are recommended. The patient swishes the solution for a minute, applying intermittent pressure with the cheek and lip musculature to force the solution into contact with all of the tooth surfaces. The solution is then expectorated.

Because young, preschool children might swallow rather than expectorate much of the solution this technique is generally contra-indicated for children younger than 5 or 6 years.

Most of the low potency rinses contain colouring and flavouring agents to make the product more attractive to the consumer. Additionally, they usually contain preservatives to inhibit bacterial growth. These products cannot be used for patients on additive-free diets.

Low potency fluoride rinse may be dispensed from the dental office for home use. Commercial low potency rinses may be purchased from a pharmacy, or a pharmacist may be directed to compound a rinse solution. Recently, low potency rinses have become available to the public without prescription.

High Potency/Low Frequency Technique

High potency/low frequency technique is the method usually used for school-based programs. This method of caries prevention is accepted as effective with a general caries inhibition of 30% to 50% after prescription for two or more years in the program. Fluoride rinsing appears effective both in the fluoride-deficient and optimally fluoridated communities.

Only children who return a consent form signed by a parent or guardian can participate in a school-based rinse program in some countries. Rinsing can be conducted at all grade levels within a school system. During a school year, about 30 weekly rinses can be scheduled. High potency

rinses are dispensed at school to implement a school-based program.

Oral Fluoride Rinse Supplement

There are dietary fluoride supplements, like fluoride tablets or drops, but available as a rinse. These products are meant to be swished to produce a topical effect to the erupted teeth and then swallowed to produce a systemic effect to teeth that have not yet erupted. The patient rinses daily with an oral rinse supplement. After rinsing for a minute, he or she then swallows. A teaspoon provides 1 mg of fluoride, which is the equivalent of a standard sodium fluoride tablet. Ideally oral rinse supplement could be used in the same circumstances that fluoride tablets are used, although not simultaneously. Rinse supplements can be started at age 3.

The need for systemic fluoride supplements and the appropriate dose are determined by the patient's age and the concentration of fluoride in the drinking water. As Fig. 8 shows oral rinse supplements are only indicated for children 3 years and older who reside in communities with 0.7 ppm F or less in water. When the level of fluoride in drinking water is less than 0.3 ppm, the patient is instructed to rinse daily and to swallow 1 teaspoon of oral rinse supplements. This provides the recommended daily allowance of 1 mg fluoride. When the level of fluoride in the drinking water is 0.3 to 0.7 ppm, the patient is instructed to rinse daily and to swallow half teaspoonful, which provides 0.5 mg F.

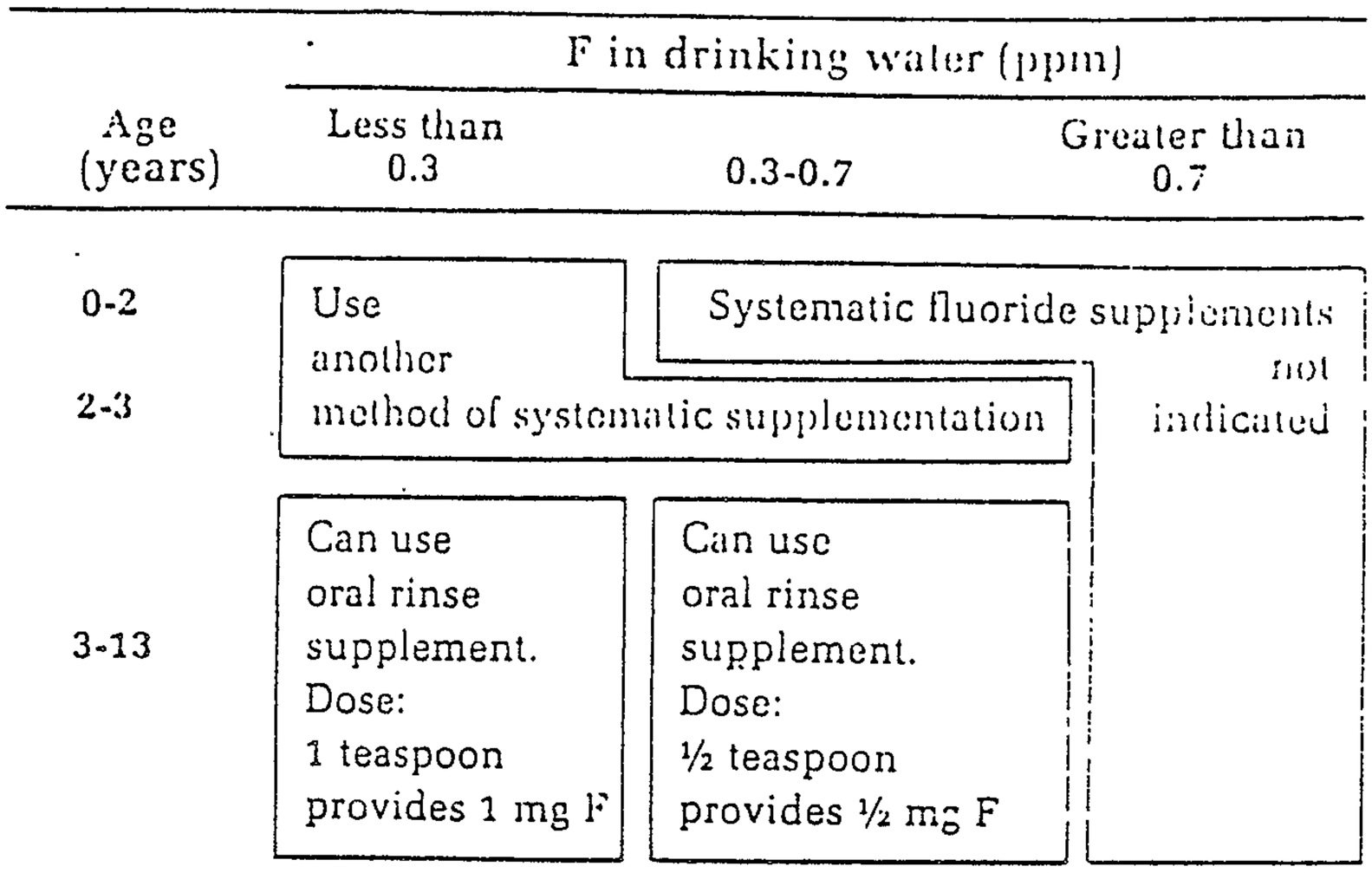

Fig. 8. ▪ Indications for oral rinse supplements.

Source: Ripa, L.W.- 1981

Ringelberg and co-workers (1982) tested the effect of different concentrations and frequencies of sodium fluoride mouthrinses within a study population of 2,014 students in Polk County, FL. Five study groups were assigned as follows: a daily 0.05% mouthrinse, a weekly 0.2% mouthrinse, or a weekly placebo mouthrinse. After two years, there was a significant difference in mean incremental DMFS between the daily 0.05% group and the control. There was also a significant difference in mean incremental proximal surfaces between both the weekly 0.2% and daily 0.03% with the control. When the study groups were combined by similar frequency or concentration, there were significant differences for all groups from the control. No differences were found between different concentrations and the same frequency or

between different frequencies at the same concentration.

4.3 EFFICACY RELATED TO TYPE OF FLUORIDE COMPOUNDS USED

Sodium fluoride has been the most frequently tested fluoride compound: such solutions would tend to have a neutral pH. Two early studies (Bibby et al., 1946; Roberts et al., 1948) suggested that acidified sodium fluoride solution was ineffective in preventing caries. It was not until Brudevold et al. (1963) had shown that acidulated phosphate fluoride (APF) solutions were likely to prevent caries that these solutions, with low pH, were tested as mouthrinses. Few trials have provided direct comparisons of NaF and APF mouthrinses. The trial of Heifetz et al. (1973) indicated that NaF was slightly more effective but the difference between NaF and APF was not statistically significant (Table 6). It can be concluded that APF mouthrinses have not been shown to be superior to those containing NaF.

Stannous fluoride-containing mouthrinses have been tested in a few trials. They do not appear to be superior to NaF-containing rinses. DePaola et al. (1977) compared directly a daily rinse containing ammonium fluoride (NH_4F, pH 5.0) with a NaF rinse acidulated to pH 4.4, caries reductions were high and virtually the same (42 per cent and 41 per cent, respectively). Likewise, caries reductions after using a daily mouthrinse containing amine fluoride appeared to be as effective as a rinse containing NaF at neutral pH - 22% and 23%, respectively (Ringelberg et al., 1978).

