USE OF FLUORIDES FOR THE PREVENTION AND CONTROL OF DENTAL CARIES OF CEMENTUM AND DENTINE OF THE ROOT

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SUMMARY

In modern dentistry there has been a gradual shift from treating caries by drilling and filling, towards prevention and control of caries by the use of oral health education and the use of various chemical agents. These agents can be used to disrupt and prevent plaque formation, which has been thought responsible for harbouring oral micro-organisms which breakdown carbohydrates into acids.

These acids will periodically attack the tooth tissue eventually resulting in carious lesions appearing on the surface.

The result of efforts over the past 40 years has resulted in a population, children and young adults, with healthier dentition. The increase in the number of older people maintaining their natural teeth has raised the possibility that root caries will become a significant problem in the future.

Of all the preventive programs available, the most effective and practical method is the use of fluorides to combat root caries.

This treatise deals with the review of the literature on the use of chemical agents such as fluorides for the prevention and control of dental caries of cementum and dentine of the root. It also deals with the anti-cariostatic action of fluoride, especially in re-mineralisation of early caries lesions.

Survey data shows that the various sources of fluoride from which man receives his fluoride intake, mainly food and water, do not contain sufficient levels of fluoride to be of any great benefit.

From studies on the benefits of adding fluoride to water, conducted in the 1940s and 1950s in the United States, it was concluded that this method of fluoride delivery was an effective method of delivering fluoride to the oral environment. With studies showing a reduction in caries incidence of between 50-60 per cent, using fluoride concentrations of 1.0 ppm.

Therefore community water fluoridation has been used to ensure that man receives sufficient fluoride intake in order to prevent and control caries.

It has been shown that systemic fluorides are most effective from birth until primary tooth eruption. However, their effects on permanent teeth, post-eruption, have been considered to be negligible.

It has also been determined that the benefits of fluoride consumption will continue beyond school age, but not indefinitely, thus consumption of fluoride must continue throughout life in order to maintain protection against root caries.

Systemic fluorides have been one source of fluoride delivery but there have been other sources such as dietary fluoride supplements and fluoride supplements.

Dietary fluoride supplements have been trialled particularly in salt and milk. However, these have had limited success as a fluoride delivery vehicle because they rely purely on the dietary habits and preferences of the community, meaning that not everyone will benefit equally.

Fluoride supplements in the form of tablets and drops have also been trialled and have been found to be effective, in particular, in areas which are isolated, do not have a community water supply or it is uneconomical to have water fluoridation because the community is too small. However, these rely on the vigilance of the parents or teachers to ensure that the supplements are used correctly, also in the case of a school application, when schools are closed for holidays the children will most likely miss out on doses of fluoride supplements.

The use of topical fluorides has been found to be beneficial in the fight against root caries. Many topical fluoride agents are available in the form of solutions, gels, prophylaxis pastes, sealants and restorative materials.

Topical fluoride preparations can be either professionally applied by a dentist or dental auxiliary at a clinic, these agents are usually high in fluoride concentration and meant to be applied on an annual or semi-annual basis, or self-applied, which can be applied at home by the patient, being low in fluoride concentration can be used regularly without danger.

The use of professionally applied topical fluoride preparations have resulted in a reduction of caries ranging between 30-40 per cent. Whereas, self-applied topical fluoride preparations have resulted in caries reductions ranging between 20-40 per cent.

The results on the caries reduction potential of topical fluorides both professionally applied and self-applied methods of fluoride delivery are somewhat similar, the only major difference being the economics of application, whereby the self-administered are cheaper than professionally administered and fluoride mouthrinses are cheaper than other agents because of the ease of application.

So perhaps a combination of different fluoride regimens is the answer to effectively preventing and controlling caries of the root.

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1 INTRODUCTION

1.1 DENTAL CARIES OF CEMENTUM AND ROOT DENTINE

It is generally recognised that dental caries is an infectious disease which causes localised destruction of the coronal and the radicular dental hard tissues induced mainly by acids produced in dental plaque [Frank, 1990].

Prevention has become the theme of modern dentistry during the last 20 years, and at a public health level has been approached in two different ways.

The first, is that there has been a growing emphasis on regular brushing and dental examinations.
The second, is the uses of fluoride for the prevention and control of dental caries.

Although dental caries has generally been considered to be a disease of childhood or early adulthood, dentists have now started to realise that it also affects older patients as well, particularly those in the age groups 50-60 years old, with figures of caries lesions given as high as 60 percent [Banting & Ellen, 1976].

The lesions in the older age groups will be mainly found on the roots of the teeth and this is of great concern because they are very difficult to treat, as we are dealing with an area which extends below the gingiva [Banting & Ellen, 1976].

Root caries has been most commonly described as a soft, irregular shaped, dark coloured, progressive lesion, either totally confined to the root surface or involving the undermining of enamel usually at the cemento-enamel junction, but clinically indicating that the lesion initiated at the root surface [Katz, 1986].

There is a general agreement that the exposure of cementum to the oral environment is a prerequisite for the development of root surface caries. All reports on root surface caries have made reference to the presence of periodontal disease, either prior to, or at the time of initiation, of root surface lesions. The root surface, due to its structure, seems to be more susceptible to chemical attacks (acids) and mechanical attacks than does enamel [Banting & Ellen, 1976].

Several characteristics of the root of the tooth itself must be considered in the etiology of root caries. The surface of the cementum is not nearly as smooth as enamel, particularly where there are remnants of Sharpey's fibres. Sharpey's fibres are those portions of the principal fibres of the periodontal ligament that are embedded in the root cementum and alveolar bone proper, and which contribute to the anchorage of the tooth [Harty & Rogston, 1987]. This might predispose the cementum to greater bacterial retention and plaque accumulation [Banting & Ellen, 1976].

Cementum is composed of approximately 55 percent organic framework consisting of collagenous fibrils embedded in a ground substance and 45 percent inorganic material in the form of calcium salts. Therefore, the high organic content of cementum may be an important determinant in the histopathology of root surface caries as it could retard de-mineralisation and function as a framework upon which re-mineralisation can more readily take place [Banting & Ellen, 1976].

The anatomy of the cemento-enamel junction itself may possibly influence the course of root caries. The cementum and the enamel meet end-to-end at the cemento-enamel junction in about 30 percent of teeth. However, in 5-10 percent of teeth they do not meet at all, and in studies conducted by Ramsay and Ripa (1969), it was shown that this did not occur in over 30 percent of cases, leaving the dentine exposed to the oral environment, whereas in the remaining 60-65 percent of teeth the cementum overlaps the enamel at the cemento-enamel junction [Banting & Ellen, 1976].

The absence of cementum in the imperfect end-to-end joint at the cemento-enamel junction may physically facilitate the caries process in that area providing ready access to the dentine and may account for the large number of lesions observed there [Banting & Ellen, 1976].

Eventually the lesions increase in size coalescing at the base of the fissure, the enamel lesion broadens as it approaches the underlying dentine [Murray, 1989].

In view of the difficulties encountered in treating dental caries, prevention seems to be the best approach in controlling caries in the cementum and dentine of the root [Banting & Ellen, 1976].

The use of fluorides will increase the resistance of the cementum and dentine of the root to acid attacks. Topical fluorides have been advocated for use on cementum to increase its resistance to decalcification.

Toothpastes, mouthrinses, gels and varnishes have been suggested as vehicles for fluoride because of their ease of application and their ability to remain on the root surface for extended periods of time [Banting & Ellen, 1976].

1.2 FLUORIDES AND DENTAL CARIES

Dental caries, or tooth decay, is a pathological process of localised destruction of the tooth tissue by micro-organisms (bacteria) [Newbrun, 1980].

Dental Caries is a multifactorial disease in which there is an interplay of three major factors which results in dental caries [Newbrun, 1980].

(i) The host, primarily the saliva and teeth.

(ii) The microflora, bacteria living in plaque which produces acids when it breaks down sugars (fermentation).

(iii) The substrate or a suitable diet for bacterial fermentation to occur.

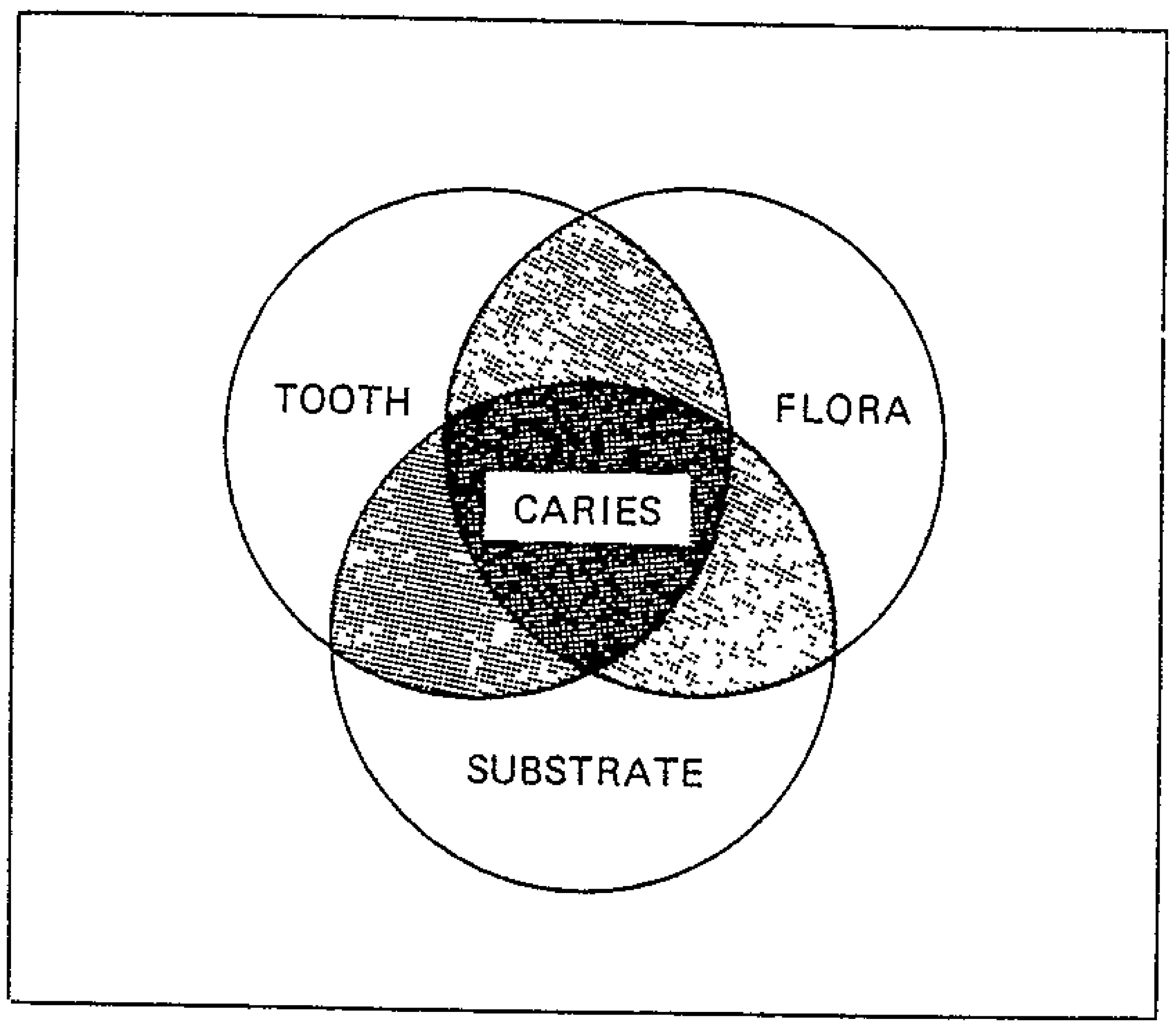
In addition to the above factors, time is also very important.

Only if all three factors are present will clinical caries become evident, a good example of 'disease ecology' [Burt et al., 1983].

The interplay between the major factors responsible for dental caries is diagrammatically depicted in Figure 1.

Figure 1: A diagrammatic representation of the primary (essential) factors in dental caries etiology. Concurrent interaction of three factors over a period of time (overlapping circles) is essential for caries to develop [Keyes, 1960].

Source: Nikiforuk, 1985 page 74.



Preventive procedures aim to upset this ecosystem by influencing the host enamel, the bacterial agent or the plaque substrate. Dietary control, for example, aims to reduce the substrate.

Fluoride acts in several ways. When ingested during the period of tooth development, it is deposited in the enamel to produce more acid resistant enamel. When applied topically, fluoride continues to strengthen enamel, aid remineralization and exerts antibacterial action [Burt et al., 1983].

The question then arises as how to best administer fluorides to the tooth environment in order to achieve the desired results.

Fluorides can be administered in one of two ways:

(i) Systemic - Community water fluoridation
- Dietary supplements
- Fluoride supplements

(ii) Topical - Fluoride preparations directly applied to the tooth environment

Community water fluoridation

Trials were conducted in the United States in the 1940s, with community water fluoridation, the results from these trials were conclusive enough to make community water fluoridation acceptable in many countries over the following 40 years.

Community water fluoridation has thus far proved to be the most cost effective way of providing fluorides to large sections of the population simultaneously, effectively and with a guarantee of success [Burt et al., 1983].

Some fluoride is already found in drinking water from all sources. In concentrations between 0.7 and 1.2 parts per million (ppm), fluoride reduces tooth decay experience by 50-60 per cent in population groups consuming such water continuosly since birth [Burt et al., 1983].

This range of concentrations allows for the fact that people in warmer climates drink more water, on average, than do people in cooler climates [Burt et al., 1983].

Some 30-40 years of epidemiological studies established the relationship of natural fluoride in drinking water to the prevention of dental decay [Burt et al., 1983].

Three North American community experiments were begun in 1945 to determine whether the addition of fluoride to bring its concentration in drinking water to 1.0 ppm could significantly reduce the incidence of dental caries in the community. In each case 15-18 years of supplemnetal fluoride resulted in caries reductions of 50-70 per cent [Burt et al., 1983].

Results such as those obtained in the early investigations have been replicated in many other countries under a variety of conditions. Dental caries reductions of approximately 50 per cent have been consistently reported [Burt et al., 1983].

While water fluoridation is principally associated with reduced tooth decay in children, adults born, raised and continuing to live in fluoridated communities have demonstrated better dental health than have adults in non-fluoridated communities [Burt et al., 1983].

The repeated topical action of fluoride, in addition to the systemic benefits obtained during tooth development is probably responsible for these continued benefits. Stamm and Banting (1980) have demonstrated that lifelong residence in fluoridated areas leads to a significant reduction of root caries in adults of all ages in comparison to the prevalence found in non-fluoridated areas [Burt et al., 1983].

Having looked at water fluoridation, we should also take a brief look at other methods of systemic fluoridation such as dietary fluoridation, salt and milk and fluoride supplements, tablets and drops.

Fluoride as a food additive

Fluoride is found naturally in relatively high concentrations in certain foods such as fish and tea [Mellberg & Ripa, 1983].

In some countries, it has been added in controlled amounts, to salt or milk, prior to marketing and distribution, in order to provide cariostatic benefit [Mellberg & Ripa, 1983].

Wespi first promoted the use of salt as a fluoride delivery vehicle in the mid 1940s. Since then controlled studies have been conducted in Switzerland, Columbia, Hungary and Spain [Mellberg & Ripa, 1983].

Initially, supplemntation was at the level of 90 mg F/Kg of salt. However, this level was later increased to concentrations ranging between 200-350 mg F/Kg of salt [Mellberg & Ripa, 1983].

Marthaler (1978) reviewed the studies that had been caried out in this area and reached the conclusion that the cariostatic effectiveness of fluoride supplemented salt can equal that reported for water fluoridation [Mellberg & Ripa, 1983].

Studies conducted in Switzerland showed that when 250 ppm fluoride was added to salt there was a reduction in the incidence of caries in the order of 60 per cent [Burt et al., 1983].

The major problem with this technique is that not every community consumes salt at the same rate, because of the broad individual and cultural and dietary variations.

In milk fluoridation, fluoride is added to the milk, studies exploring the feasibility of milk as a fluoride vehicle [Muhler & Welddle, 1955; Ericsson, 1958] have given equivocal results, perhaps because milk in the gastrointestinal tract may reduce the absorption of ingested fluoride. In the few studies carried out with fluoridated milk, there is no agreement concerning the optimum fluoride concentration [Burt et al., 1983].