Table 6 Effect of neutral sodium fluoride mouth rinses on the permanent teeth of children residing in fluoride-deficient communities

Study	Initial age (years) of subjects	Rinse concentration	Rinsing frequency	Duration of study	Percent reduction* DMFT	DMFS
Koch	9–11	0.5% NaF	3-4 times/year	3 years		18
Padron & Maiwald	6–7	0.2% NaF	once/2 weeks	28 months		47
	8–9					32
	10–11					28
	12–13					11
Torell & Ericsson	11	0.2% NaF	once/2 weeks	2 years		21
Koch	9–11	0.5% NaF	once/2 weeks	3 years		23
Moreira & Tumang	7	0.1% NaF	once/2 weeks	2 years		23
Koch	10	0.5% NaF	once/2 weeks	3 years	20	25
Kann	6–16	0.2% NaF	once/2 weeks	2 years		30
Birkeland	8	0.2% NaF	once/2 weeks	6 years		31**
Lundstam	6–15	0.2% NaF	once/2 weeks	9 months		36
Bennie et al.	6	0.2% NaF	once/2 weeks	5 years	49	42
Fjaestad-Seger et al.	5–9	0.2% NaF	once/2 weeks	1 year		58
Forsman	10–12	0.2% NaF	once/2 weeks	2 years		80
Horowitz et al.	6	0.2% NaF	once/week	20 months	25	16
	11	0 2% NaF	once/week	20 months	52	44
Ripa et al.	5–13	0.2% NaF	once/week	2 years	20	20
Ringelberg et al.	8–12	0.2% NaF	once/week	2 years	21	22
Moreira & Tumang	7	0.1% NaF	once/week	2 years		25
Gallagher et al.	11–13	0.4% NaF	once/week	2 years	34	34
Heifetz et al.	10–12	0.66% NaF	once/week	2 years		38
Petchel & Mello	5–13	0.2% NaF	once/week	2 years	50	
Brandt et al.	11.5***	0.2% NaF	twice/week	2 years		39
Moreira & Tumang	7	0.1% NaF	3 times/week	2 years		47
Ringelberg et al.	11	0.05% NaF	once/day	18 months	11	11
	11	0.05% NaF + SnF_2 dentifrice	once/day	18 months	9	11
Aasenden et al.	8–11	0.05% NaF	once/day****	3 years	26	27
Rugg-Gunn et al.	11–12	0.05% NaF	once/day	34 months	32	36
Torell & Ericsson	11	0.05% NaF	once/day	2 years		49
Kasakura	10–11	0.25% NaF	once/day	2 years		80
Weisz	5–9	0.25% NaF	twice/day	2-10 years		80–90

*Based on caries incidence or prevalence data.
**Compared to self-brushing 4-5 times per year with 0.5% NaF solution.
***Mean age.
****Rinse and swallow.

Source: Mellberg and Ripa, 1983

The possibility of enhancing the effectiveness of NaF mouthrinses by the addition of ions such as Al, Mn, Fe, Mg, Zr and K has been studied by Swedish research workers for over 20 years. Although some results suggest effectiveness may be increased by the presence of various combinations of the above ions, their superiority to simple NaF mouthrinses has not been established. In summary, alternative compounds to NaF have a less pleasant taste, and have not been shown to be more effective than neutral NaF solution. Sodium fluoride therefore, is the compound of choice at present.

4.4 EFFECTIVENESS OF FLUORIDE MOUTHRINSES ON THE PRIMARY DENTITION

In 1975, the council on Dental Therapeutics of the American Dental Association stated that both neutral sodium fluoride and acidulated phosphate fluoride rinses were 'effective agents for use in reducing the incidence of dental caries'. The conclusion of the council was based upon a review of 19 clinical trials in which the effect of mouthrinsing on the permanent teeth was assessed. No trials of the effect of mouthrinsing on the primary dentition were included in the councils review. This is not surprising since, at that time, no such reports were available.

In the same year, the National Institute of Dental Research sponsored 17 demonstration programs throughout the United States in which approximately 80,000 school children were to rinse once a week with a neutral 0.2% sodium fluoride solution. Since children in the kindergarten through sixth

grade were participants of the program, an opportunity was afforded to assess the impact of fluoride rinsing on primary teeth. After two years, a 20% reduction in caries prevalence (dfs/child) of the primary teeth was reported.

Glass and co-workers (1970) have demonstrated that when caries in the primary dentition of progressively older children is analyzed by df surfaces per subject (dfs/child), a distortion of the true caries situation can occur because the number of subjects, reflected in the denominator of the equation, remains constant while the number of teeth or surfaces at risk to decay, which is reflected in the numerator, decreases from exfoliation. However, if caries were analyzed according to the number of tooth surfaces at risk (dfs/100), the caries rate do not appear to be influenced by the exfoliation phenomenon.

Birkeland and co-workers (1977) evaluated the effectiveness of fluoride rinsing on the primary dentition based upon changes in dental treatment needs in Norwegian school children. Although there was a decrease in the number of primary teeth requiring extractions during a 3-year period, the data for the number of teeth requiring filling were equivocal.

Horowitz and co-workers (1977) evaluated a school-based program involving daily ingestion of an acidulated phosphate fluoride tablet, weekly rinsing with a 0.2% NaF solution, and home use of a fluoride-containing dentrifice. After 2 years, these investigators reported only minimal differences and no consistent pattern when the caries

prevalence of the primary molars of six, seven, and eight-year-old participants was evaluated.

Ripa and Leske (1979), in their study found the caries prevalence reduction to the primary teeth after three years of weekly supervised rinsing with a 0.2% NaF solution failed to achieve the magnitude of reduction observed for the permanent dentition. After 2 years of rinsing, the reductions in caries prevalence in both the primary and permanent dentition were approximately 20%. After 3 years of rinsing, however, the reduction in caries prevalence for the permanent teeth was 40% compared to only 17% for the primary teeth in the same children. These results indicate that the effect of topical fluoride therapy to the primary teeth is less than that for the permanent teeth.

In the seven-year findings by Ripa et al. (1982), for almost every year of the rinsing program, there was a gradual decline in caries prevalence scores in the deciduous teeth of participating children. After seven years, the caries prevalence reduction from baseline was 42.5%. The greatest reduction occurred on proximal surfaces which is consistent with the known effect of topical fluoride (Tables 7 and 8).

Stooky (1966) has indicated that the caries reductions to the primary dentition from operator-applied topical fluoride treatments are generally lower than those reported for the permanent dentition. Based upon the results of Horowitz et al, Ripa et al. and Birkeland et al., the same seems to be true for self-administered fluoride rinses.

Table 7. Mean Carious Surface Prevalence Scores for the Deciduous Teeth of First, Second, and Third Grade Children at Baseline and After Participation in the Fluoride Mouthrinsing Program

	Grade One		*Grade Two*		*Grade Three*		*Grade One to Three*	
Examination*	$\bar{X}$ dfs/ child	Per cent Difference	$\bar{X}$ dfs/ child	Per cent Difference	$\bar{X}$ dfs/ child	Per cent Difference	$\bar{X}$ dfs/ child	Per cent Difference
Baseline (1975)	3.29	—	4.37	—	5.60	—	4.42	—
First year (1976)	3.55	+ 7.9	4.25	− 2.8	4.75	−15.2	4.18	− 5.4
Second year (1977)	2.68	−18.5	3.64	−16.7	4.27	−23.8	3.53	−20.1
Third year (1978)	2.68	−18.5	3.32	−24.0	4.27	−23.8	3.42	−22.6
Fourth year (1979)	2.63	−20.1	2.80	−35.9	3.51	−37.3	2.98	−32.6
Fifth year (1980)	2.64	−19.8	2.82	−35.5	2.89	−48.4	2.78	−37.1
Sixth year (1981)	1.87	−43.2	2.93	−33.0	2.99	−46.6	2.60	−41.2
Seventh year (1982)	1.70	−48.3	3.23	−26.1	2.70	−51.8	2.54	−42.5

* Examinations conducted in the fall, at the beginning of an academic year

Source: Ripa, Leske and Andre Varma, 1984

Table 8. Mean Caries Prevalence Scores of Site-Specific Deciduous Tooth Surfaces for First, Second, and Third Grade Children at Baseline and After Participation in the Fluoride Mouthrinsing Program

	Proximal Surfaces		*Buccolingual Surfaces*		*Occlusal Surfaces*	
Examination*	$\bar{X}$ dfs child	Per cent Difference	$\bar{X}$ dfs child	Per cent Difference	$\bar{X}$ dfs/ child	Per cent Difference
Baseline (1975)	1.60	—	0.75	—	2.08	—
First year (1976)	1.49	− 6.9	0.73	− 2.7	1.96	− 5.8
Second year (1977)	1.16	−27.5	0.60	−20.0	1.76	−15.4
Third year (1978)	1.07	−33.1	0.70	− 6.7	1.64	−21.2
Fourth year (1979)	1.07	−33.1	0.49	−34.7	1.42	−31 7
Fifth year (1980)	0.95	−40.6	0.52	−30.7	1.32	−36.5
Sixth year (1981)	0.86	−46.3	0.43	−42.7	1.32	−36.5
Seventh year (1982)	0.81	−49.4	0.52	−30.7	1.20	− 42.3

* Examinations conducted in the fall, at the beginning of an academic year.

Source: Ripa, Leske and Andre Varma, 1984

One reason for different magnitude of response to topical fluorides observed for the permanent and primary dentitions may be the difference in tooth age. The primary teeth of school age children represent an 'old' tooth population when the number of years since eruption are considered, while the permanent teeth in these children represent a 'younger' population. Many studies have shown that newly-erupted teeth receive greater protection from fluoride compared to teeth that have been exposed to the oral environment for several years. While it would be interesting to evaluate the effects of fluoride rinsing on a preschool population in order to study recently erupted primary teeth, such a study is contra-indicated (at least with a 0.2% NaF concentration), since Ericsson and Forsman (1969), have reported that young children swallow, rather then expectorate, most of a rinse solution.

4.5 MOUTHRINSING IN DIFFERENT CLINICAL SITUATIONS

4.5.1 Effectiveness in a Fluoridated Community

It has been amply demonstrated that the prevalence of dental caries can be reduced by 50 to 65% in communities if residents consume optimally fluoridated water from birth. Although water fluoridation is highly effective in reducing the prevalence of dental caries, additional measures should be developed to prevent the dental decay that remains despite fluoridation. Rinsing in school with a fluoride solution is a logical choice for investigations, because it is simple to carry out and is inexpensive. It should also

be noted that some communities that have otpimally fluoridated water have initiated fluoride mouthrinse programs in hopes of providing additional protection against tooth decay to their students. The results of few studies suggest that children who reside in optimally fluoridated communities may benefit from added protection of a fluoride mouthrinse.