Fluoride supplements

When an individual consumes a fluoride tablet, fluoride-vitamin drops, or other fluoride preparations, the ingested fluoride is dissolved from the stomach and small intestine into the bloodstream. Fluoride is absorbed as the ion (F^-) and provided it is ingested in solution or easily soluble form, absorption will be rapid and relatively complete [Mellberg & Ripa, 1983].

Fluoride supplements provide both a systemic and a topical benefit as they are chewed or swallowed they dissolve in saliva [Mellberg & Ripa, 1983].

Two types of fluoride supplements commonly used are drops and tablets. Drops and tablets are effective caries inhibiting agents which exercise their benefit through mainly topical means [Stephen, 1993].
Results of caries trials in which drops or tablets were used in the home vary from excellent to poor, depending on the compliance rates of both parents and children.

However, delivery in schools has caries reduction rates varying as well with the highest rate been given as 80 per cent reduction and the lowest rate given as 20 per cent reduction, depending on the care and the amount of supervision given to children [Stephen, 1993].

At the individual level, the slow intra-oral dissolution of fluoride tablets can be of great benefit for coronal caries in children, adolescents and possibly medically compromised adults, their contribution on a community basis cannot be readily compared with that of water fluoridation or dietary fluoridation [Mellberg & Ripa, 1983].

Dosages tend to vary from 0.25 mg/tablet to 1.0 mg/tablet, depending on the amount of fluoride present in the water supply, whereas drops tend to have 0.1 mg F per drop [Mellberg & Ripa, 1983].

Community-based measures have the advantage of reaching all (or many) members of the community, but their disadvantage is that they cannot be tailored to the needs of each individual. Individually based measures can be applied in public programmes, usually under supervision, or applied in the private office where the best opportunity exists for meeting the specific needs of each individual [Burt et al., 1983].

Now we look at several methods of topical fluoridation which can be employed in the prevention and control of dental caries. Two methods used are self applied and professionally applied:

a. Self Applied Topical Fluorides

Fluoride mouthrinsing, which involves mouthrinsing with fluoride solutions. This has proved to be a feasible and effective method for the prevention of dental caries in school children. The findings of more than 30 studies in several countries indicate that the incidence of dental decay can be reduced by about 35 per cent when this procedure is used daily, weekly or fortnightly. In most of these studies, children have rinsed either daily with 0.5 per cent sodium fluoride or weekly with 0.2 per cent sodium fluoride [Burt et al., 1983].

Brushing with fluoride solutions, gels and prophylaxis pastes. Brushing and flossing per se, without the use of a therapeutic dentifrice, solution, paste or gel, is not an effective means of preventing caries. Probably the reasons are the inherent inability of the toothbrush to penetrate fissures and internal areas, a problem made worse by inefficient brushing action [Burt et al., 1983].

Programmes of toothbrushing with fluoride-containing prophylaxis pastes were popular in several countries like the United States in the 1960s and 1970s. Most of these studies and programmes involved the use of 9.0 per cent stannous fluoride with zirconium silicate abrasive with the recommended frequency of application being 1 to 3 times per year [Burt et al., 1983].

b. Professionally Applied Topical Fluorides

There are many studies to show that professionally applied topical applications of 2.0 per cent sodium fluoride (NaF), 8.0 per cent stannous fluoride (SnF_2) and acidulated phosphate fluoride (APF, 1.2 per cent fluoride ion in 0.1 M phosphoric acid either in solution or gel) can reduce the incidence of dental caries. Children in areas with insufficient fluoride in their water supplies have been shown to develop 30-40 per cent less decay when these agents are applied semi-annually [Burt et al., 1983].

Sodium fluoride solutions are not used very much now. Applications of APF or SnF_2 solutions are recommended at least annually for public health programmes, though better results have been achieved with bi-annual applications [Burt et al., 1983].

Fluoride-containing varnishes and coatings are available in some countries. These products are designed to achieve high fluoride uptake by maintaining contact between both the enamel and fluoride for a longer period of time than is achieved in conventional methods of topical application [Burt et al., 1983].

Evaluations of the effectiveness of topical fluoride applications in fluoridated areas show that the additional benefits are real but modest [Horowitz & Heifetz 1969; Englander et al., 1971].

Professionally applied topical fluorides in public health programmes in fluoridated areas, however, usually are not considered justified on cost-effectiveness grounds. Even in non-fluoridated areas, professionally applied topical applications are an expensive way to provide the dental benefits fluoride in public programme when compared to water fluoridation or self-administered by mouth rinsing [Corpron 1979; Heifetz 1979].

Professionally applied topical fluorides may, however, be more appropriate for special groups such as the mentally retarded [Burt et al., 1983].

In the private dental office, professionally applied topical fluorides are relatively expensive, though suitable for use with selected patients.

They may be of questionable value for private patients in fluoridated areas, especially for those patients who use fluoride toothpaste and perhaps a daily fluoride rinse at home [Burt et al., 1983].

Fluoride Prophylactic Pastes

Collective data have not shown a clearcut cariostatic effect from applications of fluoride prophylactic pastes used alone, so they should not be considered a replacement for topical fluoride applications of fluoride solutions or gels [Burt et al., 1983].

1.3 AIM OF THESIS

Dental caries of cementum and dentine of the root (root surface dental caries) is a very difficult condition to treat, due to the fact that we are dealing with an area which extends below the gingiva.

This region is difficult to work with because it is very close to the pulpal tissue and thus very sensitive. Hence the best approach in dealing with this condition is to prevent and control root caries lesions.

Studies have shown that fluoride is an effective tool which can be used in the prevention and control dental caries of the cementum and dentine of the root.

The aim of this thesis is to study how Systemic and Topical Fluorides can be most effectively used in the prevention and control of dental caries of cementum and dentine of the root, by reviewing some of the available literature in this field.

2 PHYSICO-CHEMICAL ASPECTS OF FLUORIDE ON DENTINE AND CEMENTUM OF THE ROOT

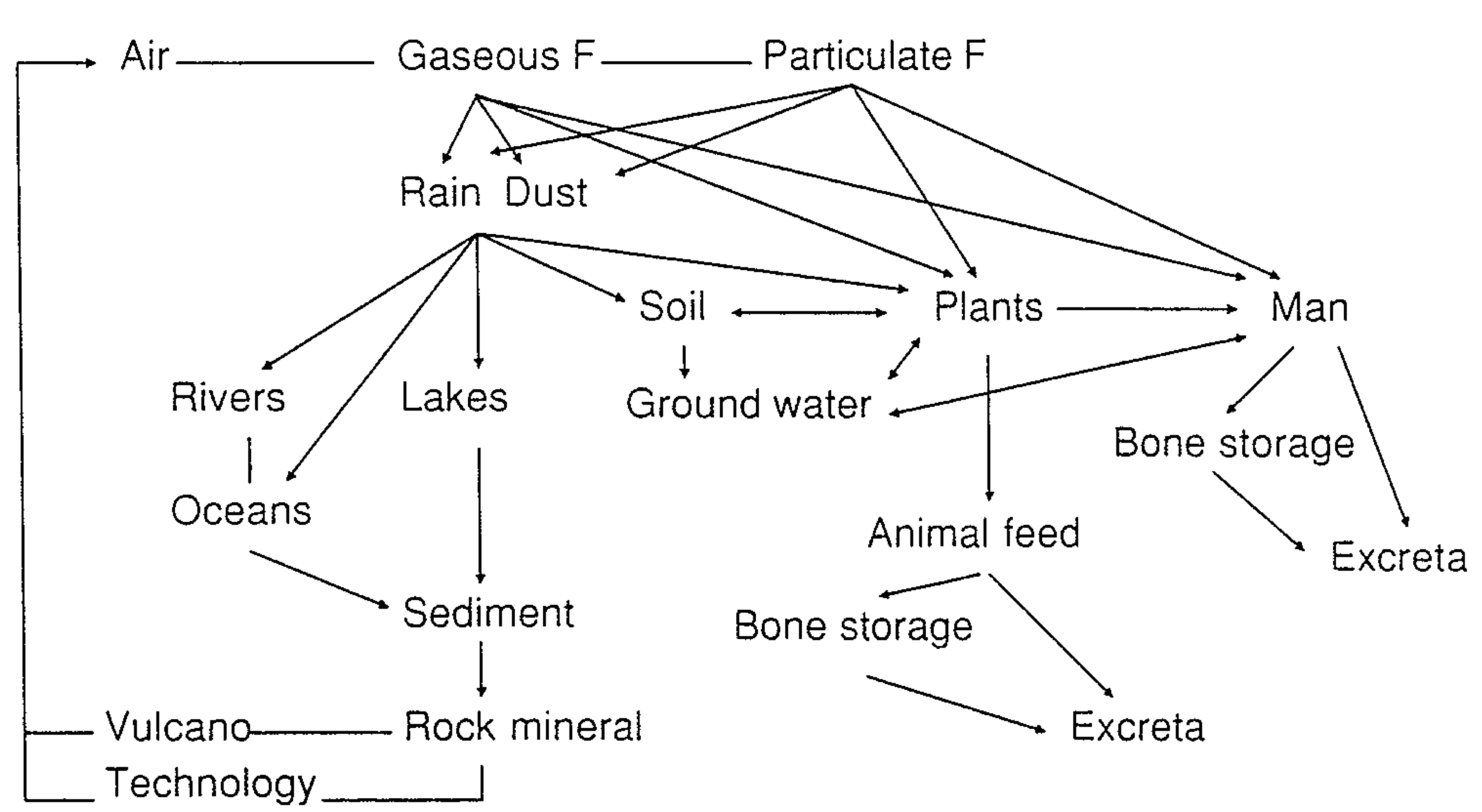
2.1 SOURCES OF FLUORIDE TO THE ORAL ENVIRONMENT

Fluoride is a trace element found naturally occurring in the environment. The abundance of fluorides as trace elements in the environment ranks 13th amongst the elements found in the earth's crust [Smith & Ekstrand, 1988].

The dispersion of fluoride (F) in the biosphere can be represented in Figure 2.

Figure 2: Dispersion of fluoride (F) in the biosphere

Source: **Smith & Ekstrand, 1988 page 14.**



Fluoride enters the atmosphere by volcanic action and by the entrainment of soils and water particles due to the action of wind on these surfaces. Fluoride is returned to the earth's surface by deposition as dust, or in rain, snow and fog [Smith & Ekstrand, 1988].

Fluoride in soils is thought to be derived from the geological parent material. The average concentration of fluoride in rocks and soils has been estimated to be 650 ppm. Fluoride enters the hydrosphere by leaching from soils and minerals into the ground water [Smith & Ekstrand, 1988].

The concentrations of fluorides in water are affected by factors such as availability and solubility of fluoride containing minerals, porosity of rocks or soils through which water passes, residence time, temperature, pH, and the presence of other elements which may complex with fluoride. However most surface water contains less than 0.1 ppm of fluoride [Smith & Ekstrand, 1988].

Fluorides are also widely distributed in the atmosphere originating from the dusts of fluoride-containing soils, from gaseous industrial wastes, from the burning of coal fires and from gases emitted in areas of volcanic activity. However, fluoride intake from air cannot be considered as a major source to man, unless he lives in a heavily polluted area here there is major dust pollution [Smith & Ekstrand, 1988].

Fluoride enters vegetation by uptake from soils and water, by absorption from the air and by deposition from the atmosphere. The normal concentration of fluoride in vegetation, leaves, generally ranges between 2 ppm and 20 ppm on a dry weight basis. However, it must be noted that the concentration will vary amongst species of plants, age of the leaf, soils, use of fertilisers, irrigation and other factors [Smith & Ekstrand, 1988].

Intake of fluoride by man is via the ingestion of water and food which contain or store fluoride and in turn become a source of fluoride to the oral environment.
From an analysis of daily fluoride intake (mg) from individual food groups in the USA, it was found that most food items contain less than 0.5 ppm of fluoride [Smith & Ekstrand, 1988].

The data for the daily fluoride intake from individual food groups is summarised in Table 1.

Table 1: Daily fluoride intake (mg) from individual food groups in the United States in a fluoridated area.

Source: Smith & Ekstrand, 1988 page 22.

Food Group	Fluoride (mg)
Dairy products	0.013
Meat, fish, poultry	0.044
Grain, cereal products	0.241
Potatoes	0.018
Leafy vegetables	0.027
Legumes	0.037
Root vegetables	0.010
Fruit	0.006
Oil, fats	0.003
Sugars, adjuncts	0.001
Total intake	1.383
Total intake minus beverage	0.400

There are a few exceptions such as fish and shell-fish free from bone and skin, contain less than 1 ppm but over 10 ppm with these components present [Smith & Ekstrand, 1988].

The contribution of individual food groups to the daily total fluoride intake is on average 25 percent, the rest coming from water and beverages [Smith & Ekstrand, 1988].

Other sources of fluoride to the oral environment come from topical fluoride preparations such as dentifrices and mouthrinses [Smith & Ekstrand, 1988].

After topical fluoride applications of various fluoride products some fluoride is inadvertently or intentionally swallowed and systemic absorption occurs.

It is important here to distinguish between the fluoride dose swallowed following the daily use of fluoride toothpaste and the dose swallowed after professional application of fluoride products with very high fluoride concentrations [Smith & Ekstrand, 1988].

This is best summarised by Table 2 shown below.

Table 2: Fluoride content of some common dental fluoride preparations.

Source: Smith & Ekstrand, 1988 page 25.

	Type of preparation		Fluoride concentration (ppm)	Amount used		Total fluoride dose (mg)
Topical by dental personal	2%	NaF sol.	9100	2–3	ml	18–27
	10%	SnF_2 sol.	24250	2–3	ml	49–73
	5%	NaF varnish	22600	0.5–1	g	11–23
	1.23%	APF gel	12300	3–4	g	37–49
	9%	$SnF \cdot ZnSiO_4$	22500	2	g paste	45
Home treatment	0.05%	NaF sol.	226	10	ml/day	2.3
	0.2%	NaF sol.	910	10	ml/week	9.1
	0.5%	APF gel.	5000	3–4	g/trays	15–20
	0.4%	SnF_2 gel	970	2	g/brush	2
Dentifrice	0.22%	NaF	1000	2 × 1	g[1]	2
	0.47%	SnF_2	1000	2 × 1	g[1]	2
	0.76%	MFP	1000	2 × 1	g[1]	2
	0.145%	F	1450	2 × 1	g[1]	2.9

[1] Twice daily use

The above data is a summary from the literature showing fluoride dose ingested by small children following the use of fluoride-containing toothpastes. The fluoride dose ingested ranges from 0.10-0.40 mg in small children [Smith & Ekstrand 1988].

The data also suggest that the amount ingested is inversely related to age and directly related to the amount applied to the toothbrush. These studies are based on toothpastes containing 0.1 per cent fluoride (1,000 ppm) [Smith & Ekstrand 1988].

2.2 FORMS AND REACTIONS OF DIFFERENT TYPES OF FLUORIDES

The role of calcium fluoride in the caries process needs to be looked at further. Traditionally fluoride applications were aimed at increasing the content of firmly bound fluoride in the enamel and also preventing the formation of calcium fluoride [Featherstone et al., 1988].

Calcium fluoride was considered to be rapidly removed because of its relatively large solubility and this was verified by experiments (Kalter 1980) where calcium fluoride deposits were leached in tap water and did indeed show a rapid removal of any loosely bound fluoride [Featherstone et al., 1988].

However, it has been demonstrated that a different situation exists in the oral fluid. In vivo, calcium fluoride is actually retained for much longer periods, which was attributed to the high calcium and fluoride content of the saliva compared to tap water. After a single fluoride mouthrinse a considerable portion of fluoride was found to be present as calcium fluoride, even after seven days in vivo leaching [Featherstone et al., 1988].

Additionally, under conditions of cariogenic challenge CaF_2 was found to be converted to fluoroapatite (FAP).

This revised understanding of the role of calcium fluoride is utilised below to help describe the action of commercially available fluoride products [Featherstone et al., 1988].

The diversity of fluoride agents which are available to the public is quite large. There are three main categories.

1 Inorganic agents, which include

NaF, SnF_2, NH_4F

and in these cases the salts are readily soluble providing free fluoride.

2 Monofluorophosphate containing agents, such as

Na_2FPO_3

and in this case the fluoride is covalently bound in the FPO^{2-}_3 ion and apparently requires hydrolysis to free the F^-

3 Organic fluorides, such as

Amine fluoride, Silane fluoride

Products available to the general public, normally include toothpastes and mouthrinses, with fluoride concentrations of 1,000 ppm fluoride and 1,500 ppm fluoride respectively and they may contain any of the agents mentioned above in varying concentrations [Featherstone et al., 1988].

Whereas, products used by dentists are normally high in fluoride concentration as listed in table 3 below and are generally not intended for daily applications, like toothpastes and mouthrinses, but rather applied on a six- or twelve-monthly basis and can also have any of the agents mentioned above, these products come in the form of gels, liquids, pastes and varnishes [Featherstone et al., 1988].

Table 3: Fluoride agents commonly used in clinical practice showing the concentration of fluoride, the amount of fluoride usually used in milligrams with each application.
Source: Nikiforuk, 1985 page 75.

Class	Type	Conc % F	Amt	Total mg F
Topical	2% NaF	1	5 ml/arch	50
	8–10% SnF_2	2–2.5	5 ml/arch	100–125
	1.23% APF	1.23	5 ml/arch	61.5
Home treatment	0.5% APF	0.5	6 g – trays	30
			2 g – brush	10
	0.4% SnF_2	0.1	6 g	6
			2 g	2
Prophy paste	9% SnF_2·$ZrSiO_4$	2.25	2 g	45
	1.2% APF·SiO_2	1.2	2 g	24
Dentifrice	0.2% NaF	0.1	2 g	2
	0.4% SnF_2	0.1	2 g	2
	0.76% MFP	0.1	2 g	2
Rinses	0.05% NaF	0.025	7–10 ml	1.75–2.5
	0.2% NaF	0.1	7–10 ml	7–10
	0.1% SnF_2	0.025	7–10 ml	1.75–2.5

Daily use of fluoride toothpastes or fluoride mouthrinses will provide relatively low concentrations of fluoride on a routine basis and will elevate the fluoride in saliva for a length of time ranging from minutes to hours. It will also elevate the fluoride in the plaque and will provide fluoride at the time of acid challenge and at the time of subsequent remineralisation [Featherstone et al., 1988].

Sodium fluoride-containing pastes (NaF)

Sodium fluoride (NaF) is a white, odourless powder material which is used in toothpastes, mouthrinses and varnishes in concentrations of 2 per cent. Sodium fluoride in toothpaste or other products immediately provides free F^- ions to interact with the stages of the caries process.

Monofluorophosphate pastes (MFP)

The MFP-containing products with fluoride concentrations of 0.76 per cent, provide the MFP ions together with some free F^- ions, both of which can diffuse through the plaque and into the enamel providing a source of F^- ions subsequent to hydrolysis to again interact.

Monofluorophsphate can be hydrolysed in plaque and is also hydrolysed under acidic conditions at the surface of apatite crystals providing phosphate and fluoride ions.

Stannous fluoride (SnF_2)

SnF_2 is widely used in topical applications, second after NaF. For topical applications, it is used at the concentration of 8 or 10 per cent solution of SnF_2 , at pH 2.1 and for dentifrices its concentration is 0.4 per cent in calcium pyrophosphate abrasive system. This provides fluoride ions and stannous ions which act as an anti-microbial agent. In addition, stannous fluoride can produce stannous phosphate fluoride precipitates, which should slow down the caries process, but because it causes stains as a side effect, its popularity is decreasing, despite its caries inhibition [Nikiforuk, 1985].

Amine fluoride

This is essentially an ionic fluoride compound used in concentrations of 1.25 per cent which readily provides free fluoride ions. Its enhanced reactivity has been attributed to the greater affinity of the hydrophilic counter ions to the enamel [Featherstone et al., 1988].

Acidulated phosphate fluoride (APF)

APF is used in concentrations of 1.23 per cenr, this readily etches the enamel surface providing calcium ions which can interact with the fluoride and precipitate large amounts of calcium fluoride which can act in the same way. Further, the hydrogen ions present will complex with the fluoride and produce HF, which will readily diffuse deep into the enamel [Featherstone et al., 1988].

Therefore there is a chemical rationale for the observed clinical effectiveness of these topical agents. Other agents, such as amine fluoride and silane fluoride, again provide a complexed store of fluoride ions and may enhance diffusion through caries enamel, releasing fluoride at appropriate times and appropriate sites.

2.3 LOCALISATION OF FLUORIDE IN DENTINE AND CEMENTUM

Dentine, like cementum, is a mesenchymal tissue, mesenchymal tissues have collagenous matrices and these are retained during the process of mineralisation. The apatite crystallites are small and their surface area as well as their capacity to take up fluoride is consequently much larger [Weatherell & Robinson, 1988].

Fluoride uptake is facilitated by the tubular structure of dentine and also by the fact that it is less mineralised and highly hydrated. Also because it is metabolically active, and continues to grow throughout the life of the tooth, the fluoride concentration of dentine is greater than that of enamel [Weatherell & Robinson, 1988].

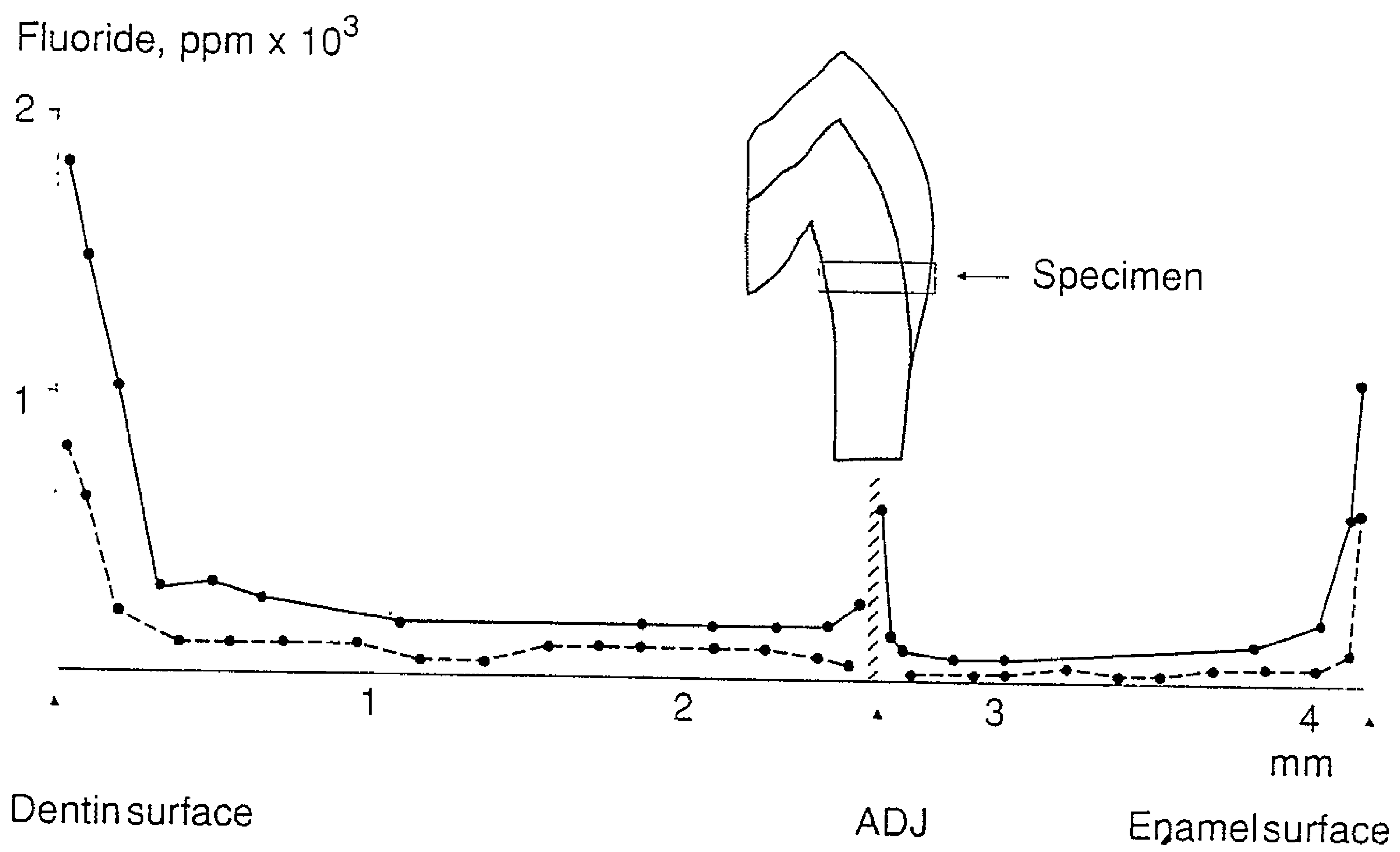
In permanent teeth, the average concentration of fluoride in dentine appears to increase up to the age of about 40, when the fluoride concentration approaches a plateau level, the height of which depends upon the concentration of fluoride in the environment [Weatherell & Robinson, 1988].

Taking into consideration the detailed distribution pattern of fluoride in dentine, the situation is rather more complex than might be indicated by such average data.

Fluoride concentrations are highest at or near the surface limits of the tissue, as shown in Figure 3. In the case of dentine, this is the pulpal surface, where, fluoride continues to be absorbed and probably increases in concentration throughout life.

Figure 3: Distribution of fluoride across the enamel and dentine of a tooth from a low-fluoride district (o- - -o)
dentine of a tooth from a high-fluoride district (o———o)

Source: **Weatherell & Robinson, 1988 page 44.**



This will be partly due to the fact that dentine continues to form throughout life and will constantly accumulate fluoride by accretion during the process of mineralisation. It is also due to the fact that uptake by exchange also tends to be maximum in mineralising regions [Weatherell & Robinson, 1988].

Fluoride will, therefore, be taken up preferentially at the pulpal surface by accretion, exchange and absorption. It is difficult to identify or to distinguish between the influence and interplay of these various factors on the basis of fluoride concentrations alone. For instance, while newly formed dentine, primary or secondary, will avidly absorb and incorporate fluoride by accretion and exchange, a certain length of time will be required to accumulate significant concentrations of the element [Weatherell & Robinson, 1988].

It is, therefore, possible that those outermost areas of tissue which are actively growing and, therefore, most reactive from the point of view of fluoride uptake, might have a relatively low fluoride concentration. This is presumably why fluoride concentrations tend to be low in secondary dentine [Weatherell & Robinson, 1988].

The newly formed tissue, although avidly absorbing fluoride, has had relatively little time to accumulate enough of the element [Weatherell & Robinson, 1988].

Conversely, a totally quiescent dentine surface can passively absorb and accumulate very large amounts of the element, given sufficient time to incorporate fluoride by exchange [Weatherell & Robinson, 1988].

The distribution pattern of fluoride in the primary dentition is complicated by the process of physiological resorption which occurs at the pulpal surface prior to exfoliation. During the period of dentine formation, the fluoride concentration increases with age. As in permanent teeth, this increase is largely associated with the pulpal surface [Weatherell & Robinson, 1988].

Deciduous exfoliation is brought about by the resorption of this pulpal surface, where osteoclasts and Howship's lacunae appear. The age at which this occurs varies with the type of tooth and with the sequence of exfoliation [Weatherell & Robinson, 1988].

The osteoclasts preferentially remove the high-fluoride dentine near the pulpal surface and this continues until the tooth's anchorage in the jaw is lost and the tooth exfoliates. The fluoride concentration in the pulpal surface of deciduous dentine rises during the period of root formation and falls during the period of resorption [Weatherell & Robinson, 1988].

This general phenomenon is seen in all deciduous teeth, although the levels of fluoride achieved during the formation phase and the extent of fluoride loss during the resorptive phase, as well as the timing of these events varies with the tooth type. The greatest rise, as well as the greatest fall, in fluoride concentration are found in the pulpal surface of multi-rooted teeth [Weatherell & Robinson, 1988].

This presumably reflects the fact that such teeth take a relatively long time to form and require an equally long time resorb the roots before the teeth are shed [Weatherell & Robinson, 1988].

Resorption in a multi-rooted tooth is rarely equal in all of the roots. Often one, or even two roots may be completely resorbed and still the tooth may retain its position in the mouth because of the anchorage afforded by a single unresorbed root. This situation cannot arise in incisors or canines, which exfoliate as soon as resorption of their single root is sufficiently advanced [Weatherell & Robinson, 1988].

The periods of formation and resorption and the rise and fall in fluoride concentrations of single-rooted teeth are therefore much less than multi-rooted teeth [Weatherell & Robinson, 1988].

As in the permanent teeth dentition, the fluoride levels in deciduous dentine reflect the amounts of fluoride available. Studies have shown that in areas with low fluoride level (less than 0.01 ppm), fluoride concentrations in the pulpal surface were shown to increase from about 180 ppm at age 3 to about 250 ppm at age 7 and then drop to 100 ppm at age 12, prior to exfoliation [Weatherell & Robinson, 1988].

Whereas, in areas with high fluoride levels in drinking water (around 2.0 ppm), the fluoride concentrations in pulpal surface dentine rose from about 600 ppm at age 3 to almost 1000 ppm at age 7, finally falling to 500 ppm at age 12 [Weatherell & Robinson, 1988].

The outer layer of the tooth root is covered by a thin layer of cementum. Like dentine, cementum is a collagenous based mesenchymal tissue differing, however, in histological structure and resembling bone more than dentine [Weatherell & Robinson, 1988].

Cementum is a very thin layer of tissue in some regions is less than 50 μm thick and this makes it very difficult to sample or analyse and hence making clinical investigations rather difficult [Weatherell & Robinson, 1988].

From analyses carried out on material which seemed to consist predominantly of cementum, it was concluded that its average fluoride concentration was higher than that of any other skeletal or dental tissue. This may be correct but needs to be qualified.

The average concentration of fluoride in cementum is high because the tissue is very thin. All of it is, therefore near to the tissue surface and, therefore, accessible to the fluoride present in blood.

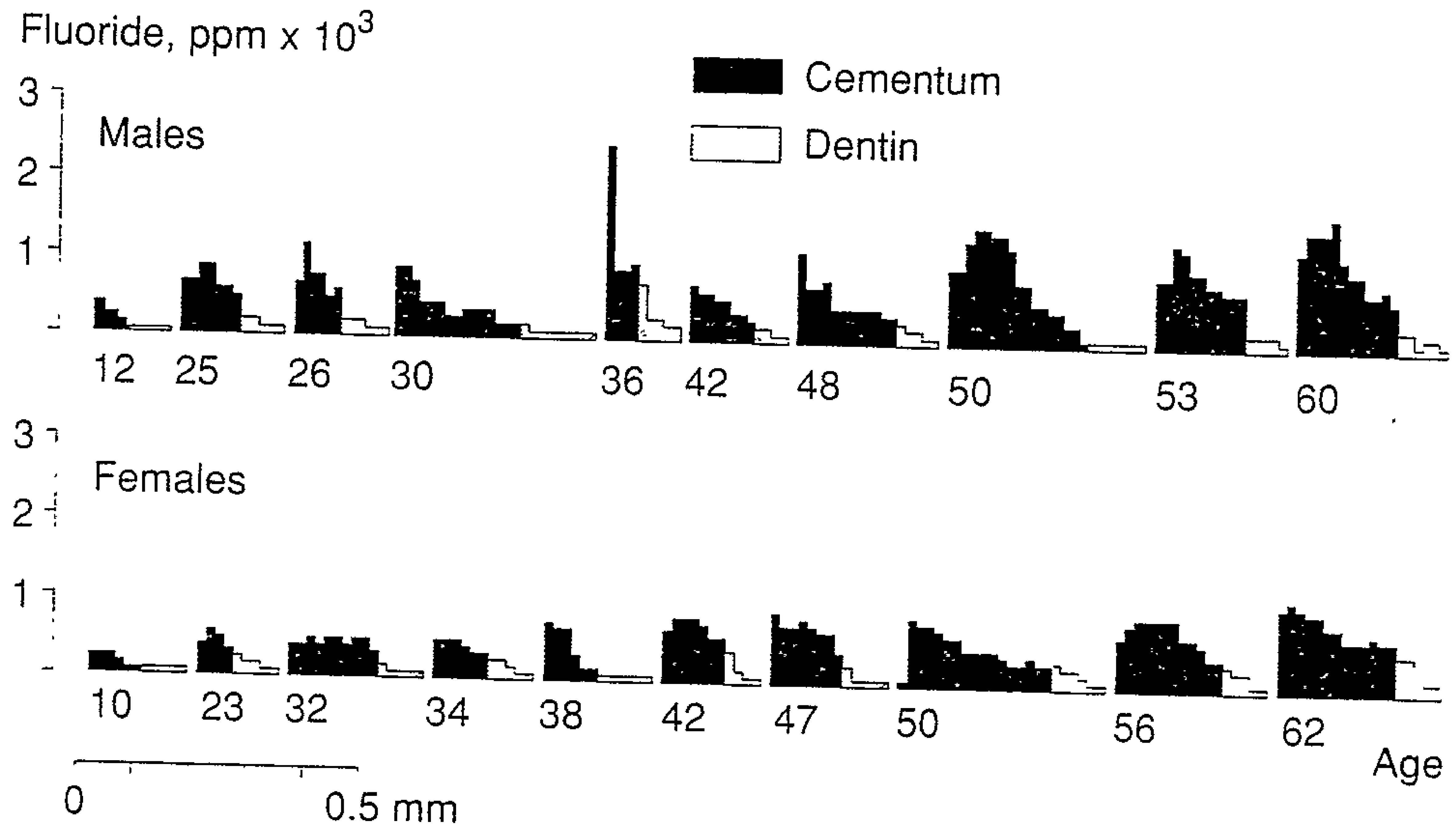
Work with the electron probe carried out by Hals & Selvig (1977) and more recent analyses of thin layers progressively removed from the root surface (Nakagaki, 1985), have shown that, as in other mineralised tissues, fluoride concentrations generally decrease from surface to interior [Weatherell & Robinson, 1988].