In a study conducted in the city of Des Moines, Iowa, by William S. Driscoll et al., 1981, the findings after 18 months indicated that both daily and weekly mouthrinsing with fluoride solutions in school imparted significant caries-preventive benefits. The observed benefits were in addition to those realized by the children from consumption of optimally fluoridated drinking water.

The association of two preventive methods of dental caries-water fluoridation combined with fluoride mouthrinses was studied by Ben-Hur Wey Moreira et al., 1981. The experimental group performed weekly fluoride mouthrinses besides ingestion of artificially fluoridated water. The control group drank only the artificial fluoridated water. After two and a half years, there was a reduction of 25.4 to 30% in the incidence of dental caries in the experimental group.

In two previously conducted studies of fluoride mouthrinsing in fluoridated areas, Radike and co-workers (1973) evaluated daily mouthrinsing in school with a 0.1% stannous fluoride solution (0.025% F) (Table 9). After 20 months, two examiners independently observed respective differences of 33 and 43% in incremental DMF surfaces, compared with a control group that used placebo rinse.

Table 9 Effect of fluoride mouth rinses on the permanent teeth of children residing in optimally fluoridated communities

Study	Initial age (years) of subjects	Type of rinse	Rinsing frequency	Duration of study	Percent reduction DMFT	DMFS
Radike et al.	8–13	0.1% SnF_2	once/day	20 months		33–43*
Laswell et al.	8–9	0.044% NaF APF, pH 4	once/day	28 months		23
	8–9	0.25% NaF APF, pH 4	once/week	28 months		46
Heifetz et al.	10–11	0.2% NaF + APF gel-tray**	once/week	30 months		30

*Two examiners.
**Gel-tray application was made on 5 consecutive days, repeated 3 times a year.

Source: Mellberg and Ripa, 1983.

The other study was carried out in Sweden by Hagglund (1969). Although details of the study design and treatment procedures were not reported the study involved rinsing once a week with a neutral sodium fluoride solution of the same concentration as that used for the weekly procedure in Des Moines (0.2% NaF). An evaluation of the procedure after five years showed a 30% reduction in dental caries for children who used the fluoride rinse.

Laswell et al., 1975, have also reported the results of a school-based study of daily and weekly fluoride mouth-rinsing in a fluoridated community. In their study, an acidulated phosphate-fluoride rinse was used at fluoride concentrations of 200 ppm for the daily regimen and 1000 ppm for the weekly regimen. After 28 months of study, the weekly rinse group showed a 46% reduction in DMFS increment compared with controls. Surprisingly, the daily regimen resulted in a much smaller reduction in caries of 23%, which was not statistically significant. The authors did not

attempt to explain the relative lack of effectiveness of the daily rinse.

Interestingly, the relative caries-preventive benefits found in Des Moines and in the aforementioned studies by Hagglund and by Radike and co-workers are similar to those found in several other investigations of daily or weekly rinsing with sodium fluoride solutions in non-fluoridated areas. In contrast, percentage reductions in caries reported for certain other fluoride procedures in fluoridated areas have generally been smaller than those reported for the same procedure in non-fluoridated areas.

Stannous fluoride, acidified sodium fluoride and neutral NaF mouthrinses have been tested in children residing in communities with optimal water fluoridation. The results of their studies, presented in Table 9, suggest that an additive effect can be realized from fluoride rinsing by children already benefiting from community water fluoridation. This impression is further substantiated by the findings of DePaola and co-workers (1977), who found that children with prior exposure to systemic fluoride had the same percentage of caries reduction when either an acidified sodium fluoride or an ammonium fluoride mouthrinse was used, compared to children with no history of systemic fluoride exposure.

4.5.2 Effectiveness in Combination with Other Fluoride Therapy

Various combinations of self-applying fluorides may produce additive benefits, particularly those that incorpor-

ate different concentrations of fluoride, frequencies of application, and methods of administration. In 1972, a combined fluoride program was initiated by Horowitz et al. for elementary school children in Nelson County, VA, a rural area with fluoride deficient water supplies. In the school based component (supervised by class teachers), children rinse weekly with a 0.2% NaF solution and are given a tablet daily that contains 1 mg fluoride. In the home based component (unsupervised), children brush with a 0.1% fluoride tooth paste. Each component of the program has been shown to reduce the incidence of dental caries when used alone.

Table 10 Mean prevalence of DMFS in 1972 and 1980, by age. Nelson County, VA.

Age	1972 (baseline) No. of children	1972 (baseline) Mean no. DMFS	1980 No. of children	1980 Mean no. DMFS	Difference in mean DMFS	Difference from 1972 (%)
6	164	1.14 (0.15)*	105	0.57 (0.11)	0.57	50.0
7	187	1.74 (0.16)	134	1.14 (0.16)	0.59	34.2
8	223	3.34 (0.22)	122	1.87 (0.20)	1.47	44.1
9	214	5.40 (0.30)	133	2.34 (0.21)	3.05	56.6
10	215	5.97 (0.33)	98	3.12 (0.32)	2.84	47.7
11	230	7.23 (0.41)	112	4.16 (0.35)	3.07	42.4
12	161	8.73 (0.57)	69	5.26 (0.43)	3.47	39.8
13	145	10.50 (0.74)	96	5.44 (0.47)	5.06	48.2
14	148	15.78 (0.98)	101	5.94 (0.58)	9.83	62.3
Total	1.687	6.31 (0.15)	970	3.22 (0.11)	3.09	49.0

*Standard error of the mean

Source: Horowitz, Meyers, Heifetz, Driscoli and Li, 1984

Findings in Nelson County after 8 years (1980) indicate that participating children have many fewer carious tooth surfaces than their counterparts at the baseline, who had not participated in the caries preventive program. As the program has continued and children have participated longer periods, benefits have steadily improved. Percentage reduction in DMFS prevalence for continuous participants

were 18% after 2 years, 35% after 4 years, 45% after 6 years, and 49% after 8 years.

Although benefits to children in Nelson County are large, Ripa and others reported a 55% reduction in the prevalence of DMF surfaces among school children who participated only in a weekly fluoride mouthrinsing program for 6 years, a slightly greater benefit than was detected in Nelson County after 8 years.

Moreover, Blinkhorn and others (1983), reported that no additional benefit accrued to children who used both fluoride mouthrinse daily and a fluoride toothpaste compared with those who used either regimen alone. But results of their study confirm the caries inhibiting effects of both MFP dentrifices and NaF mouthrinses. A possible explanation for this may be found from the current theory on the topical effect of fluoride. This suggests that the frequent application of low concentrations of fluoride to the teeth is important. It is possible that had the rinse been used at a different time of the day than the dentrifice, then an additional benefit may have resulted. This suggestion is supported by the observation that in trials of fluoride rinsing where no control is exercised over the haphazard use of fluoride dentrifice at home, the rinse has been shown to be of benefit. In addition, the rinsing is separated from the brushing, then more time could be given to the rinsing procedure, possibly making it more effective. Caries prevention regimens should continue to utilize fluoride mouthrinses alone at school, encouraging the participants to brush with a fluoride dentrifice regularly at home.

Ashley and co-workers (1977) evaluated a program of daily rinsing with acidified NaF and brushing with a monofluorophosphate dentrifice, either alone or in combination. A 14% caries reduction was reported for the group that rinsed, and a 27% reduction was reported for the group with combined therapy (Table 11). Ringleberg and co-workers (1978) evaluated the effects of an amine fluoride mouthrinse and a neutral NaF rinse, both alone and with an amine fluoride or stannous fluoride dentrifice respectively. No difference was noted by the addition of the therapeutic dentrifices (see Table 12). While the results of these two studies seem contradictory, a significant difference between them was that in the study by Ashley et al., dentrifice use was supervised in the classroom, while in the study by Ringelberg et al., the dentrifice was used at home.

Horowitz et al. (1980) evaluated a school-based program involving daily use of 1 mg acidulated phosphate fluoride tablet and weekly rinsing with a 0.2% neutral NaF solution. Additionally, the children used either a stannous fluoride or monofluorophosphate dentrifice at home. After 3 years a 35% reduction in caries prevalence was reported. Although a comparison group that only rinsed was not included, considering the combination of fluoride therapy that was employed, these results cannot be considered dramatic.