In cementum, as in dentine, both the total fluoride content and the average concentration of fluoride increase with age, as shown in Figure 4.

Taking all factors such as, fluoride concentration, thickness of tissue and age of subject, into account, cementum fluoride concentrations seem roughly similar to dentine [Weatherell & Robinson, 1988].

Figure 4: Fluoride concentrations per cementum mineral, in layers obtained from the roots of 20 lower incisors (10 males, 10 females) from subjects aged 16-62 years. With concentration of fluoride in drinking water less than 0.2 ppm.

Source: Weatherell & Robinson, 1988 page 48.



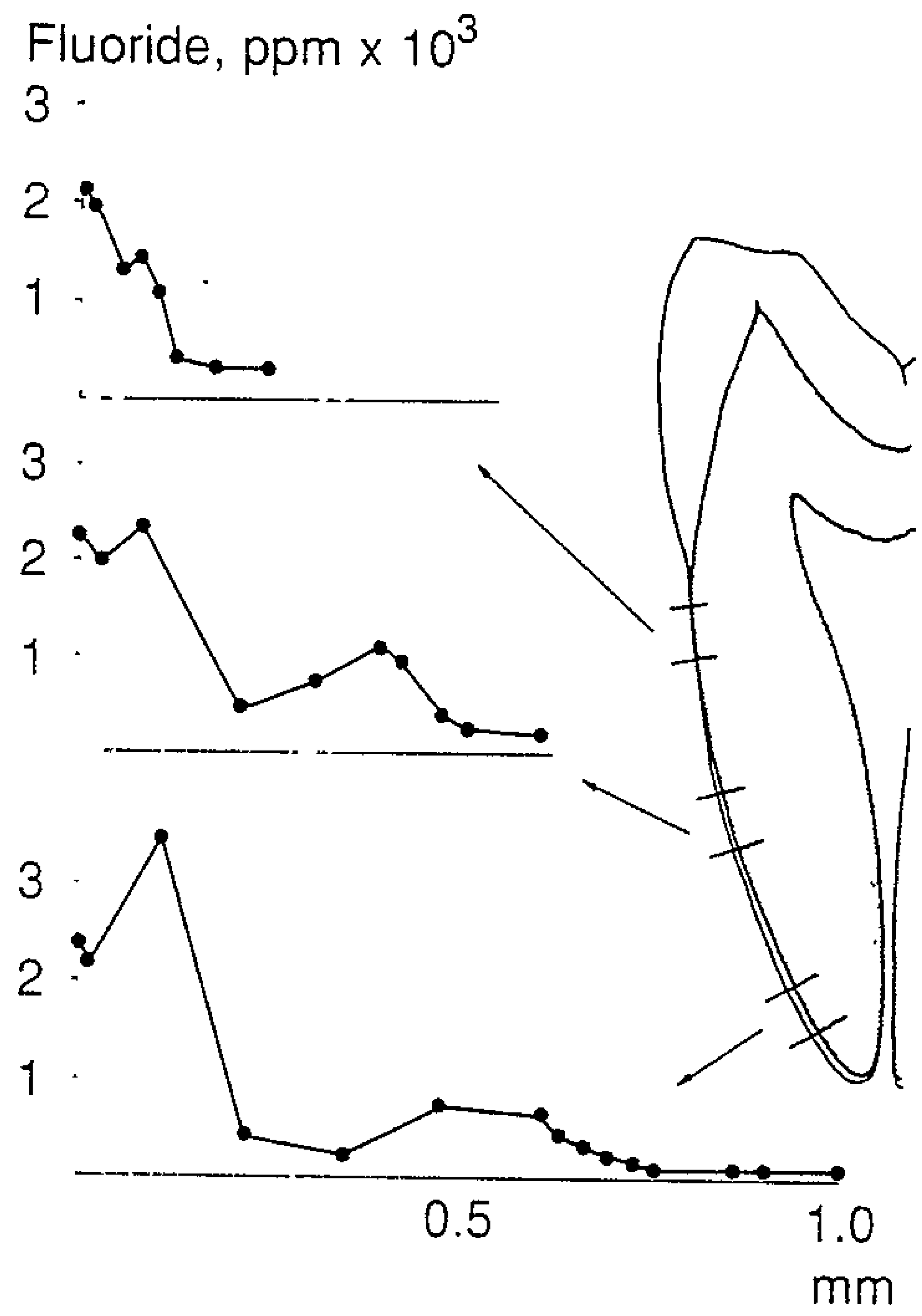
Detailed studies of fluoride variations in cementum carried out by Nakagaki (1985) have shown that maximum fluoride concentration does not always occur in the most superficial outer layer. This is probable because, as with dentine, the most superficial cementum has not had enough time to accumulate significant amounts of the element, having been recently, and perhaps rapidly deposited [Weatherell & Robinson, 1988].

It was also found that, whereas, fluoride concentrations often decrease steadily across the cemento-enamel junction into the underlying dentine, this smooth gradient was occasionally interrupted by a small intermediate peak. This sometimes gave the fluoride profile a fairly recognisable shape and similar profiles tended to be found in different areas of the same tooth as shown in Figure 5.

It is not known whether the occasional peak reflected fluctuations in fluoride content of the diet of if they were due to some structural feature which enhanced the capacity of the tissue to absorb fluoride and what local effect if any the relative high fluoride content might have on cementum [Weatherell & Robinson, 1988].

Figure 5: Patterns of fluoride distribution at three sites in a vertical section of a permanent molar from a 60-year-old.

Source: Weatherell & Robinson, 1988 page 49.



2.4 AVAILABILITY OF FLUORIDE IN THE TOOTH ENVIRONMENT

In the tooth environment, fluoride is found in oral fluids such as saliva and gingival crevicular fluid. Systemic fluoride can enter the oral cavity in the salivary secretions and, in minute quantities, from the crevicular fluid [Geddes & Rolla, 1988].

Saliva is secreted from three pairs of major glands and numerous minor glands. While crevicular fluid is a transudate which passes through the attachment of the gingival epithelum to the cervical cementum of the tooth and is, in composition, more like serum than saliva [Geddes & Rolla, 1988].

Fluoride is also found in plaque fluid, which is the aqueous phase in dental plaque. This provides the aqueous medium for the exchange of diffusing substances between saliva through plaque with its constituent micro-organisms, and the tooth and gingival crevice area [Geddes & Rolla, 1988].

It is believed that the concentration of ionic fluoride in saliva, crevicular and plaque fluid is clinically important [Geddes & Rolla, 1988]. However, there is poor agreement in the published data on the precise concentrations of fluoride in oral fluids. There are three main reasons for the discrepancies. Firstly, concentrations are far too low to accurately measure [Geddes & Rolla, 1988].

Secondly, the difficulty in sampling some fluids, for example, sublingual and minor gland secretions and crevicular fluid [Geddes & Rolla, 1988].

Thirdly, fluctuations occur in the concentrations of fluoride over a 24 hour period, the whole saliva and plaque fluid concentrations are altered by microbial and epithelial cell components [Geddes & Rolla, 1988].

Modern methods of fluoride analysis indicate that endogenous salivary levels of fluoride are around 0.01-0.05 ppm, but are 30 per cent less than, the corresponding serum concentrations. The data available does not suggest any great difference in concentration between different major salivary gland secretions [Geddes & Rolla, 1988].

Whole saliva concentrations are somewhat higher than corresponding duct secretion concentrations, presumably because of exogenous sources retained in and released from the microbial and epithelial containments [Geddes & Rolla, 1988].

Few studies have attempted quantitative analysis on crevicular fluid. Available data indicate that crevicular fluid concentrations are directly related to those of plasma [Whitford et al., 1981].

Plaque fluid concentration are higher than the corresponding saliva endogenous concentrations. Metabolic studies suggest that as the pH of plaque decreases during glycolysis a proportion of the weakly bound fluoride becomes ionised and may, in turn, affect bacterial metabolism [Geddes & Rolla, 1988]. Further, the increased ionic plaque fluid concentration may fall as ionic fluid diffuses out the plaque [Geddes & Rolla, 1988].

The size of the saliva 'sink' into which diffusion could occur may, for long periods during the day and night, be only a thin film of saliva over the tooth and plaque surface. The ionic fluoride in plaque may quickly establish an equilibrium with a small quantity of saliva, thus, the rate of fluoride removal becomes dependent upon the rate with which saliva flows over the plaque and tooth surfaces [Geddes & Rolla, 1988].

3 CARIOSTATIC EFFICACY OF THE COMBINED USE OF FLUORIDES

Ideally, fluoride should be supplied systemically, in a precise dose, for optimum mineralisation of bones and teeth. In addition, topical fluoride should be available throughout life for continuous re-mineralization of early caries lesions. This ideal is difficult to attain, but controlled water fluoridation almost achieves it, combining a high likelihood of ingestion of approximately the correct quantity of fluoride with lifelong topical action [Konig, 1989].

To meet the fluoride requirement, those populations which do not consume water with an optimum fluoride (F) content, will need to use topically applied fluorides in order to achieve maximum effectiveness in caries inhibition [Konig, 1989].

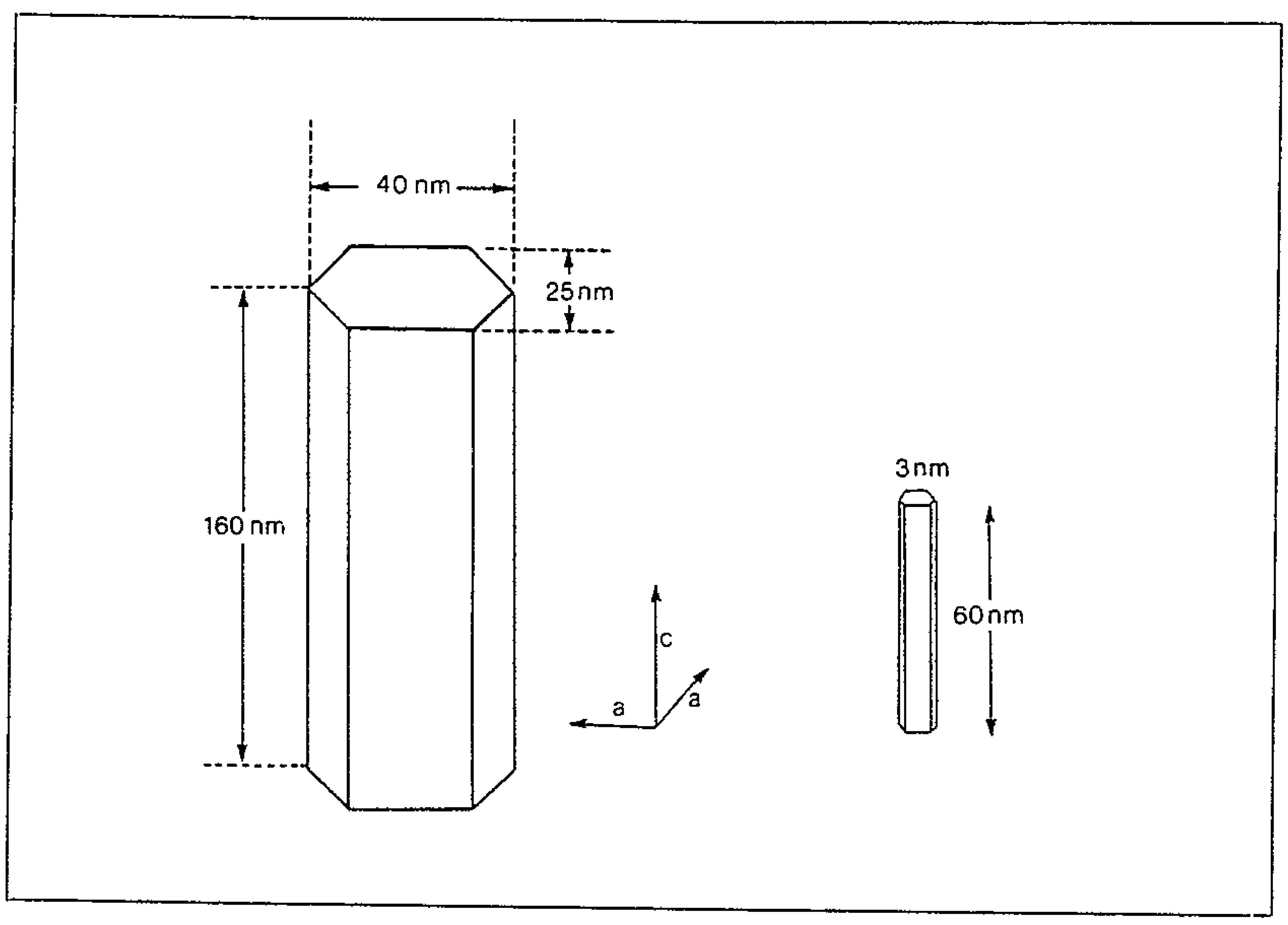
3.1 EFFECTS OF FLUORIDE ON DENTINE AND CEMENTUM

3.1.1 Effect on acid resistance of dentine and cementum

Dentine and cementum are made up mesenchymal tissue, mesenchymal tissues have a collagenous matrices and these are retained during the process of mineralisation [Weatherell & Robinson, 1988]. The apatite crystallites are small compared to enamel and have a tubular structure, as shown in Figure 6.

Figure 6: Diagram showing the relationship between a typical crystal in human enamel (left) and a smaller crystal typical of dentine (right).

Source: Nikiforuk, 1985 page 274.



and their surface area as well as their capacity to take up fluoride is consequently much larger [Weatherell & Robinson, 1988]. In the case of dentine, much of the fluorides penetrate along the dentinal tubules, thus resulting in the articular zone being more resistant to acid attacks than intertubular dentine [Selvig, 1968].

Saxegaard, (1987) reported that after the application of 2 per cent sodium fluoride (NaF) on dentine and cementum, the major component on the surface of dentine and cementum was calcium fluoride (CaF) (alkali soluble) although they did not rule out the possibility of hydroxyfluoroapatite formation (alkali insoluble).

Recent data has shown that CaF is more stable in the oral environment than it was previously believed [Ogaard et al., 1984]. The cariostatic effect of CaF seems to be that it acts as a significant reservoir of fluoride (F) ions which could be directly deposited in areas of demineralisation and thus reducing the loss of mineral by promoting re-precipitation of stable apatite structures [Ogaard et al., 1984]. Calcium fluoride may prevent the dissolution of underlying dental tissue due to its acid resistant properties [Ten Cate and Diujsters, 1983].

Fluoride present in the acid buffer markedly reduces the acid reactivity, thus, the presence of fluoride during an acid challenge reduces the solubility rate at the crystal surfaces of dentine and this presumably is an anti-cariostatic influence in the plaque fluid [Featherstone et al., 1984].

3.1.2 Effect on dentine and cementum de- and re-mineralisation

Demineralisation can be defined as the reduction of mineral content of a tissue. While re-mineralization, on the other hand, is the restoration of mineral salts to the tissue [Harty & Rogston, 1987].

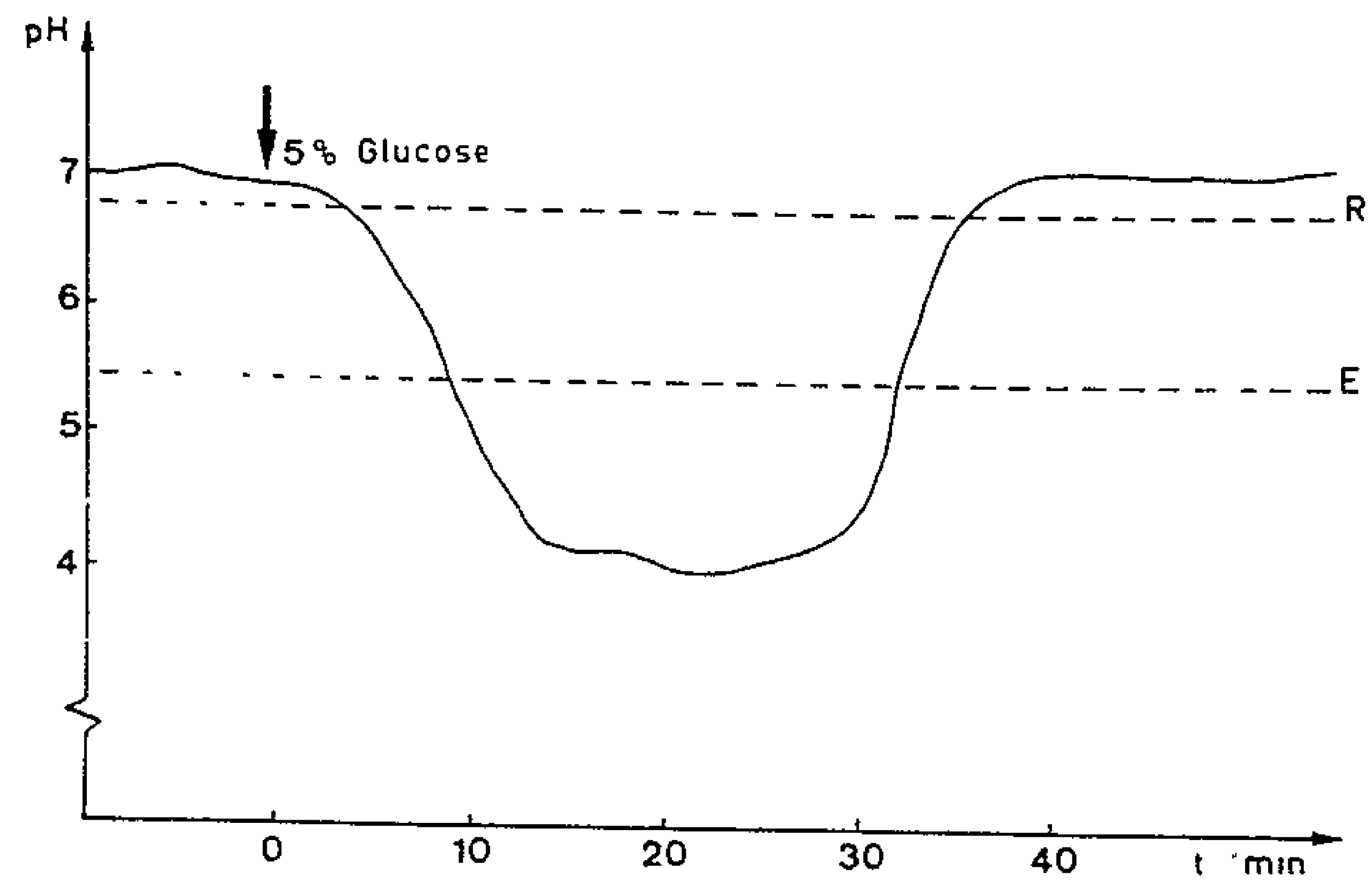
The composition and solubility of cementum and dentine is difficult to discern [Hoppenbrouwers et al., 1987]. In this respect, they are usually evaluated together. They both contain carbonate, magnesium, and inorganic material. The large collagen fibres, known as Sharpey fibres, in the cementum and tubuli in the dentine, provide easy entry for bacteria and their metabolic products (acids) [Surmont & Martens, 1989].

These physical and chemical properties are a possible explanation for a pH of 6.7 being the critical value for root dentine [Hoppenbrouwers et al., 1987].

Compared to enamel, de-mineralisation of root mineral starts at an earlier stage and continues over a longer period as shown in Figure 7.

Figure 7: Oral pH drop after the intake of 5% glucose,with the level of the critical pH (6.7) of root mineral (R) and the critical pH (5.4) of enemel (E).

Source: Surmont et al., 1989 page 16.



The onset of the lesions displays a multifocal pattern of de-mineralisation. The initial de-mineralisation shows a subsurface lesion. However, this intact surface layer is very weak and can be destroyed rapidly. After a quick onset of demineralisation, the physico-chemical process is diffusion controlled [Surmont et al.,1989].

De-mineralisation of root dentine starts at a higher pH, compared to enamel. Thus, sucrose is not solely responsible for a drop in pH below the critical pH. Consequently, it is possible that some nutrients bring about the drop in pH between 6.7 (critical pH of root dentine) and 5.4 (actual critical pH of enamel, suggested by Krasse, (1985)). Two major aspects of fluoride action are the, inhibition of de-mineralisation by fluoride and the enhancement of re-mineralization by fluoride, of dentine and cementum [Featherstone et al., 1988].

In a simple outline, the plaque bacteria metabolises fermentable carbohydrates, producing organic acids such as lactic, acetic and propionic acids [Featherstone et al., 1988]. These acids can diffuse through plaque into the enamel and underlying tissues, dentine and cementum and thus dissolve mineral (calcium, phosphate and fluoride) wherever a susceptible site is reached [Featherstone et al., 1988].

The minerals from the crystal lattice diffuse out of the tissue and into the oral environment resulting in demineralisation [Featherstone et al., 1988]. If this process is reversed the mineral goes back into the tissue and damaged crystals are rebuilt, then we have remineralization [Featherstone et al., 1988].

Fluoride acts by inhibiting mineral loss at the crystal surfaces and by enhancing this rebuilding or remineralization of calcium and phosphate in a form of more resistant to subsequent acid attacks [Featherstone et al., 1988].

After the application of fluoride, such as sodium fluoride (NaF) on dentine and cementum the major component on the surface of the dentine and cementum is calcium fluoride (CaF) (alkali soluble) [Saxegaard et al, 1987].

The cariostatic effect of calcium fluoride (CaF) seems to be that it acts as a significant reservoir of F^- ions which could be directly deposited in areas of demineralisation and thus reducing the loss of mineral by promoting precipitation of stable apatite structures [Ogaard et al., 1984].

Ellingsen, (1987) also believed that exposure of root surfaces to topical fluorides would act as an inhibitor to caries, due to the formation of calcium fluoride, on the surface of dentine and cementum.

Ten Cate and Diujsters, (1983) suggested that the calcium fluoride layer left behind on dentine and cementum may also prevent dissolution of the underlying dental tissues by making then more resistant to acid attacks.

The main value of topical fluoride application is that it enhances the remineralization of the early caries lesions rather than to increase the content of stable fluoroapatite of the tooth tissue [Ogaard et al., 1984].

Cementum readily takes up fluoride from fluoridated water [Nakata et al., 1972], as does dentine [Yoon et al., 1960].

The reduction of demineralisation by fluorides was due to the specific absorption of fluorides to the crystal and it is derived from the interstitial fluid of the root hard tissue [Hoppenbrouwers et al., 1987].

Fejerskov, (1981) concluded that the major cariostatic effect of water fluoridation was probably due to the regular increases in fluoride ion activity in the oral fluids where the fluoride ion might exchange with an hydroxide (OH) group in the hydroxyapatite crystal to form fluoroapatite, a more stable structure, i.e.,

$$Ca_{10}(PO_4)_6(OH)_2 + 2OF^- \text{-------}> Ca_{10}(PO_4)_6F_2 + 2OH^-$$

hydroxyapatite ---------------> fluoroapatite

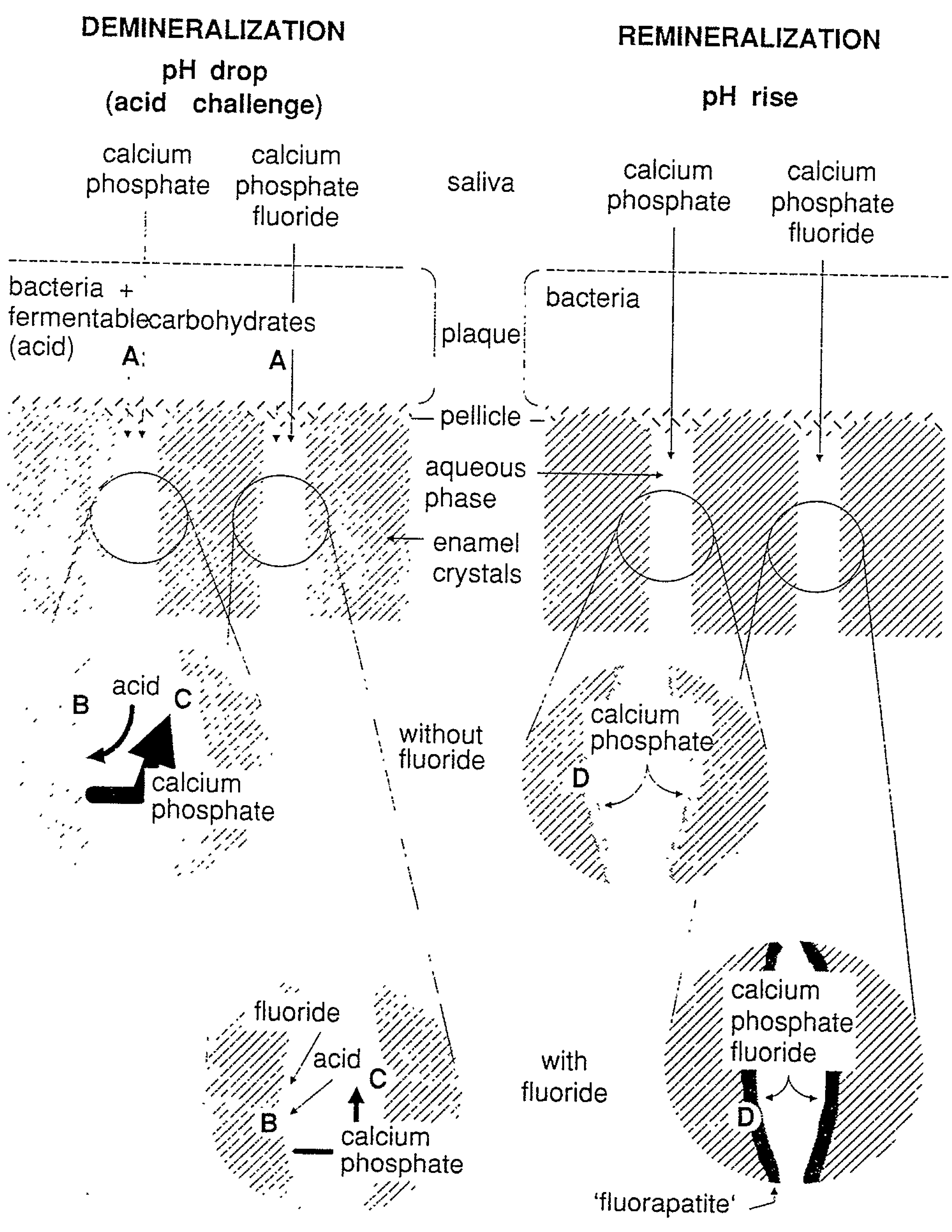
Apatite crystals are also surrounded by other ions like magnesium, carbonate and fluoride.

Magesium and carbonate exhibits poor crystallinity, whereas fluoride has good crystallinity as well as the ability to replace magnesium and carbonate in the apatite crystal thus the enhanced stability of the crystal structure [Murray & Rugg-Gunn, 1982].

This process of de-mineralisation and re-mineralization is best illustrated by the schematic diagram in Figure 8 below.

Figure 8: Schematic diagram illustrating demineralisation and remineralization of dental tissue during periods of acid challenge.

Source: Featherstone et al., 1988 page 126.



3.1.3 Solubility Hypothesis

When parts of tooth roots become exposed to the oral environment plaque forms on their surfaces. Depending on the composition of its fluid phase, the plaque may exert a de-mineralising or a mineralising action on the root hard tissues or be in equilibrium with them [Hoppenbrouwers et al., 1987].

According to Driessens et al. (1986), the outermost layer of mature dental enamel behaves like hydroxyapatite. Hence the bulk mineral (hydroxyapatite) of this layer would start to dissolve when the pI_{OHA} of the plaque fluids exceeds the value of 118 [Hoppenbrouwers et al., 1987].

Nyvad and Fejerskov, (1982) found that the root surfaces of human teeth are more vulnerable to chemical destruction than is dental enamel. They suggested that this is due to their peculiar structure and to their chemistry [Hoppenbrouwers et al., 1986].

Investigations of the vulnerability of roots to demineralisation (Hoppenbrouwers et al., 1986) revealed that cementum and dentine are indistinguishable from each other either by radiography or by the dissolution behaviour of their respective organic phases. Therefore it is justifiable to study their chemical behaviour unseparated [Hoppenbrouwers et al., 1987].

The root mineral appears to dissolve in buffer solutions saturated with respect to hydroxyapatite (pI_{OHA}114) unlike the mineral of dental enamel, which suggests that the mineral of the root is more soluble than that of enamel [Hoppenbrouwers et al., 1987].

Considering the structure of the root hard tissues, it appears that both cementum (Armitage,1980) and dentine (Avery,1980) are more permeable than dental enamel. Dibdin and Poole, (1982) have shown by water vapour sorption that the specific surface of dentine is approximately 20 times greater than that of dental enamel [Hoppenbrouwers et al., 1986]. As far as the chemistry of the mineral of the root hard tissue is concerned, it is expected that it will be more soluble than the mineral of surface dental enamel because of its higher carbonate and magnesium contents [Driessens, 1982].

Investigations were carried out by Leach, (1959) on powdered dentine and enamel, it was found that the mineral of dentine is more soluble than that of enamel [Hoppenbrouwers et al., 1986].

Studies carried out by Hoppenbrouwers, (1985) with the aim of comparing quantitatively the in vitro demineralisation of intact enamel and intact unexposed dental roots with buffer solutions of pH 5.0 and with various discrete degrees of saturation with respect to hydroxyapatite.

The studies showed that a slight decrease in the pH of the plaque fluid lead to de-mineralisation of the root hard tissues. In addition, it was found that the rate of demineralisation of the root hard tissues at pH 5.0 and at a degree of undersaturation of the buffer solution with respect to hydroxyapatite, corresponding with a pI_{OHA} value between 117 and 122, where pI_{OHA} is the degree of saturation with respect to hydroxyapatite, is much greater than that of surface dental enamel [Hoppenbrouwers et al., 1986].

These findings, together with the much higher value of the critical pH, the critical pH for root hard tissue ranges between 6.8 and 6.0, while for dental enamel ranges between 5.9 and 5.2, for the root hard tissues than for surface dental enamel, indicate that te root hard tissues are more vulnerable to de-mineralisation than is surface dental enamel [Hoppenbrouwers et al., 1986].

3.2 EFFECTS OF FLUORIDE IN PLAQUE

3.2.1 Fluoride Concentration in Plaque

Dental plaque contains surprisingly high concentration of fluoride, estimated at between 6 and 179 ppm [Silverstone et al., 1981].

The concentration of fluoride in plaque may be increased by rinsing with 0.2 per cent sodium fluoride, but remains higher than controls rinsed with sodium chloride for only 24 hours or less [Silverstone et al., 1981].

The fall in plaque fluoride concentration after a fluoride rinse is probably due mainly to the growth of new plaque bacteria and the accretion of new matrix [Silverstone et al., 1981].

There is little doubt that the majority of the plaque fluoride is not present as free ions. The concentration of ionic fluoride in human dental plaque has been estimated to be only 1-2 ppm [Silverstone et al., 1981].

Nevertheless, this concentration is still higher than that in saliva (commonly 0.1 ppm), or in plasma (0.14-0.19 ppm in people using water with up to 2.5 ppm of fluoride, and slightly raised at 0.26 ppm in people whose drinking water contains 5.4 ppm of fluoride) [Silverstone et al., 1981].

Dental plaque may be expected to be saturated with calcium phosphate, and several species of oral bacteria have been shown to calcify when exposed to such saturated solutions in pure culture [Silverstone et al., 1981].

Extensively mineralised plaque (calculus) has been shown to contain both hydroxyapatite and brushite, and although frank mineralisation is not often observable in soft plaque, the occurrence of microcrystals within and between the cells cannot be discounted [Silverstone et al., 1981].

Early mineralisation of plaque appears to begin in the intercellular matrix. It seems likely that the fluoride bound in dental plaque is extensively in the form of fluoroapatite and it has been suggested that plaque bacteria 'concentrate' fluoride [Silverstone et al., 1981].