Heifetz et al. (1979) conducted a school-based program involving weekly rinsing with a neutral 0.2% NaF solution and gel-tray treatments applied 15 times a year in three sets of five applications each. After 30 months, 30% caries reduction was obtained (see Table 13). Since this

Table 11. Effect of acidified sodium fluoride mouth rinses on the permanent teeth of children residing in fluoride-deficient communities

Study	Initial age (years) of subjects	Rinse concentration and pH	Rinsing frequency	Duration of study	Percent reduction DMFT	Percent reduction DMFS
Heifetz et al.	10–12	0.66% NaF APF*, pH 4	once/week	2 years		28
Packer et al.	8–9	0 25% NaF APF, pH 4	once/week	28 months		41
Ashley et al.	12.3***	0.02% NaF APF, pH 3.5	once/day	2 years		14
	12.3	0.02% NaF APF, pH 3.5 +MFP dentifrice**	once/day	2 years		27
Kani et al.	10	0.1% NaF APF, pH ?	once/day	3 years		20–30
Frankl et al	14***	0.044% NaF APF, pH 4	once/day	2 years	26	22
Aasenden et al.	8–11	0.044% NaF APF, pH 4	once/day****	3 years	32	30
Packer et al	8–9	0.044% NaF, APF, pH 4	once/day	28 months		27
Luoma et al.	11–15	0.044% NaF succinic acid/NaOH buffer, pH 5.9	once/day	2 years		31
DePaola et al.	10–12	0.2% NaF APF, pH 4 4	once/day	2 years		47
Finn et al.	8–13	0.02% NaF APF, pH 3.5	twice/day	26 months	16	18
	8–13	0.04% NaF APF, pH 3.5	twice/day	26 months	28	29

*APF = acidulated phosphate fluoride.
**MFP = monofluorophosphate.
***Mean age.
****Rinse and swallow

Source: Mellberg and Ripa, 1983

Table 12. Effect of non-sodium fluoride mouth rinses on the permanent teeth of children residing in fluoride-deficient communities

Study	Initial age (years) of subjects	Type of rinse	Rinsing frequency	Duration of study	Percent reduction DMFT	Percent reduction DMFS
McConchie et al.	10*	0.04% SnF_2	once/day	2 years	20	20
	10	0.08% SnF_2	once/day	2 years	20	17
Swerdloff & Shannon	11–15	0.1% SnF_2**	once/day	5 months	33	31
Ringelberg et al.	11	amine fluoride (250 ppm F)	once/day	18 months	11	21
	11	amine fluoride (250 ppm F) + amine F dentifrice	once/day	18 months	19	22
DePaola et al.	10–12	0.2% NH_4F, pH 4.4	once/day	2 years		54

*Mean age.
**Some of study population drinking optimally fluoridated water

Source: Mellberg and Ripa, 1983

Table 13. Effect of fluoride mouth rinses on the permanent teeth of children residing in optimally fluoridated communities

Study	Initial age (years) of subjects	Type of rinse	Rinsing frequency	Duration of study	Percent reduction DMFT	DMFS
Radike et al.	8–13	0.1% SnF_2	once/day	20 months		33–43*
Laswell et al.	8–9	0.044% NaF APF, pH 4	once/day	28 months		23
	8–9	0.25% NaF APF, pH 4	once/week	28 months		46
Heifetz et al.	10–11	0.2% NaF + APF gel-tray**	once/week	30 months		30

*Two examiners.
**Gel-tray application was made on 5 consecutive days, repeated 3 times a year.

Source: Mellberg and Ripa, 1983

study was conducted in an optimally fluoridated community, this can be considered a promising result

A 2½ year trial involving the use of an MFP tooth-paste in combination with a range of mouthrinses containing 0, 0.025, 0.05 or 0.1% NaF concluded that there was an additive effect (Triol et al., 1980). The greatest reduction occurred with the most concentrated fluoride rinse, but the difference among the three fluoride mouthrinsing groups was not statistically significant.

Poulsen, Kirkegaard et al., 1984, tested the caried-preventive effect of fluoride rinses in a population of school children receiving systemic restorative care and fluoridated toothpaste at home. In this study 365 second to fourth-graders completed a 3-yr clinical trial. Rinsing was done every second week during the school year with 10 ml of an 0.2% neutral NaF solution. The trial was performed under double-blind conditions. The caries increment on teeth erupted at baseline was 1.75 DMFS in the fluoride group and 1.83 DMFS in the placebo group. The caries

increment on teeth erupting during the trial was 0.73 DMFS in the fluoride group and 0.99 DMFS in the placebo group.

Poulsen, Gadegaard et al., 1981, compared the caries-preventive effect of a daily fluoride-containing lozenge and fortnightly rinses with a fluoride solution. The study demonstrated a lower caries-preventive effect on teeth already erupted, after daily use of a fluoride containing lozenge compared to fortnightly rinses with NaF. No statistically significant effect could be found in teeth erupting during the study, but the trend was the same as for teeth present at baseline. This shows that daily use of the lozenges tested in the present study is less effective in preventing caries than daily rinses with neutral NaF. Two explanations for this could be suggested. Firstly, Bruun and Givskov (1979) have suggested that the flavouring agent in chewable tablets may stimulate salivary flow. This in turn encourages swallowing and reduces the fluoride concentration in saliva by dilution. Secondly, the more complex formulation of chewable tablets and lozenges may result in decreased release of fluoride.

These results are in contrast to those of Holm et al. (1975), who found no statistically significant difference in 2-year caries increment between a group of children who daily chewed two tablets each containing 0.21 mg fluoride as NaF and another group of children who rinsed weekly with 0.2% NaF solution (corresponding to 0.1% fluoride). It should be noted, however, that a non significant 13% higher increment was found in the fluoride tablet.

Torell and Gerdin (1977) advocated that the enamel surface of highly caries-active children should be supplied not only with fluoride ions but also with certain other trace elements. In a four year clinical trial they registered a significantly greater caries reduction when fortnightly NaF rinsing was combined with topical paintings employing a ferric-aluminium manganous fluoride solution than when the rinsing was combined with NaF paintings.

In some clinical trials caries reduction has been achieved by employing 'ferric fluoride' solutions for tooth brushing, mouthrinsing or topical paintings. Several iron fluoride solutions are reported to increase the acid resistance of the enamel more than neutral, alkali fluoride solutions (Craig, 1979).

4.5.3 Effectiveness on Different Tooth Surfaces

It is well established that the per cent reduction in caries following water fluoridation is greater in free smooth surfaces (buccal and lingual) and least in fissure surfaces. This pattern has also been observed in fluoride mouthrinsing trials. The effectiveness of fluoride rinsing on the caries activity of different tooth surfaces is summarised in Table 14. Like other methods of fluoride therapy, fluoride rinsing provides preferential protection to the smooth tooth surfaces, while the least benefit is derived by the pits and fissures of the occlusal surfaces.

Table 14 Effect of fluoride mouth rinses on different tooth surfaces

Study	Rinse, frequency, and duration	Percent caries reduction—all surfaces	Percent caries reduction by type of surface		
			Occlusal	Buccolingual	Proximal
Ashley et al.	0.02% NaF, pH 3.5; once/day, 2 years	14	5	22*	24
Koch	0.5% NaF; once/2 weeks, 3 years	25	5	35-38	31
Rugg-Gunn et al.	0.05% NaF; once/day, 34 months	36	32	55	33–56**
Luoma et al.	0.044% NaF, pH 5.9; once/day, 2 years	31	1	9	43
Ripa et al.	0.2% NaF; once/week, 2 years	20	20	15***	40

Source: Mellberg and Ripa, 1983

The caries increment recorded in different types of tooth surfaces in adolescent school children who have rinsed daily in school for 3 years with a 225 ppm fluoride rinse is shown in Fig. 9. The percent caries reductions were highest for free smooth surfaces and anterior approximal surfaces (55 to 56%, respectively). The percent reduction for fissure caries is 32%.

FLUORIDE MOUTHRINSING AND DENTAL CARIES

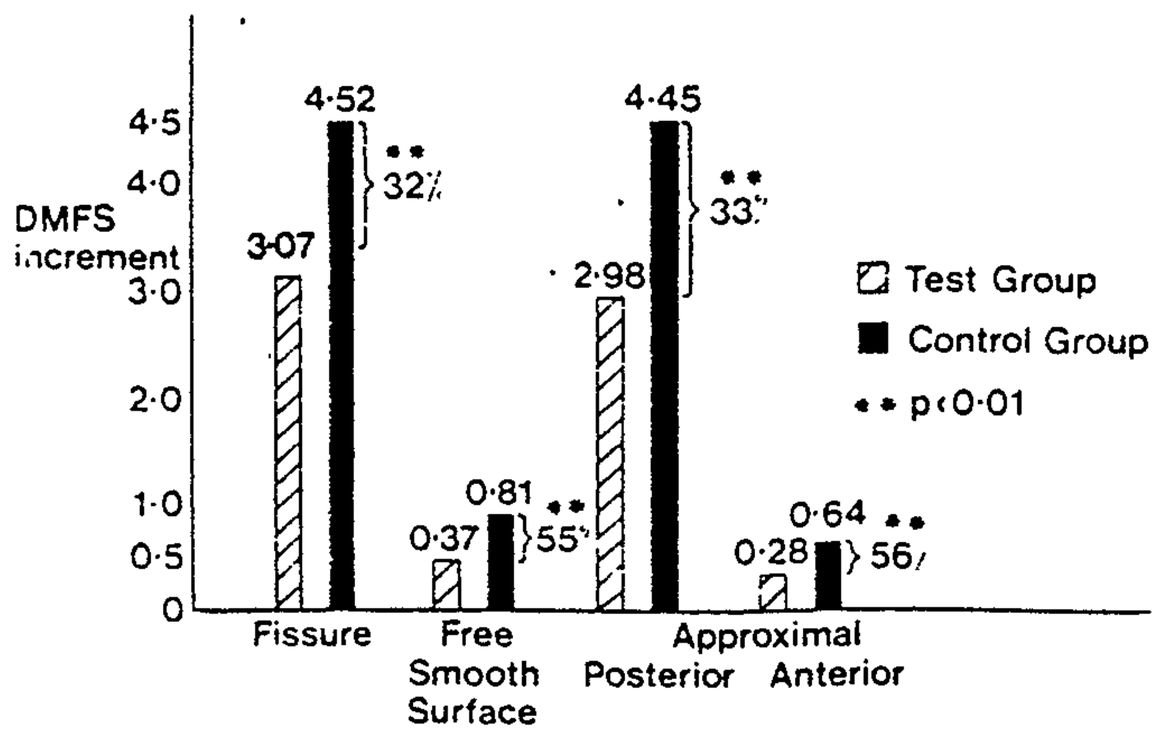

Fig. 9 Three-year DMFS increments for all children taking part in a clinical trial of daily rinsing with 0·05 per cent NaF, given for each surface type separately (From Rugg-Gunn et al., 1973.) (*Reproduced by kind permission of the Editor, 'British Dental Journal'.*)

Horowitz et al. (1971) also found substantial caries reductions in all types of tooth surface after weekly rinsing with a 900 ppm fluoride rinse, while in children very high increment Koch (1967) observed no reduction in fissure surfaces but substantial reductions in other surfaces. Ashley et al. (1977) also found only 5% caries reduction in fissure surraces compared with 54% reduction in other surfaces.