Clearly, any apatite or other phosphates that crystallise within bacteria will be available as a 'sink' for fluoride. It is also possible that intracellular proteins bind fluoride [Silverstone et al., 1981].

What is less clear is whether non-mineralising bacteria take up fluoride to a higher concentration than that of their environment.

In a series of determinations of the permeability of streptococci to fluoride at 8.5 ppm, fluoride entered the cells but cellular concentration was rather less than the extracellular concentrations. In these experiments, an indirect assay of cellular concentration was used because of the ease with which fluoride could be washed from the cells which were not mineralised [Silverstone et al., 1981].

3.2.2 Anti-Bacterial Effect of Plaque Fluoride

The fluoride concentration in saliva from major salivary glands of subjects on a moderate fluoride intake is in the range of 0.01-0.03 ppm. While fluoride levels in whole saliva are about double those found in the parotid or submandibular ductal saliva, these levels of fluoride have no significant anti-bacterial effect [Nikiforuk, 1985].

Levels of fluoride (ppm, dry weight) in scrapings from tongue and from dental plaque are in the range of 14-19 and 15-64 ppm, respectively [Jenkins & Edgar, 1977].

Levels of fluoride in plaque are therefore between 100 and 10,000 times that of saliva, indicating that fluorides are concentrated in plaque [Nikiforuk, 1985].

Studies by Birkeland and Charlton (1976), indicate that the ionic fluoride activity of neutral plaque is only between 0.08 and 0.8 ppm (less than 2 per cent of the total) and, like the level in saliva, is too low to inhibit the metabolism of plaque bacteria. However, when the plaque is acidified, either by adding acid in vitro or resulting from bacterial metabolism in vivo, fluoride ions are liberated from bound forms and about 30 per cent or more of the total may be free (ionised). It appears that plaque fluoride acts as a reservoir for the ionised form as the pH drops, and favours re-mineralization as well as inhibits bacteria [Nikiforuk, 1985].

Plaque fluoride originates from prolonged day-to-day contact with the low levels of fluoride in saliva and gingival fluid. Plaque fluoride is higher in subjects that consume fluoridated water than in those that do not and this increase probably occurs from direct contact of plaque with the drinking water [Nikiforuk, 1985].

Also, plaque from subjects in fluoridated areas shows a slightly smaller pH drop when incubated in vitro with sucrose, than does plaque from individuals living in low fluoride areas. Thus indicating that plaque fluoride exerts a small inhibitory effect on bacteria [Jenkins & Edgar, 1977]. The pH at which much of the bound fluoride is released (5.0) is also the pH at which bacteria become most sensitive to fluoride [Birkeland & Charlton, 1976].

The nature of the bound fluoride is a controversial subject. Some fluoride is bound to inorganic ions as calcium fluoride, and some may be bound within bacteria [Jenkins & Edgar, 1977].

Frequent topical application of fluoride preparations such as gels, solutions or mouth rinses can also produce transient concentrations of fluoride high enough to inhibit bacterial acid production. However, bacterial enzymes responsible for synthesis of extracellular glucon and fructon from sucrose are unaffected by 5.0mM of sodium fluoride [Carlsson et al., 1969; Hamilton, 1977].

3.2.3 Plaque Fluoride and Acid Production

Dental plaque may produce acid or base according to the types of bacteria present and the substrate molecules available to it. In all living organisms the metabolic pathways leading from substrates (for example, glucose) to end products (for example, lactic acid) are linked to energy generating systems [Silverstone et al., 1981].

The relationship between glucose fermentation and the growth of cells is fixed for bacteria using glycolysis. Because many of the bacteria of plaque use this metabolic process, it is possible to estimate the order of magnitude of lactic acid production by plaque as a consequence of growth on carbohydrate [Silverstone et al., 1981].

Given the composition of mixed dental plaque as far as it is presently known, it is reasonable to assume that plaque will have produced approximately its own weight of acid during growth. This is likely to be an overestimate because of the operation of the PFL [Pyruvate Formate Lyase] system at low growth rates [Silverstone et al., 1981].

Although carbohydrates from foodstuffs are available only intermittently to plaque bacteria, many oral bacteria store glycogen for use later, and some extracellular carbohydrates and carbohydrates from salivary glycoproteins, may also be used.

Therefore, carbohydrate fermentation is possible in plaque most of the time, although the magnitude of the process is obviously greatest when fermentable carbohydrates are ingested [Silverstone et al., 1981].

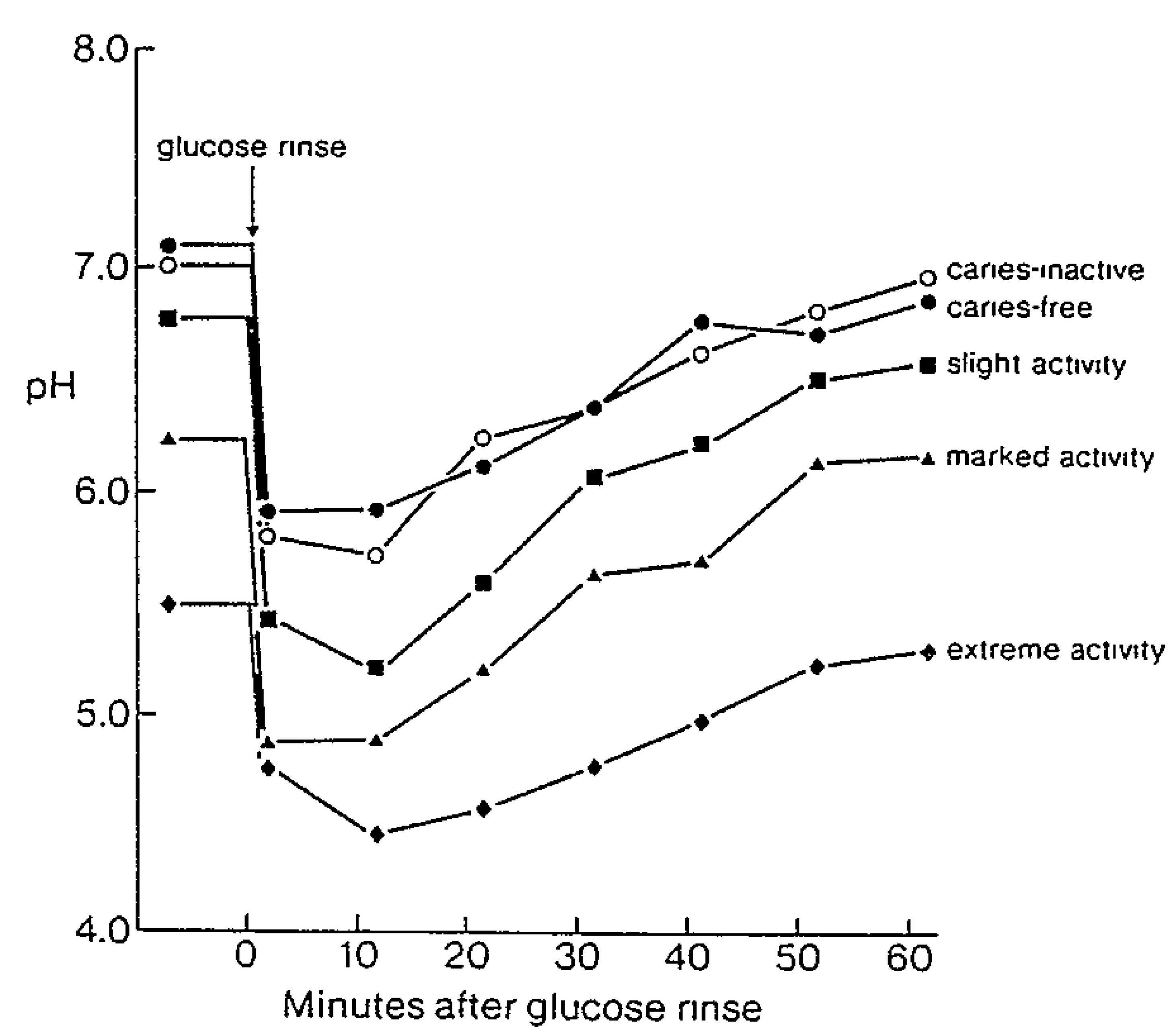
The amount of plaque per day that can be scraped from the mouth of an individual who is observing standard oral hygiene procedures varies from 1 mg to 50 mg or more. Therefore, the quantity of lactic acid likely to be produced per day is of the sam magnitude [Silverstone et al., 1981].

While it is true that some plaque bacteria obtain their energy by fermentation of amino acids rather than carbohydrates, the fermentation of individual amino acids rarely producing bases, and fermentation of mixed amino acids by plaque bacteria generally cause a fall in pH. Therefore, amino acid fermentation does not counteract the acid production of carbohydrate fermentation, although amino acid decarboxylation may [Silverstone et al., 1981].

The most dramatic pH effects are observed in acute acid production, when fermentable carbohydrates are ingested. The pH of plaque may fall from close to 6 to around 4 in a matter of minutes, and this sharp fall in pH, followed by a slow return to the resting pH when the fermentable carbohydrate is exhausted, is called the 'Stephan curve' which is shown in Figure 9 below.

Figure 9: 'Stephan curve' showing the net result of acid production in plaque, plot of pH response in plaque as a function of time.

Source: Nikiforuk, 1985 page 152.



3.2.4 Effects of Fluorides on Oral Micro-organisms

Interference with the metabolism of micro-organisms involved in caries formation has long been proposed as a possible mechanism for the topical effect of fluoride [Mellberg & Ripa, 1983].

Evidence showing an effect on plaque micro-organisms has been derived from studies of single organisms, salivary sediment, and plaque itself. Although plaque obviously is the most suitable substrate for study, saliva is more readily available and easier to study [Mellberg & Ripa, 1983].

Plaque contains higher levels of fluoride than saliva, showing that it is capable of concentrating and retaining it by means of combination with inorganic or organic materials [Mellberg & Ripa, 1983]. Although only a small amount of fluoride in the aqueous phase of plaque is in a free ionic state (0.1 to 1.0 ppm), much more is released (1 to 5 ppm) when the pH is lowered to levels found during caries formation [Mellberg & Ripa, 1983].

The concentration of fluoride in plaque from communities with fluoridated drinking water is about twice as high as in non-fluoridated communities. After use of fluoride mouth rinses or dentifrices, it can reach 100 ppm for periods of minutes, although it may remain elevated for several hours or more [Mellberg & Ripa, 1983].

The natural low concentrations of fluoride in plaque at acid pH (1 to 5 ppm) have been found to reduce the amount of acid formation, while the higher concentrations (e.g. 70 ppm) achieved after the use of fluoride rinses or dentifrices are able to reduce the formation of polysaccharides [Mellberg & Ripa, 1983].

Much higher concentrations (10,000 ppm) are lethal to bacteria and reduction in vivo of Streptococcus mutans was shown after repeated use of APF gel in mouth rinses. Fluoride that is firmly bound to enamel will not have an effect unless it is released during caries dissolution, whereupon it may attenuate further acid formation [Mellberg & Ripa, 1983].

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, therefore, fluoride will be more effective as a natural antibacterial agent if this concentration and frequency of use are increased [Mellberg & Ripa, 1983].

3.2.5 The Enzyme Inhibition Hypothesis

The anti-enzyme theory of fluoride action is based on the fact that fluoride is known to inhibit many enzymes including phosphates, catalase, peroxidase and cytochrome oxidase, hexokinase, phosphoglucomutase, enolase and succinate dehydrogenase [Silverstone et al., 1981].

Most of these studies are of isolated enzymes examined in vitro, and interpretation of these results in terms of whole cells, where the enzyme are compartmentalised and, in many cases, coupled in metabolic sequence, is highly problematic [Silverstone et al., 1981].

The only biochemical analysis of the effects of fluoride in moderate concentration upon an oral micro-organism has been carried out on Streptococcus salivarius. Fluoride at 9 ppm completely blocked the synthesis of glycogen when non-growing cells were incubated anaerobically with glucose at pH 7.0 [Silverstone et al., 1981].

Inhibition of glycogen synthesis was 15 per cent at 1 ppm fluoride and 50 per cent at 2-3 ppm fluoride. Degradation of fluoride was nowhere near as sensitive as glycogen synthesis, and 135 ppm fluoride were required to inhibit glycogenolysis by 50 per cent [Silverstone et al., 1981].

The sensitivity of glycogen synthesis in vivo was not paralleled by the sensitivity of enzymes of glycogen synthesis in vitro [Silverstone et al., 1981].

This indicates a highly fluoride sensitive site in glucose absorption and phosphorylation. The degradation of endogenous glycogen was negligibly reduced by 36 ppm fluoride, a concentration that completely suppressed the metabolism of exogenous glucose [Silverstone et al,. 1981].

The concentration of fluoride in plaque therefore seems sufficient to inhibit uptake ad phosphorylation of glucose. Whether it actually does so in plaque depends on the pH, and the proportion of fluoride sequestered as inactive calcium salts [Silverstone et al,. 1981].

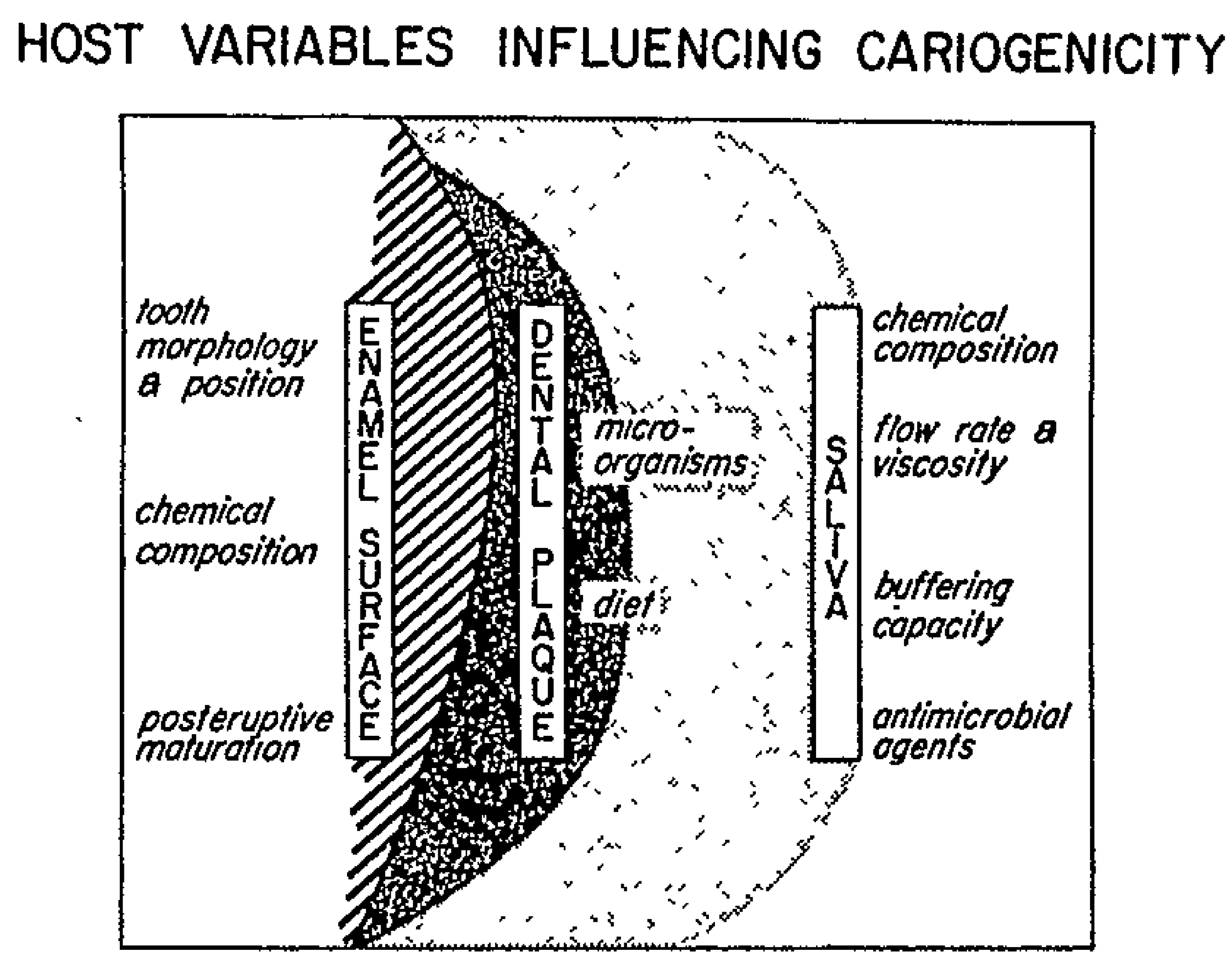
A fall in pH, increased the activity of a given amount of fluoride, probably by increasing the conversion of fluoride to undissociated HF which can then cross cell membranes. However, a fall in pH also favours the uptake of fluoride by the enamel and thus reduces the quantity of fluoride available for inhibition [Silverstone et al,. 1981].

3.3 Effects of Fluorides on Tooth Morphology

The important host factors that influence the tooth's susceptibility to decay are shown in Figure 10 below.

Figure 10: Host variables influencing cariogenicity.

<u>Source:</u> Mellberg & Ripa, 1983 page 25.



Such factors as diet, plaque, and bacterial flora have already been discussed earlier. These are mainly environmental factors and are generally altered by a change in the behaviour of the host [Mellberg & Ripa, 1983].

The other factors, relating to the tooth and saliva, are intrinsic to the host. Nevertheless, under the proper circumstances, these are also modifiable [Mellberg & Ripa, 1983].

The relative position of teeth and their morphology influences caries susceptibility. The surfaces of the teeth that are most caries susceptible, the occlusal and proximal surfaces, are also the ones that are least easily cleaned by toothbrushing and are least accessible to the saliva [Mellberg & Ripa, 1983].

These areas provide protective enclaves for the retention of plaque and food debris. The proximal surfaces of teeth that are crowded and have light contact areas are considered to be more susceptible to decay because of their greater propensity to harbour plaque. Conversely, teeth with proximal spacing, in which the surfaces are more accessible to the saliva, are less prone to develop caries [Mellberg & Ripa, 1983].

The areas of the teeth most susceptible to dental caries are the occlusal surfaces and those with deep fissures are considered to be most prone to caries [Mellberg & Ripa, 1983].

Studies of the effect of water fluoridation on tooth size and shape have suggested that fluoride tended to make the teeth slightly smaller and, more important, to give them shallower fissures. The reduction in fissure size associated with water fluoridation is modest. Consequently, the effect on dental caries by this mechanism is questionable [Mellberg & Ripa, 1983].

However, a study of the use of systemic fluoride supplements indicated an anticaries effect due to altered tooth morphology, although the assessment of the fissures was subjective [Mellberg & Ripa, 1983].

Studies were carried out by Aasenden and Peebles (1974) on three groups of children.

Group I: Consisted of children from an area with non-fluoridated drinking water and who received fluoride supplements from shortly after birth. The daily dose was 0.5 mg F until age 3 and 1.0 mg F thereafter.

Group II: Consisted of children from the same community but who did not receive fluoride supplements at all.

Group III: Consisted of children from an area with fluoridated drinking water.

The morphology of the pits and fissures was recorded as "typical" or "atypically shallow". Atypcal fissure angles appeared wide, the explorer did not catch in either pits or fissures, and the finding was general throughout the mouth, with both deciduous and permanent teeth having favourable morphology [Mellberg & Ripa, 1983].

Table 4 can be used to illustrate results of studies.

Table 4: Effects of fluoride supplements on enamel fluoride, fluorosis, fissure morphology and dental caries.

Source: Mellberg & Ripa, 1983 page 66.

Group	Enamel F (ppm)	Fluorosis (Percent very mild to moderate)	Shallow fissures (Percent)	Caries (DFS)
I. F. Supplements	3,060	67	47	1.57
II. No Supplements	1,700	4	4	7.93
III. F Water	2,320	33	24	3.16

Data from *Aasenden* and *Peebles*.[305]

The fluoride supplements produced teeth with more fluoride, more fluorosis, more shallow fissures, and significantly lower caries scores.

4 THE USE OF FLUORIDES IN THE PREVENTION AND CONTROL OF DENTAL CARIES IN THE DENTINE AND CEMENTUM OF THE ROOT

4.1 CLINICAL EFFECTIVENESS OF VARIOUS FLUORIDE METHODS AND PROGRAMS

The effects of fluoride on caries can be divided into two main categories: The first being, the effect of fluoride taken systemically, by the ingestion of water, fluoridated milk and salt or as supplements, in the form of tablets and drops. The second being, the effect of those applied topically in the form of solutions, gels, mouthrinses and toothpastes, these are in much higher concentrations than found in systemic fluoride sources [Murray, 1989].

This division, is an all too often simplistic one, in that those methods in the systemic group may also have a topical effect, for example, fluoride taken in the water supplies, in addition to being absorbed and incorporated into developing teeth may also exert a topical effect, both pre-eruptively by means of the tissue fluid contacting the maturing surface of the tooth and post-eruptively as the water washes over the tooth surface [Murray, 1989].

Similarly 'topical methods', for example, fluoride in toothpaste, as well as being brushed onto the surface of the tooth is ingested to a certain degree, particularly in young children and so fluoride from this source can be incorporated into the teeth that are still developing within the jaw [Murray, 1989].

4.1.1 Clinical aspects of fluoride in caries prevention

Now we must deal with the question "does the cariostatic effect of systemic fluoride persist after exposure to fluoride has ceased ?". We find that many studies have been conducted (13 in total) dealing with this question. Results from these studies have been compared, however the results were found to be conflicting. In results obtained from populations which had no access to fluoride dentifrices, little if any residual effect was found [Marthaler, 1988].

However, recent work suggests that at least part of the protection persists beyond school age. Results from clinical trials conducted over a 6 year period using fluoride tablets given to young school children daily, showed that in early erupting teeth, the difference between the fluoride group and the control group was maintained, but the average increments during the post treatment period were similar (1.40 DMFS and 1.43 DMFS). By contrast, in teeth that had erupted during treatment period, the increment was lower in the fluoride group (1.28 DMFS) than in the control group (2.21 DMFS).

Four years after discontinuation of the treatment, the overall difference between the fluoride group was still 34 per cent, which was even more than the difference of

32 per cent for the control group [Marthaler, 1988].

Long term studies comparing schoolchildren who were given fluoride tablets daily from age 6 to 15 years and a controlled group with no preventive programs were conducted in 1964-65 and then again 10 years later. The results showed that caries increments were lower beyond school age in these subjects who had received fluoride supplements during their childhood in a school-based prevention program [Marthaler, 1988].

The conclusion from the detailed analysis was that the protective effect of fluoride does persist after treatment has ceased [Marthaler, 1988].

4.1.2 Pre-eruptive ingested fluoride effects

The absorbed fluoride is transported through the body via the circulatory system and will be present in the extracellular fluid that bathes the teeth [Mellberg & Ripa, 1983].

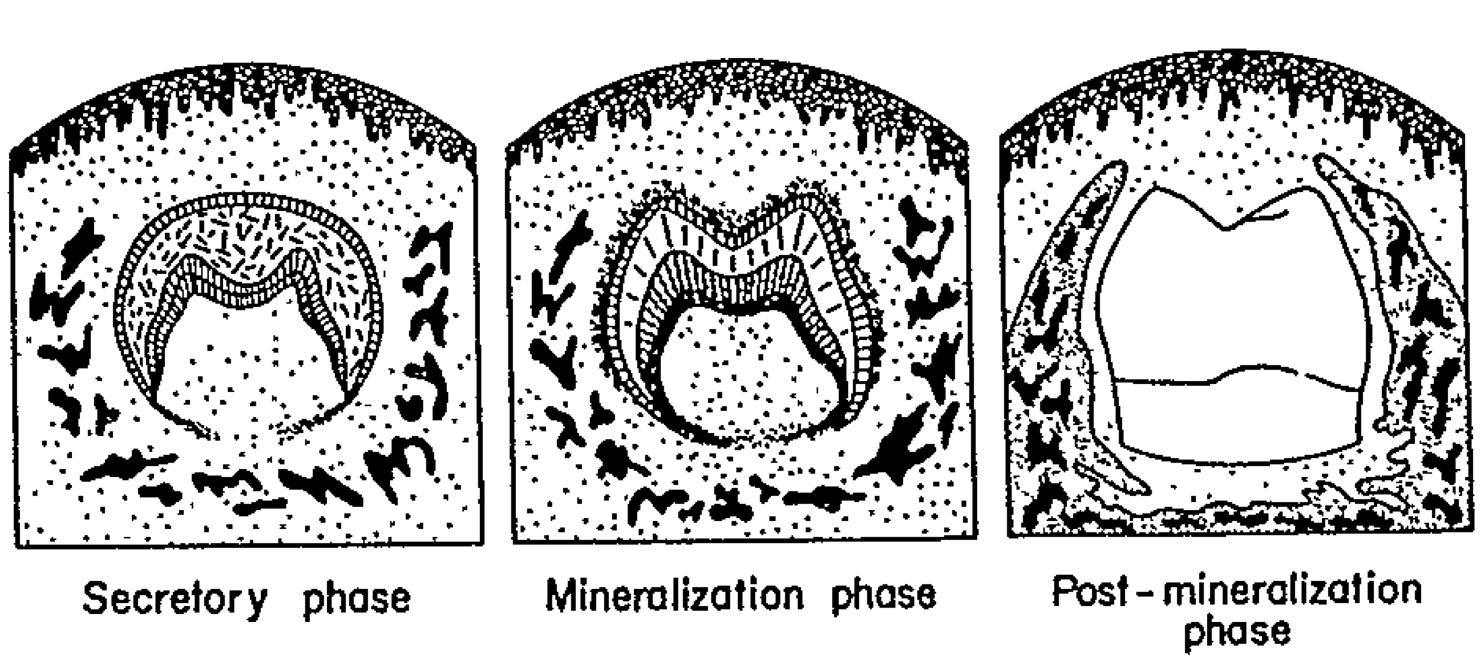
Teeth do not erupt immediately after completion of mineralisation of the tooth crown, instead they remain in the jaws until approximately two-thirds of their roots are formed [Mellberg & Ripa, 1983].

The pre-eruptive period of crown formation can be divided into three phases: a phase of organic matrix deposition (secretory phase); a phase of rapid mineralisation (mineralisation phase) and a post-mineralisation phase where the crown formation is complete and the roots are developing. This can be illustrated in figure 11 below.

Figure 11: The three phases of developing tooth, at each phase fluoride can be deposited.

<u>Source:</u> **Mellberg & Ripa, 1983 page 124**

PRE-ERUPTIVE PHASES of the TOOTH CROWN



During the phase of mineralisation, fluoride becomes incorporated into the precipitating apatite crystals of the teeth [Mellberg & Ripa, 1983].

Clinical and laboratory evidence, Thylstrup (1990) has suggested that systemic fluoride plays a more minor role in caries inhibition than was previously thought. Due to reduced functional usage, erupting teeth tend to accumulate plaque which has a cariogenic potential. For this reason, the period from tooth emergence to the establishment of interproximal contact and full occlusion is the most critical for caries initiation [Thylstrup, 1990].

According to Thylstrup, (1990) the maximum protection against caries is obtained when teeth erupt into an environment with low concentrations of ionic fluoride.
Similar studies conducted with topically administered fluoride regimens, including fluoride-containing dentifrices, indicate that pre-eruptive effect of fluoride is of borderline significance relative to the more significant post-eruptive effects [Thylstrup, 1990].

A shift in thinking has occurred over the past 20 years, and importance has been given to post-eruptive administration of fluoride, this shift in thinking has been due to the accumulating clinical evidence of the substantial caries inhibition obtained by post-eruptive administration of fluoride [Thylstrup, 1990].

4.1.3 Post-eruptive ingested fluoride effects

During the past 20 years there has been a growing tendency to reconsider the relative importance of the pre-eruptive fluoride ingestion effects. Rather, there has been a shift towards the post-eruptive effects of fluoride ingestion [Thylstrup, 1990].

The process of reconsideration is based on accumulating clinical evidence of the substantial caries inhibition obtained by post-eruptive administration of fluoride [Thylstrup, 1990].

Klein (1946) and Russell (1949) demonstrated that fluoride ingestion had an effect when consumed post-eruptively. This observation was later confirmed by Backer Dirks et al (1961) and Marthaler (1967). They drew attention to the fact that post-eruptive effects would be lost unless fluoride was also consumed post-eruptively [Groeneveld et al., 1990].

Lemke et al (1970) found that after discontinuation of water fluoridation, the caries incidence of children living in a fluoridated area, increased to the level of those living in a non-fluoridated area. These type of data provide strong support for a post-eruptive effect [Groeneveld et al., 1990].

Since it was observed by Backer Dirks (1961), Marthaler (1967) that any pre-eruptive effect would soon be lost without post-eruptive continuity it can be concluded that there is no post-eruptive effect of fluoride on the initiation of dental caries, but rather the progression of existing caries would be affected by post-eruptive ingestion of fluoride. This would, firstly inhibit de-mineralisation and secondly, promote re-mineralization [Groeneveld et al., 1990].

4.1.4 Topical fluoride preparations

Investigations on the topical application of fluorides to erupted teeth have been going on since the early 1940s. Based upon the assumed mechanism that fluoride will be deposited in the outer layers of enamel, making the teeth more resistant to acid dissolution, topical fluoride application by dentists, hygienist, or other dental auxiliary has become an established caries preventive procedure in most dental offices [Mellberg & Ripa, 1983].

Currently, the dentist has a choice of topical fluoride agents. Additionally, the fluoride may be used in an aqueous solution, a viscous gel, a prophylaxis paste, or a dental varnish.

Topical fluorides fall essentially into two categories: firstly, there are those which are professionally applied by a dentist in a surgery and secondly, those which are self-administered by the patient at home [Murray, 1989].

In practice those employed by the dentist (professionally applied) are of high fluoride concentration and are applied at regular but infrequent intervals, perhaps twice a year. Whilst those which are self-applied, are low in fluoride concentration and are applied at frequent intervals, often daily [Murray, 1989].

4.1.4.1 Professionally Applied Topical Fluorides

Such fluoride agents may include simple aqueous solutions of sodium fluoride and stannous fluoride, and low pH solutions and gels of acidulated phosphate (APF) system. Other agents comprise fluoride prophylaxis pastes and fluoride containing varnishes [Murray, 1989].

Fluoride Solutions

These are the first of the professionally applied topical fluoride preparations to be discussed, and include the following:

Sodium Fluoride (NaF)

Sodium fluoride was the first topically applied fluoride compound. Studies using this agent were initiated by Bibby and Knutson in the 1940s, in the United States public health service. The public health service recommended that a 2 per cent sodium fluoride (NaF) solution be used [Mellberg & Ripa, 1983].

Treatments were given in a series of four appointments. At the initial appointment the teeth were first cleaned with an aqueous pumice slurry. The teeth were either isolated by quadrant or by half-mouth (right an left sides). Using cotton-tipped applicator sticks the 2 per cent NaF solution was painted on the air-dried teeth so that all surfaces were visibly wet. Then, with the teeth still isolated, the solution was allowed to dry for 3 to 4 minutes [Mellberg & Ripa, 1983].

This procedure was repeated for each of the isolated segments until all of the teeth were treated. A second, third and fourth fluoride application, each not preceded by a prophylaxis, was scheduled at intervals of approximately one week. This procedure was called the Knutson [1948] technique. The four-visit procedure was recommended for ages 3,7,10 and 13 years, coinciding with eruption of different groups of primary and permanent teeth [Mellberg & Ripa, 1983].

This resulted in a caries reduction of about 40 per cent [Nikiforuk, 1985]. Thus, most of the teeth would be treated soon after their eruption, maximising the protection afforded by the topical application [Mellberg & Ripa, 1983].

The solution of NaF is relatively stable when kept in a plastic container, so a fresh solution is unnecessary for each patient. The solution is not irritating to the gingiva and does not stain tooth structures or restorations [Diorio, 1983].

However, the four-visit regimen at specific ages, as had been recommended by the US public health service, was not convenient for most private practice offices in which patients were normally recalled at 6 or 12 monthly intervals.

Probably for this reason, the use of NaF solutions has largely been superseded by other fluoride compounds, which are recommended for application on a schedule that is more convenient for the office routine [Mellberg & Ripa, 1983]. The results on the effect of NaF solutions can be summarised in table 5 below.

Table 5: Effect of professionally applied neutral sodium fluoride solutions on the permanent teeth of children living in fluoride deficient communities.

<u>Source</u>: Mellberg & Ripa, 1983 page 182.