Kogh (1967) observed that anterior teeth benefit most from fluoride mouthrinsing, but his observation that caries reduction was greater in lower teeth (28%) than in upper teeth (19%), possibly due to pooling of rinse in the floor of the mouth, was not substantiated by Rugg-Gunn et al. (1973), who found equal reductions in both jaws. They were aware of Koch's results and urged the children to rinse thoroughly.

4.6 EFFECT OF MOUTHRINSING WITH FLUORIDE SOLUTION ON DENTAL PLAQUE

A number of studies have shown that fluoride inhibits glycolysis in oral microorganisms and reduces acid production significantly. Jenkins et al. (1969) demonstrated the effect of low concentrations of fluoride on plaque, while Bibby and Vankesteran (1940), Jenkins (1959), and Sandham, Kleinberg (1969, 1973) obtained similar results with organisms from saliva. Analysis of plaque fluoride was not reported until 1961, when Hardwick (1961) and later Hardwick and Leach (1962) found concentrations between 6 and 179 ppm.

Plaque uptake of fluoride from NaF mouthrinses and

from fluoride containing dentrifice may attain high levels of fluoride, but no prolonged effect is seen. The plaque fluoride uptake 12 hours after rinsing with 0.2% NaF solution is detectable with the fluoride electrode upon extraction with 0.5 M perchloric acid at room temperature and may not be in a form able to exert an effect on plaque metabolism. In this regard, Stephan and Jenkins (1971) could demonstrate a reduction in in vitro acid production only by plaques collected within 1 hour after rinsing with NaF solution when total plaque fluoride would be expected to be at a high level.

Dennis H. Leverett et al. (1981) studied the effect of daily mouthrinsing with stannous fluoride on dental plaque and gingivitis. The four-month results of this study support earlier findings of a plaque-inhibiting effect of SnF_2. The concomitant effect on gingivitis was marginal. In a recent study by Leverett et al. (1984), two groups of children, ages 12 to 15, rinsed daily for 28 months with aqueous fluoride solutions, one group using 0.05% NaF and the other group using 0.1% SnF_2. The SnF_2 group had less plaque accumulation after 4 months, but no difference was apparent at 16 and 28 months. Gingivitis was less severe in the SnF_2 group throughout the study, although the difference did not reach statistical significance. The 0.1% SnF_2 solution, used daily as a mouthrinse inhibits plaque formation, although this inhibitory effect is not apparent after 16 months of rinsing.

Yankell et al. (1982), using 250 ppm and 100 ppm SnF_2 mouthrinsing solutions, found reductions in viable

plaque organisms from 74-80% and 90-99%, respectively. In the same study, Yankell et al., demonstrated that the plaque scores were significantly lower with the SnF_2 mouthrinse than with the placebo control.

The efficiency of 0.05% NaF and 0.1% SnF_2, used daily as caries inhibitory mouthrinses, has been reasonably well established in human populations. Tinanoff et al. (1983) demonstrated, in scanning electron microscope (SEM) studies, almost total inhibition of plaque and bacteria with a twice-daily rinse of 0.1% SnF_2. Svatun et al. (1977) using 10 ml solution containing 25 mm SnF_2 two times per day, found that the plaque inhibiting effect of the SnF_2 solution was equivalent to that of 2.2 mm of chlorhexidine. In a related study Svatun et al. (1977) compared the plaque-inhibiting effects of 0.2% SnF_2, 0.3% SnF_2, and 0.1% chlorhexidine gluconate with distilled water as the control. All experimental rinses were significantly more effective than the control.

Svanberg et al. (1983) studied the effect of SnF_2, administered as mouthrinses or topically applied, on Streptococcus mutans, Streptococcus sanguis and Lactobacilli in dental plaque and saliva. Mouthrinsing with SnF_2 reduced the S. mutans population in plaque and saliva and the proportions of S. sanguis in plaque. The effect was of short duration: 2 weeks after treatment the values of S. mutans in plaque and saliva were even higher than the pretreatment values. Topical SnF_2 applications reduced the S. mutans population in plaque and saliva but did not reduce the proportion of S. sanguis in plaque. The effect was more

prolonged. Four weeks after treatment the S. mutans population in interproximal plaque remained significantly reduced and the salivary levels of organisms had not fully returned to pretreatment levels. Both SnF_2 treatments significantly increased the salivary levels of Lactobacilli. The values of Lactobacilli in saliva remained significantly increased 4 weeks after the SnF_2 mouthrinsing but had almost returned to pretreatment levels within 2 weeks after the topical SnF_2 applications. The findings suggest that the cariogenic potential of dental plaque is differently affected depending on whether a drug is administered or is applied topically.

Dorothy et al. (1982) measured plaque acidogenicity (Stephan curves) and fluoride concentrations in 40 subjects before and during a 1-2 month period of daily mouthrinsing with 48 mM NaF. Plaque fluoride concentration increased an average 12-fold during the rinsing period and there was also a small, but statistically significant ($p < 0.025$), average increase of 0.11 units in the pH minimum of the Stephan curve. This increase was slightly larger (0.20 units) for the group of 27 subjects whose pH minima prior to fluoride-rinsing were 5.7 or lower. Inclusion of 48 mM NaF in the sucrose rinse used to induce the Stephan curve for 4 subjects raised the average pH minimum by 0.70 units. The effect of fluoride rinsing on plaque acidogenicity and fluoride concentration was lost within 4-10 days of withdrawal of the rinse. It is concluded that a reduction in plaque acidogenicity may support the cariostatic action of fluoride on enamel solubility.

In a New Zealand study (Pearce et al., 1983) a mouthrinse solution designed to precipitate fluoride containing hydroxyapatite into dental plaque has been tested on natural plaque in vivo. Nineteen children aged 10 or 11 years rinsed ten times over a four-day period, and the effect on acid-extractable F, Ca, and inorganic phosphate (Pi) concentrations was determined. Immature plaque developing during the course of the trial showed a 320% increase in F, a 190% increase in Ca, and a 97% increase in Pi five h after the last rinse, by which time all soluble ions would have diffused into saliva. Mature plaque of intermediate age showed smaller but still statistically significant increases in Pi and F five h after the last rinse, and these did not diminish further during the next three days. The association between increase in Ca and increase in Pi, and increase in F, together with the value of the Ca/P ratio, suggested that a fluoro hydroxy apatite was precipitated in plaque plaque samples. The considerable between-subject variation in response to the mouthrinse is possibly related to individual differences in plaque flora. Theoretical considerations as well as newer experimental evidence suggest that this plaque mineral should exert a caries protective effect on the underlying enamel.

Klock et al. (1985) compared the effect of SnF_2 and NaF mouthrinses on caries incidence, salivary S. mutans and gingivitis in high caries prevalent adults living in a fluoridated area. Subjects rinsed twice a day with either SnF_2 or NaF (200 ppm F). Subjects in both groups continued to be caries active during the course of the study. However,

at the first year examination subjects rinsing with SnF_2 had less S. mutans/ml saliva, a lower caries incidence and less gingivitis. After 2 years the S. mutans levels in the SnF_2 rinsing group remained significantly less. Both caries incidence and gingivitis were lower in the SnF_2 group after 2 years but the difference was not significant.

4.7 POSTTREATMENT BENEFITS FROM PARTICIPATION IN A SCHOOL-BASED FLUORIDE MOUTHRINSING PROGRAM

Certain cariostatic topical fluoride procedures have been shown to permanently increase the concentration of fluoride in the outer layer of sound enamel. Leske and co-workers (1985) conducted 'The Three Village mouthrinsing program' which is the longest continually monitored school-based program of its kind in the United States. Begun in 1975 in the elementary schools, grades Kindergarten through 6, of the Three Village central school district, Long Island, New York ($F \leq 0.1$ ppm), this voluntary program enrols new kindergarten children each year, while newly promoted seventh grade children graduate to the junior high schools and leave the program.

To date, more than 7000 children have participated. The program involves rinsing for 60 seconds once a week with 10 ml (5 ml for kindergarten) of a 0.2% neutral NaF solution. Junior high school students, seventh to ninth grades who had participated in a weekly fluoride mouthrinsing program as elementary school students, demonstrated posttreatment benefits from fluoride rinsing. After participation in the program for six to seven years (170 to 203 scheduled rinses)

followed by discontinuation of rinsing for six months to two and one-half years, there was a 57.1% reduction in the DMFS prevalence. The greatest percentage reduction, 81.3% occurred on proximal surfaces. The posttreatment caries protective benefit of fluoride mouthrinsing increased directly with the duration of past participation in the program. This report confirms Leske and co-workers' previous findings that the benefits of fluoride mouthrinsing persist after children discontinue their participation in the program.

Haugejorden, O. and co-workers (1985) compared caries prevalence in two groups of 21 year olds 6-7 years after discontinuation of school-based preventive programs consisting respectively of fortnightly rinsing or brushing 3-5 times per year with NaF solutions. Stratified random samples of 125 persons were drawn from appropriate population registers. Blind clinical and radiographic examinations were carried out and the subjects were interviewed concerning their dental health behaviour. The results revealed significantly lower mean DMFS score in the rinsing than in the brushing group ($p < 0.001$). Comparisons with results of other studies suggest persistence of benefits of school-based preventive programs after discontinuation.

4.8 SAFETY OF FLUORIDE MOUTHRINSES

Dilute fluoride rinses for use at home or in school-based programs are currently popular as a simple way to expose teeth to fluoride frequently. Although final Food and Drug Administration (FDA) clearance is still pending,

several companies have introduced mouthrinse products for nonprescription sales. Today approximately ten million children are participating in fluoride mouthrinsing programs at schools in the U.S.A.

All products for daily use at home contain NaF, APF or SnF_2 at fluoride concentrations below 0.025%. The recommended 10 ml volume for all these rinses contain less than 2.5 mg F (0.25 mg F/ml x 10 ml), a safe amount, even if they are accidentally swallowed. To reach the STD limit (Safely Tolerated Dose), the hypothetical two-year-old would have to swallow at one time more than twelve ounces of a neutral NaF rinse (0.23 mg F/ml x 348 ml = 80 mg F) and to reach the CLD (Certainly Lethal Dose), about 1.5 quarts of rinse (0.23 mg F/ml x 1391 ml = 320 mg F). The largest commercially available bottle of a NaF rinse contains about 509 ml or 118 mg F (0.23 mg F/ml x 509 ml), an amount above the STD of fluoride, but well below the CLD for our two-year-old. It is unlikely that a child could consume the entire 509 ml, and most of the solution would probably be regurgitated.

Margins of safety for school fluoride rinsing program should be based on a five-year-old, the youngest school-age child at risk. Assuming a weight of 33.1 lbs (15 Kg) for a small five-year-old child in kindergarten, the STD would be 120 mg F (8 mg F/kg x 15 kg) and CLD would be 480 mg F (320 mg F/kg x 15 kg). Thus to exceed the STD, a five-year-old would have to swallow more than four and a half ounce of solution (0.9 mg F/ml x 133 ml = 120 mg F) from a mixing bottle or about 13 cups containing 10 ml

solution. To ingest the CLD, more than eighteen ounces (0.9 mg F/ml x 533 ml = 480 mg F) would have to be swallowed, or about fifty-three cups containing 10 ml. Again, because soluble fluoride is a powerful emetic, the kindergarten children would be likely to vomit before such large volumes could be consumed and absorbed.

U.S. suppliers of fluoride mouthrinse products for school programs sell concentrated sodium fluoride powder, mostly in packets of two and three grams. A two-gram packet of NaF contains about 909 milligrams of fluoride, an amount that, if ingested without prompt treatment, would be fatal for school children through about twelve years of age. Misuse of a three gram packet would prove even more dangerous. Schools are directed to keep stored packets in securely locked places and inaccessible to children until they are used, but methods of security vary and are not always rigorously enforced.

4.8.1 Effect on Developing Teeth

The enamel organ is particularly sensitive to high concentrations of fluoride. Repeated high doses of systemic fluoride can result in enamel fluorosis, which clinically manifests as unesthetic hypoplastic or hypocalcific defects of the tooth crown. For this reason it is important to evaluate the effect of inadvertent repetitive ingestion of fluoride while mouthrinsing. Several variables influence the amount of solution that may be retained while rinsing. Among these are the age of the participant, the volume of solution used for rinsing, and the rinsing time.

Ericsson and Forsman (1969) found that most two and three-year-old children could not perform mouthrinsing without swallowing the solution. They also reported that three and four-year-olds could keep the solution in their mouths for 30 seconds, and five and six-year-olds for 60 seconds and expectorate most of the rinse. The amount of solution retained decreased with age. When rinsing was performed with 7 ml, the average 3-year-old retained 14% of the solution, whereas the average 5- to 6-year-old retained 5 to 7%.

Birekeland (1973) studied the amount of retained fluoride from mouthrinsing in 10- and 11-year-old children and in adults using 7 ml and 10 ml of solution. He found that both age groups retained about 14 to 15% of the solution. However, retention was significantly increased when 10 ml, rather than 7 ml, were used. By age 8, all of the permanent teeth, exclusive of third molars, will usually have completed mineralization of the tooth crown. Since fluoride rinsing is not recommended for preschool children, the period of concern relative to tooth development is from age 5 or 6 to age 8.

Rinsing is usually performed for 60 seconds using either 5 or 10 ml of solution. The most common rinsing regimens use either a 0.05% NaF solution daily (low potency/high frequency) or a 0.2% solution weekly or every 2 weeks (high potency/low frequency). Assuming that the maximum amount of solution retained is 20%, the amount of fluoride retained with these regimens varies from 0.2 mg to 1.8 mg. The inadvertent ingestion of 0.2 to 0.4 mg fluoride daily

(low potency/high frequency technique) by 6- to 8-year-old children, even if they are receiving optimal systemic fluoride from other sources, would not be expected to cause a cosmetic problem to the developing dentition. Likewise, there is no evidence to indicate that the infrequent ingestion of 0, 9 or 1.8 mg fluoride (high potency/low frequency technique) in this age group would cause cosmetic problems.

4.8.2 Effect on Gingival Health

Not all of the fluoride retained from mouthrinsing is swallowed. A small amount is retained intraorally, especially in the dental plaque. In general, it has been found that fluoride rinsing either has no effect on the level of gingivitis, or reduces it and that it has no effect on plaque accumulation or reduces it. Thus, routine fluoride rinsing has not been found to adversely effect gingival health.

4.8.3 Extrinsic Staining of Teeth

Some staining of the teeth has been associated with the use of stannous fluoride mouthrinses but not with NaF mouthrinses. McConchie and co-workers (1977) reported staining in 'a very small number of children' who were rinsing daily with a 0.04% or 0.08% SnF_2 solution. The investigators indicated that the children who developed stains exhibited a poor level of oral hygiene.

4.8.4 Acute Toxicity

A death has been reported (Horowitz, 1977) in which a young child was given a cup of fluoride solution with which to rinse. In this instance, a 3-year-old, who was being examined in a dental clinic, was given a 3-ounce (45 ml) cup containing 4% SnF_2 (10,000 ppm F). The cup thus contained 435 mg of fluoride. Approximately 5 minutes after using the solution, the child vomited and had a convulsive seizure. He died 3 hours later. Not only the amount and concentration of the rinse was incorrect (too much solution; too high fluoride concentration), the frequency incorrect (once-a-year office application has never been recommended), and the age of the child incorrect (pre-school children cannot be expected to master the rinsing technique), but the treatment was not even indicated since the child was free of caries and resided in a fluoridated community. This episode tragically illustrates the maxim that any therapeutic agent that is incorrectly prescribed or administered is potentially harmful.

There are no published records of deaths from topical fluorides in Australia, but there is recorded death attributed to an overdose of fluoride tablets (Monsour and Kruger, 1985). There are no published data on the prevalence of other levels of acute fluoride toxicity in Australia resulting from the use of fluoride supplements in preventive dentistry.

5. COST BENEFIT AND COST EFFECTIVENESS

Treatment of an individual patient involves explanation by the dental practitioner of the alternatives available and agreement between the two parties on the proposed treatment plan. In some cases, a patient may be prepared to pay more for having caries-preventive therapy than he would have to pay to have restored the teeth which would have become carious without the preventive therapy. This is perfectly ethical as long as the patient is fully informed. But decisions in public health about different health-care strategies are usually made solely on a monetary basis. The community will demand that the health planner provides the best possible health services for their money.

Since the planner will have to decide between various strategies he will have to be able to estimate - (1) the cost of proposed measure, and (2) the benefit likely to accrue from that measure - both in monetary terms. This is cost benefit analysis and is a well recognized procedure in public health planning. Whereas the cost of operating a preventive program is largely independent of the caries activity of the population, the program's benefits are not; the higher the susceptibility to decay, the greater the benefits of prevention. According to Davies (1974), cost benefit ratio is defined as the cost of implementation divided by the savings in costs of treatment.

$$\text{Cost-benefit ratio} = \frac{\text{Cost of implementation}}{\text{Savings in costs of treatment}}$$

In caries prevention it is frequently necessary to

decide between alternative ways of achieving the same primary objective of caries prevention. It then becomes unnecessary to calculate the benefit in monetary terms and this can then be expressed in terms of the number of carious teeth or surfaces prevented. This is cost effective analysis which enables the planner to determine the least expensive of several alternatives of achieving a stated objective. Professional applications of topically applied fluorides, for example, are not cost-effective in public health programs. A far greater number of people can benefit from a weekly fluoride mouthrinse program than could benefit from a program of equal cost which used professionals to apply topical fluorides. While weekly fluoride mouthrinsing does not preclude the use of topically applied fluorides in private dental offices, it may be desirous to consider the cost-effectiveness on an individual basis in light of the patient's caries rate, financial status and treatment needs.

For caries prevention, an estimate of efficiency is often obtained by evaluating the costs of various preventive techniques incurred for preventing one surface of tooth decay per child. To be meaningful, a cost-effectiveness analysis must have accurate effectiveness and cost data as inputs. The cost-effectivness of fluoride mouth rinse in non-fluoridated areas appears to vary according to the age of the children involved. Assuming that in 6-to-7 year-old children fluoride mouth rinses saves 0.12 surfaces a year, it is clear that over the first 3 to 4 years the procedure is not cost effective. Four years of rinsing at an annual cost of approximately $5.00 indicates that for a program

expenditure of $20,00 less than one-half a surface of decay has been averted. Alternatively two children in this age range would have to rinse for four years at a total cost of $40.00 to save one surface of decay. Given that the 1981 fee for a one-surface amalgam filling was approximately $19.92, a strong doubt is cast over the efficiency of school-based weekly fluoride mouth rinsing programs as a procedure for the younger age groups.

$$\text{The cost effectiveness ratio is defined as} = \frac{\text{cost (dollars) of procedure/child/year}}{\text{1.0 DMF surface saved/child/year}}$$

The most thorough review of cost-effectiveness of methods of caries prevention was achieved at a conference in Ann Arbor, Michigan, in 1978 (Burt, 1978). Table 15 is taken from this publication and provides a guide to the order of efficiency of fluoride programs. The table is compiled with the assumption of a caries increment of 2 DMFS per child per year in a fluoride-low area, and the costing is given in US dollars as calculations were made on US wages and material costs. It is probable that in many estimates both the cost and the benefit are underestimated, although benefits are more likely to be underestimated than costs (Burt, 1978). Because disease levels and resources will vary from community to community, a public health planner must estimate cost-effectiveness ratios based as much as possible on local information.

A weekly fluoride rinsing program was started in Round Lake County, Illinois, by Dismer, G.A., in 1977. The Round Lake area was chosen as a non fluoridated area to measure, and North Chicago was chosen as a fluoridated area (F = 1

TABLE 15

Ranking of estimated cost-effectiveness of alternative topical fluoride procedures

Procedure	*Estimated percent reduction*	*$ Cost per 1.0 DMFS saved*	*Rank*
Weekly mouthrinse 0.2% NaF solution	*25*	*$1.00*	*1*
Semiannual "brush-in" 9% SnF Zircate paste	*25*	*$2.50*	*2 (tie)*
Prof.-applic. 2.0% NaF sol, multiple-chair method	*40*	*$2.60*	*2 (tie)*
Annual prof.-applic. APF gel (1.23% F) in preformed trays	*40*	*$4.40*	*4*
Toothbrushing 5 x yr APF sol (0.6% F)	*20*	*$5.60*	*5*
Toothbrushing at home 0.1% fluoride dentifrice	*20*	*$10.00*	*6*
Annual prof.-applic. 8.0% SnF	*20*	*$21.00*	*7 (tie)*
Daily self-applic. APF gel (0.5% F) in custom trays	*80*	*$21.30*	*7 (tie)*

SOURCE: *Heifetz, S.B. - Cost-effectiveness of topically applied fluorides: In "Relative Efficiency of methods of Caries Prevention in dental public health" - Workshop Proceedings, University of Michigan, June 5-8, 1978 (pp 69 - 104).*

ppm). The amount of decay reduction from 1978-80 and the cost benefit analysis for each community was determined. Fig. 10 shows the appropriate cost of the fluoride program. The cost of the program was shown as the same in both school districts. The cost benefit ratio in the non-fluoridated community was $3.35 for each dollar spent on the program. In the fluoridated area a cost benefit ratio was 5.56.

Doherty and co-workers (1984) studied the cost of school-based mouthrinsing in 14 demonstration programs in USA. They examined the structure of costs and their variation among a number of programs and, variations in per capita costs. The costs per participants for each complete school year are shown in Table 16. Total costs are divided between explicit and implicit factors; with explicit costs being subdivided into labour and 'other' (mainly supplies and equipment), and implicit costs being, with insignificant exceptions, entirely for labour. Total costs, from which costs per participant could be derived, were obtained for 14 of the 17 programs. Information had been recorded for four periods.

				Start-up and
Period	I	July	1975-1976	15 treatments
	II	Sept.	1976-1977 (May)	30 treatments
	III	Sept.	1977-1978 (May)	30 treatments
	IV	Sept.	1978-1978 (Dec.)	15 treatments.

For periods II and III, respectively, total per participant costs (standard deviation and range) were $4.96 ($2.20:

FIGURE 10

Monetary Savings per child from reduced decay (North Chicago)

4.37 decayed surfaces - 1978
3.31 decayed surfaces - 1980

1.06 surfaces reduction at $10 per filling surface

(Cost analysis)

1205 surfaces nonexistent due to reduced referral rate = $\frac{\$12,050}{2,225 \text{ students}}$ = $5.42

$10.60 Monetary Savings
5.42

$16.02

Cost of Program (per child) =

$0.50 per child for materials/year (3 years) = $1.50

.5 hours/week administration of program by school nurse (3 years) = $1.29

Health Department cost of program for 6,000 children (3 years) (manhours, ordering, car expenses) = $ .09

$2.88

Results: A saving of $5.56 for each dollar spent for the program in North Chicago.

Monetary Savings per child from reduced decay (Round Lake)

4.29 decayed surfaces - 1978
3.54 decayed surfaces - 1980

.75 surfaces reduction at $10 per filling surface = $7.50

(Cost analysis)

393 surfaces nonexistent due to reduced referral rate $\frac{3930}{1816}$ = $2.16

$7.50
2.16

$9.66 Monetary Savings

Cost of Program (per child) = the same as North Chicago - $2.88

Results: A savings of $3.35 for each dollar spent for the porgram in Round Lake.

Source: Dismer, 1977

TABLE 16. Average per participant costs of 14 mouthrinse programs (1978 dollars)

Cost category	Mean	Standard deviation	Range
		PERIOD II	
Total	$4.96	$2.20	$2.35 - 8.05
Explicit	3.35	2.28	0.87 - 7.73
labour	2.74	2.23	0.34 - 7.20
other	0.61	0.16	0.47 - 1.03
Implicit	1.61	0.92	0.00 - 3.26
		PERIOD III	
Total	$4.45	$2.17	$1.46 - 7.94
Explicit	3.01	1.79	0.75 - 6.86
labour	2.31	1.70	0.35 - 6.29
other	0.70	0.33	0.40 - 3.34
Implicit	1.44	0.94	0.04 - 3.03

Annual number of children: Mean: 3045. SD: 1696. Range 907-6079.

Aggregate average costs for the four periods combined:

Total - $17.47 ± $7.64 (range $6.34 - $29.02);

Explicit - $11.70 ± $7.42 (range $3.04 - $26.04);

Implicit - $5.77 ± $3.25 (range $0.82 - $11.61).

Source: Doherty and Powell, 1984

$2.35-$8.05) and $4.45 ($2.17:$1.46-$7.96). In each period explicit costs were approximately 67.5% of total costs. Labour, the most costly resource accounted for 88.3% of total costs and 82.0% of explicit costs in period II, and 84% of total costs and 76.7% of explicit costs in period III.

Systemic relationship between size and cost is given in Table 17. It shows average total and explicit costs increasing with program size in period II and, although the rate of increase was not statistically significant, in period III, and average implicit costs remained constant in both periods.

Table 18 shows estimated average explicit costs for hypothetical programs ranging in size from 1 to 5000 participants. Period III had higher explicit costs at the low end of the scale ($2.17 for the first 1000 participants) but a slow rate of increase, so that once the number of participants exceeded 2500 (approximately) costs became lower.

An impact on efficiency is observable in the differences in costs between periods II and III. Average costs were lower in the latter period. This evidence of greater efficiency may have resulted from increases in average labour productivity or, inasmuch as there was less variation in period III and the slope of the explicit cost relationship was reduced, from maturation in the organization and operation of the programs.

Stamm and co-workers (1984) reappraised school-based weekly fluoride mouthrinse programs (FMR) for the prevention

Table 17 Relationship of costs to program size

Cost category	Constant (dollars)	Change in cost per additional participant (dollars)	*t*-value
		Period II	
Total	$2.45	$0.00081 (0.00026)	3.11*
Explicit	0.43	0.00094 (0.00024)	3.93*
Implicit	2.02	−0.00013 (0.00015)	0.87
		Period III	
Total	3.26	0.00039 (0.00034)	1.15
Explicit	1.76	0.00041 (0.00027)	1.51
Implicit	1.50	−0.00002 (0.00015)	0.10

* Significant at 0.01 level, $t(12, 0.995) = 3.055$.
Standard errors are shown in parentheses.

Source: Doherty and Powell, 1984

Table 18 Estimated average explicit costs per participant (1978 dollars)

No. of participants	Average cost	
	Period II	Period III
1000	$1.37	$2.17
2000	2.31	2.58
3000	3.25	2.99
4000	4.19	3.30
5000	5.03	3.81

Source: Doherty and Powell, 1984

of dental caries in non fluoridated communities in the United States. Table 19 summarizes nominal cost estimates for US fluoride mouthrinsing programs as reported in the literature. The literature on costing FMR programs is somewhat obscure, in large part due to the varying terminology and definitions employed in expressing costs. In classical economic terms, total cost is the sum of fixed and variable costs with the latter broken down into direct and indirect cost components. However, Leverett and Sveen (1980) define total cost as the sum of actual and contributed costs. Doherty et al. (1984) equate total cost to the sum of explicit and implicit costs. Foch et al. (1984) sum direct and overhead cost to determine total cost for FMR programs. The latter authors explicitly exclude the cost of donated goods and services, a category apparently included by Leverett and Sveen and by Doherty et al.

Since the above mentioned studies covered different time periods, the costs have been converted to 1981 dollars. Using the adjusted dollar figures, the lowest mean cost estimate comes to $3.41 while the highest reaches $9.64. In the case of the low estimate, it is assured that an ongoing school dental health education program already exists so that the $3.41 figure represents an incremental cost. Further no allowance is made for overhead such as administration or slack periods nor are donated goods and services included in the cost. In the case of the high cost, $9.64, this figure relates only to variable costs and does not include a fixed-cost component. In short, neither cost figure should be seen as inflated. These comments on

TABLE 19. Estimated annual costs per child of fluoride mouthrinse programs in North America

	Estimated cost		
	Year reported	Nominal	$1981[b]
Horowitz et al.	1971	$ .31[a]	$ .81
Ripa et al.	1977	.45[a]	.68
Brunelle and Miller	1979	3.49[b]	5.24
Leverett and Sveen	1980	2.35[c]	3.53
Doherty and Powell	1980	6.01[d]	9.64
Heifetz	1982	.75[a]	1.13
Driscoll et al.	1982	.62[a]	.78
Miller and Brunelle	1983	.71 - 9.27[c]	.99 - 12.93
Doherty et al.	1983	4.70[f]	6.56
Foch et al.	1984	3.41[g]	3.41

[a]Materials cost only.

[b]Mean of 17 NIDR-sponsored demonstration programs after 2 years.

[c]Reduces to $2.02 if contributed costs are excluded.

[d]Variable costs only. Fixed costs associated with program are excluded.

[e]Same set of studies as in b; suggests a mean somewhat over $3.49.

[f]Mean cost based on 14 of studies in b. Reduces to $3.18 if implicit costs are excluded.

[g]Incremental direct cost if an ongoing dental education program already exists in the school.

[h]Adjusted costs assume nominal costs apply to period of study rather than year study reported.

Source: Stamm, Bohannan, Graves and Disney, 1984

Table 19 should suggest to the program administrator that consideration of an FMR program for 10,000 children would require a minimum annual budget in the range of $50,000 (in 1981 terms) This estimate would have to be adjusted to local circumstances, including wage rates, and to variations in the cost of overhead as well as donated goods and services.

In conclusion, the authors offered the perspective that school-based, weekly FMR programs in non fluoridated regions are less efficient than is commonly believed. An evaluation of FMR programs suggests that:

(1) effectiveness claims are modestly overstated

(2) the caries increment in untreated children is frequently overestimated

(3) the problems with longer term compliance are generally disregarded, and

(4) the true cost of operating a school-based FMR program is usually understated.

6. DISCUSSION

Today, as during the past 35 years, the best individual defence against dental decay remains proper use of fluorides. The mechanisms by which fluorides prevent dental decay are thought to vary, depending upon the agent used, its route of administration, its concentration and frequency of use, and the vehicle used to deliver it. More than one mechanism may operate simultaneously and, thus, a potential for additive effects exists from the use of multiple fluoride procedures. Perhaps the most important element in producing marked cariostasis is the frequent provision of low concentrations of fluoride to teeth and dental plaque.

Anticaries mouthrinses containing fluoride salts have been clinically evaluated by numerous investigators under a variety of conditions. A number of fluoride salts have been used in these studies and the fluoride concentrations have varied, as well as the frequency of application. Most of the studies have been conducted with either neutral sodium fluoride or an acidulated phosphate fluoride preparation. The procedures most frequently used involved the use of rinses containing approximately 0.02% fluoride applied daily or 0.1% fluoride applied weekly.

The two most common fluoride rinsing techniques combine the two variables, fluoride concentration and rinsing frequency. With the low potency/high frequency technique; the patient rinses daily with a fluoride solution containing approximately 200-225 ppm F. With the high potency/low frequency technique, the patient rinses once a week with fluoride containing

900 ppm F. An advantage of daily rinsing regimen is that if the patient misses several sessions, it is probably less critical than if he was on a weekly schedule. Another advantage of 0.05% NaF concentration (low potency rinse) is that it can be used to provide both a topical and systemic benefit when indicated for the individual patient. Because of these practical considerations, the low potency/high frequency rinsing regimen is recommended for home use. The latter technique of a 0.2% NaF solution (900 ppm) once a week is the preferred rinse procedure for school-based rinse programs.

NaF has been the most frequently tested fluoride compound. Stannous fluoride containing mouthrinses have been tested in few trials but no direct comparison with other compounds has been made. They do not appear to be superior to NaF containing rinses. Acidulated phosphate fluoride (APF) preparations generally deposit more fluoride in enamel than neutral sodium fluoride solutions. However, in fluoride rinses, they were found to be clinically equally effective.

While fluoride rinsing reduces the prevalence of caries in the primary dentition, the effects are not as great as in the permanent dentition. A principal reason for the disparate findings between the two dentitions may be the degree of post-eruptive maturation of the primary and permanent teeth at the time of first contact with the fluoride rinse. Newly erupting teeth usually show greater benefits from topical fluoride therapy than teeth that have been erupted for several years.

Few studies have demonstrated that weekly and daily mouthrinsing provide significant caries-preventive benefits beyond those already accrued from consuming optimally fluoridated drinking water. But percentage reductions in caries reported for certain other fluoride procedures in fluoridated areas have generally been smaller than those reported for the same procedures in non-fluoridated areas. The achievement of at least comparable relative effectiveness in a fluoridated area is important from a standpoint of cost-effectiveness, because the potential number of tooth surfaces that can be protected from decay by use of the procedure has already been reduced by about 50 to 65% as a result of fluoridation. This factor alone greatly reduces the cost-effectiveness of any supplemental procedure. If a supplemental procedure also proves to be less cariostatic in a fluoridated area, then cost-effectiveness is reduced even further.

Various combinations of self-applying fluorides may produce additive benefits, particularly those that incorporate different concentrations of fluoride, frequencies of application, and methods of administration.

Like other methods of fluoride therapy, fluoride rinsing provides preferential protection to the smooth tooth surfaces, while the least benefit is derived by the pits and fissures of the occlusal surface. Anterior teeth benefit most from fluoride mouthrinsing (Koch, 1967).

It would appear likely that the beneficial effect of plaque as 'biological applicator', resulting in higher enamel fluoride levels in plaque-covered areas is likely to be at

least equalled by the detrimental effect of plaque as an essential ingredient in the aetiology of caries and gingivitis. Larger data are needed to establish plaque inhibiting effects of mouthrinses.

There are some aspects of fluoride mouthrinsing that require further clarification. One question which needs to be resolved is whether the anticaries effect persists after participation in a fluoride mouthrinsing program ceases. It was shown that as the longevity of the children's participation in the rinse program increased, the residual anticaries benefit increased.

Repeated high doses of systemic fluoride can result in enamel fluorosis, which clinically manifest as unesthetic hypoplastic or hypocalcific defects of the tooth crown. For this reason, it is important to evaluate the effect of inadvertent repetitive ingestion of fluoride mouthrinsing. Several variables influence the amount of solution that may be retained while rinsing. Among these are the age of the participant, the volume of solution used for rinsing and the rinsing time.

In caries prevention it is frequently necessary to decide between alternative ways of achieving the same primary objective of caries prevention. It then becomes unnecessary to calculate the benefit in monetary terms and this can be expressed in terms of the number of carious teeth or surfaces prevented. This is cost-effectiveness analysis which enables the planner to determine the least expensive of several alternatives of achieving a stated objective. It must be recognized that all such calculations are imperfect and serve

only as the best available information for the planner. Of particular relevance is our lack of long-term knowledge of the caries-preventive effect of various fluoride procedures. Many procedures are school based and the benefit may be lost soon after the participants leave school. Almost all the studies reported in the previous chapter have been short-term clinical trials or experimental clinical trials, where the agent or procedure is given the greatest chance of showing its effectiveness. The effectiveness of a preventive regime may differ when implemented on a community basis from that observed in an experimental clinical trial, although the limited amount of data available (mainly from Scandinavia) seems to indicate that percentage reductions in community preventive schemes are experimental clinical trials are substantially similar. It is probable that in many estimates both the cost and the benefit are underestimated, although benefits are more likely to be underestimated than cost (Burt, 1978). Because disease levels and resources will vary from community to community, a public health planner must estimate cost-effectiveness ratios based as much as possible on local information.

The size of the caries increment will considerably alter the cost-effectiveness of a caries preventive measure. For example, in a community with optimum water fluoride regimes will be halved. Alternatively, if only children at high risk of developing caries are included, the ratio becomes more favourable to the preventive measure, although the organization becomes much more difficult.

7. CONCLUSIONS

A wide range of types of fluoride compound, concentration of fluoride and frequency of rinsing has been tested in many areas of the world. From the results it can be concluded that fluoride mouthrinses are amongst the most effective methods of topical fluoride therapy. As with other topical methods, effectiveness may diminish after rinsing ceases. Neutral sodium fluoride has been the most commonly tested compound, and because of its effectiveness, ease of formulation, low cost, ease of storage, and lack of taste or possible staining, it is the agent of choice. Effectiveness increases with frequency of rinsing, but substantial reductions are observed with weekly rinses. The range of effectiveness in caries prevention is 20-50%.

Fluoride rinse may be used in fluoridated communities; they impart additional benefits to other forms of fluoride therapy, including water fluoridation, topical fluorides, fluoride tablets, and fluoridated dentrifices. They are useful, however, only for patients who can swish and expectorate properly, and their use is contraindicated in preschool children on a routine basis because the swallowing reflexes are not fully developed and an excessive amount of rinse may be swallowed.

A fluoride mouthrinse program may be implemented easily in schools under the supervision of teachers and dental nurses. Mouthrinsing is relatively inexpensive, simple to do, and extremely safe. Daily rinsing would be more effective than less frequent rinsing schedules. Fluoride

rinses may be extremely valuable for patients who live in fluoridated communities, yet have previous histories of high caries activity. Fluoride rinses also may be desirable for patients undergoing orthodontic care, or who have other types of dental appliances, including partial dentures, onlays, etc.

Because of the relative safety of fluoride rinses and because they are usually formulated in low concentrations, similar to those used for a fluoride-containing dentrifice, consideration should be given to make fluoride mouthrinses available over-the-counter. Fluoride can be added easily to commercial mouthwashes. Fluoride rinses should be packaged to avoid being readily opened by young children; they also should not be sweetened excessively nor coloured brightly in order to reduce the possibility of accidental ingestion.

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