Study	Initial age (years) of subjects	No. applications per year	Duration of study (years)	Percent reduction DMFT	Percent reduction DMFS
Galagan and *Knutson*[1]	7–15	2	1	22	14
		4	1	41	34
		6	1	41	28
Galagan and *Knutson*[21]	6–16	2	1	20	13
		2	1	15	13
		3	1	27	24
Davies[22]	9–12	4	1		58
Hewat et al.[23]	13–14	4	1		18
Chrietzenberg[24]	6–12	4	1		47
Marshall-Day[25]	14–15	4	1		10
Bergman[26]	11–12	4	3		43
Cohen and *Schiffrin*[27]	6–16	4	2		43
Howell et al.[28]	8–15	4*	2	24	36
McLaren and *Brown*[29]	6–11	4*	1		39
			2		18
Nevitt et al.[30]	9–14	4	1.3		23
Harris[31]	6–11	4	5	33	
Law et al.[32]	7–13	4	1	35	36
Torell and Ericsson[33]	10	2	2		20
Averill et al.[34]	7–11	2	2	16	11
Cons et al.[35]	6–11	4*	3	17	11
Szwejda[36]	6–10	4*§	1	14	17
			2	19	21
			3	17	19
			1	48	42
			2	36	32
			3	38	41
Mercer and *Muhler*[37]	6–15	2	1	6	9
			2	29	27
Iizuka et al.[38]	6–11	4	2	36	45

*Treated only during the first study year.
§Two different application techniques employed.

Stannous Fluoride (SnF_2)

From the work carried out by Muhler (1954) and his associates, stannous fluoride became the second topical fluoride agent to gain wide acceptance [Mellberg & Ripa, 1983].

It was found that an 8 or 10 per cent solution of stannous fluoride, at pH 2.1 was an effective topical anticaries agent [Nikiforuk, 1985].

Solutions of SnF_2 are not very stable, soon after mixing, they become cloudy due to the formation of tin hydroxide. Since the stannous ion is believed to contribute to the anticaries benefits of SnF_2, aged solutions are considered to be clinically less effective [Mellberg & Ripa, 1983].

Muhler et al. (1954), recommended that a fresh solution of SnF_2 be prepared for each patient. While this recommendation has always been followed, there has been no clinical trial evaluating the efficacy of fresh SnF_2 solution compared to an aged one. Dunn and Shannon (1967) believed that aged solutions should maintain their clinical effectiveness, but support their theory only with laboratory evidence of enamel solubility reduction [Mellberg & Ripa, 1983].

Stannous fluoride is recommended for administration at 6 or 12 monthly intervals. The treatment consists of two steps, in which the teeth are first thoroughly cleaned and then a freshly prepared aqueous solution of SnF_2 is applied [Mellberg & Ripa, 1983].

Each tooth surface is cleaned with flour of pumice or other dental cleaning agent for 5 to 10 seconds and waxed dental floss is passed between the interproximal areas. A quadrant or half mouth is isolated with cotton rolls and the SnF_2 solution is applied continuously, keeping the teeth moist for about 4 minutes. The patient may not eat of drink for 30 minutes after treatment [Mellberg & Ripa, 1983].

The frequency of application depends on each patient's susceptibility to dental caries. For highly susceptible patients, the application should be repeated at least once every 6 months. If the patient is a low susceptible one, then the frequency is once a year [Horowitz et al, 1986].

Stannous fluoride solutions are not very stable, if left standing they tend to form a precipitate when stored for long periods, they oxidise to form stannic fluoride [Nikiforuk, 1985].

The stability of stannous fluoride can be improved by storing the solution in plastic bottles, and by adding glycerine or other water insoluble materials to diminish the activity of free ions, thereby reducing the rate of hydrolysis [Diorio, 1983].

Stannous fluoride solutions are currently used less frequently, primarily because of their instability, the astringent taste (mildly metallic), the formation of stains (probably due to tin sulfides) in demineralised and hypoplastic areas of teeth and at margins of fillings, and irritation of the gingiva where poor oral hygiene exists [Diorio, 1983].

From the clinical efficacy point of view a topical application of 8 per cent SnF_2 has shown a caries reduction of approximately 40 per cent or more [Muhler, 1954].

However, the caries reduction obtained by other investigators using SnF_2 (8 per cent) were generally less than those reported by Muhler. The results are summarised in table 6 below.

Table 6: Effect of professionally applied stannous fluoride solution on the permanent teeth of children living in fluoride deficient communities.

<u>Source:</u> Mellberg & Ripa, 1983 page 185

Study	Initial age (years) of subjects	No. applications per year	Duration of study (years)	Percent reduction DMFT	DMFS
Jordan et al.[49]	12–13	1	2	38	38
Law et al.[32]	7–13	1	1	19	24
Mercer and *Muhler*[50]	6–14	1	1	50	51
		2	1	53	53
Peterson and *Williamson*[51]	9–13	1	2	26	24
Salter et al.[52]	6–7	1	1	65	56
		2	1	29	30
Harris[53]	7–12	2	3	23	
Mercer and *Muhler*[46]	5–15	2	1	38(81)[§]	39(78)
			2	44(68)	47(69)
Grissom et al.[54]	6–11	2	2		16
Wellock et al.[55]	8–12	1	1	+9	0
Torell and *Ericsson*[33]	10	1	2		4
Hass[56]	6–12	1	1	30	21
Horowitz and *Lucye*[128]	8–11	1	2	+3	+8
Cartwright et al.[57]	6–19	2	2	37	
Cons et al.[35]	6–11	1	3	8	8
Mercer and *Muhler*[37]	6–15	1	1	57	57
			2	55	57
Iizuka et al.[38]	6–11	1	2	13	23

[*] Only studies using an 8% SnF_2 concentration are listed
[§] Two independent examiners.

Acidulated Phosphate Fluoride (APF)

In the 1960s, a new type of topical fluoride preparation, acidulated phosphate fluoride, was introduced by Brudevold and associates (1963). The development of APF was based on the known information that slightly demineralised enamel acquired more fluoride than unaffected enamel [Mellberg & Ripa, 1983].

Phosphate was introduced into the solution so as to suppress the breakdown of enamel and to shift the equilibrium in the direction of formation of hydroxiapatite and fluoroapatite [Mellberg & Ripa, 1983].

Currently available APF preparations all contain NaF as the active ingredient. The general formulation has 1.23 per cent of fluoride as NaF, buffered to a pH of 3.4 in 0.1M phosphoric acid. The preferred method of application of APF solutions is via the paint-on technique which has previously been described for application of SnF_2, with the exception that because APF is stable, it need not be freshly prepared for each patient as is the case for stannous fluoride solutions [Mellberg & Ripa, 1983].

Application of APF is recommended at 6 or 12 monthly intervals. Studies on the effectiveness of APF have reported a reduction of caries by as much as 28 per cent, when the reults listed in table 7 were averaged [Mellberg & Ripa, 1983].

A complete list is given in table 7 below.

Table 7: Effect of professionally applied acidulated phosphate solutions on the teeth of children living in fluoride deficient communities.

Source: Mellberg & Ripa, 1983 page 187

Study	Agent	Initial age (years) of subjects	No. applications per year	Duration of study (years)	Percent reduction DMFT	Percent reduction DMFS
Wellock and *Brudevold*[76]	1.2% F (NaF + HF)	8–11	1	1	55	71
	0.1 M H_3PO_4		1	2	67	70
	pH approximately 3					
Wellock et al.[55]	1.2% F (NaF + HF)	8–12	1	1	44	46
	0.1 M H_3PO_4		1	2	44	52
	pH approximately 3					
Muhler et al.[75]	8% SnF_2 + NaH_2PO_4, pH approximately 3	6–13	2	1	66	67
	3.6% NaF + K_2HPO_4, pH approximately 6	6–13	2	1	51	52
Averill et al.[34]	2% NaF + NaH_2PO_4, H_3PO_4, pH approximately 4.5	7–11	2	2	12	+2
Cartwright et al.[57]	1.2% F (NaF + HF)	6–9	2	2	49	
	0.1 M H_3PO_4					
	pH approximately 3					
Horowitz[77,78]	1.2% F (NaF + HF)	10–12	1	1	17	22
	0.1 M H_3PO_4		1	2	26	33
	pH approximately 3		1	3	27	30
Horowitz and *Doyle*[79]	1 2% F (NaF + HF)		2	1	28	27
	0 1 M H_3PO_4		2	2	26	33
	pH approximately 3		2	3	40	43
DePaola et al[80]	1% NaF reduced to	6–8	3	1	23	21
	0.25% after first year,		3	2	6	11
	0.1 M H_3PO_4		3	3	1	13
	pH approximately 4					
Jordan et al[81]	1.2% F (NaF + HF)	6–12	1	1	26	35
	0.1 M H_3PO_4					
	pH approximately 3					
Ingraham and *Williams*[82]	1.2% F (NaF + HF)	6–10	1	2	18	11
	0 1 M H_3PO_4					
	pH approximately 3					
Cons et al[35]	1.2% F (NaF + HF)	6–11	1	3	16	+1
	0 1 M H_3PO_4					
	pH approximately 3					
Szwejda[36]	1 2% F (NaF + HF)	6–10	1	2	20	27
	0 1 M H_3PO_4		1	3	15	20
	pH approximately 3					
Iizuka et al.[38]	2% NaF	6–11	1	2	44	44
	0.15 M H_3PO_4					
	pH approximately 3 5					
Vrbic et al.[83]	4% NaF	10–12	1	3	16	23
	0.1 M H_3PO_4		2	3	29	31
	pH approximately 4 5					
Zahran[84]	2% NaF	7–9	2	1	3	8
	0.15 M H_3PO_4		2	2	18	18
	pH approximately 3		2	3	8	17
			2	4	2	5
Downer et al[85]	1.2% F (NaF + HF)	14–15	2	3	34*	31*
	0 1 M H_3PO_4					
	pH approximately 3					

*Includes a prophylaxis with an APF paste and daily supervised brushing with an MPF dentifrice.

The major advantages of APF solutions over SnF_2 solutions are its stability, and that it does not cause staining as stannous fluoride does. Aqueous solutions are generally not flavoured and the taste is poorly tolerated by children [Mellberg & Ripa, 1983].

Amine Fluoride

Amine fluorides are a group of compounds in which inorganic fluoride (HF) is reacted with the amine portion of the inorganic compound. The amine fluorides differ from the organic fluoride compounds such as fluorinated hydrocarbons, in which fluoride is attached directly to a carbon atom [Mellberg & Ripa, 1983].

Several properties of amine fluoride include: reduced stability, increased fluoride uptake, antibacterial properties and reduced plaque formation. Studies conducted in the USA showed that amine fluoride is as much effective as SnF_2 ad NaF in the reduction of root caries but there is no evidence that it is any better [Mellberg & Ripa, 1983].

We can make a comparison of the above topical fluoride agents which we list in the following table 8 below.

Table 8: Comparisons of topical fluoride agents.

Source: Nikiforuk, 1985 page 70

	NaF	SnF_2	APF
Efficacy, %	29	32	28
Application frequency	4/year at ages 3,7,10 and 13 years	1 or 2/year	1 or 2/year
Cost	inexpensive	inexpensive	relatively inexpensive
Taste	bland	astringent	bitter
Tooth discoloration	no	yes	no
Gingival reaction	no	occasional	no

Topical fluorides have been applied to the teeth as aqueous solutions or gels and have been incorporated into prophylaxis pastes and varnishes. The results of numerous clinical studies indicate that the vehicle in which the fluoride is incorporated can influence the level o clinical effectiveness [Mellberg & Ripa, 1983].

Aqueous solutions such as NaF, SnF_2 and APF discussed above were the first professionally applied fluoride delivery vehicles. The major disadvantages were that the application of these was time consuming, as it involved a multi-step process, the first was the use of a prophylaxis and the second was the application of a topical fluoride solution. The other disadvantage was the cost of this method of fluoride delivery, because of the application time, making the benefits derived uneconomical. For this reason other fluoride delivery vehicles have been sought [Mellberg & Ripa, 1983].

Fluoride gels

Fluoride gels have been looked at as a fluoride delivery vehicle. Gels are produced by the addition of an alkyl cellulose to the fluoride preparation, which increases its viscosity. These products are essentially the same formulation as the aqueous solutions but with the addition of the gelling agent [Mellberg & Ripa, 1983].

The use of viscous gels instead of solutions as a topical fluoride reagent has several advantages. The gel adheres to the teeth for a considerable time and eliminates the continuos wetting when applied and when trays are used for applying gels it is possible to treat two or four quadrants simultaneously, saving time [Mellberg & Ripa, 1983].

Acidulated Phosphate Fluoride (APF)

Acidulated phosphate fluoride is commercially available as a gel. Clinical studies comparing APF gels and solutions indicate that both are of the same order of clinical effectiveness. The disadvantage of APF gels is limited storage time, usually 6 months, because they contain methylcellulose which tends to lose some of its viscosity [Mellberg & Ripa, 1983].

Sodium fluoride

Neutral NaF can also be prepared as a gel but none are currently available on the market in this form [Mellberg & Ripa, 1983].

Stannous fluoride

The effectiveness of water free SnF_2 gel preparations has not been tested clinically in a professional program of topical fluoride application [Mellberg & Ripa, 1983].

Fluoride gels have an added advantage in that when used in trays the entire mouth can be treated with one single application hence saving valuable time, hence it is the chosen method in many dental offices [Mellberg & Ripa, 1983].

Fluoride prophylaxis paste

Prophylaxis pastes with fluoride were developed to allow the practitioner the opportunity to provide both the cleaning and the fluoride application in one step. While the cost and time saved from this procedure is attractive, this approach has not proved to be an effective cariostatic method [Mellberg & Ripa, 1983].

One problem associated with fluoride containing prophylaxis pastes is their formulation. There is a greater difference between the ingredients of different manufacturers' prophylaxis pastes than between different fluoride gels or aqueous solutions. Formulation problems with different prophylaxis include selection of a compatible abrasive, the presence of humectants and the effect of viscosity. Use of incompatible abrasives (eg. pumice), high concentrations of humectants (eg. glycerol), or a high viscosity, greatly reduce or inhibits fluoride uptake [Mellberg & Ripa ,1983].

Results from clinical trials of fluoride containing prophylaxis pastes can be shown below in table 9.

Table 9: Effect of professionally applied fluoride containing prophylaxis pastes.

Source: Mellberg & Ripa, 1983 page 191

Study	Initial age (years) of subjects	Agent and abrasive	No. applications per year	Duration of study (years)	Percent reduction DMFT	DMFS
Bibby et al.[119]	6–15	4% NaF, pumice	2	1		25
Peterson et al.[120]	10–13	17.5% SnF_2 silex, silicone	2	2	35 (39)*	42 (34)*
Scola and *Ostrom*[121,47]	17–24	17 5% SnF_2, pumice	1	1	12	12
			1	2	26	12
Bixler and *Muhler*[122,123]	5–18	8.9% SnF_2, pumice	2	1	31	35
			2	2	30	34
			2	3	33	35
Horowitz and *Lucye*[128]	8–10	8.9% SnF_2, pumice	1	2	+8	+6
Szwejda[36]	6–10	SnF_2**	1	2	13	17
			1	3	17	19
			1	2	9	20
			1	3	19	20
Szwejda[124]	6–10	1.9% NaF, 0.8% HF, H_3PO_4, sodium metaphosphate	1	1	12	
				2	0	
				3	1	8
Peterson et al.[125]	10–13	2.1% F ($KF \cdot H_2O$), H_3PO_4, pumice	1	2	14 (12)*	16 (15)*
DePaola and *Mellberg*[126]	10–13	APF: 0 4% F, ammonium fluorosilicate, SiO_2	2	2	17	21
Barenie et al.[127]	9–14	APF 0.4% F, ammonium fluorosilicate, SiO_2	2	2	+7(+8)*	+5(+8)*

*Two independent examiners.
**No other description of the paste ingredients

Some of the first fluoride containing prophylaxis pastes used either NaF or SnF_2 with lava pumice or silex as the abrasive. Even though clinical tests on these pastes were positive they were never marketed [Mellberg & Ripa, 1983].

The first marketed fluoride containing prophylaxis paste contain SnF_2 as the active ingredient and zirconium silicate as the abrasive. Other marketed products contain either NaF, APF or monofluorophospahte (MFP). The pastes can be applied using a brush or a rubber cup in a dental handpiece with the frequency of application being either semi-annual or annual, preceding the use of a topical fluoride solution or gel [Mellberg & Ripa, 1983].

The effects of some of the professionally applied topical fluoride preparations can be summarised in tables 10, 11, and 12 on the following pages.

Table 10: Effect of professionally applied topical fluoride on permanent teeth of children living in optimally fluoridated communities.

Source: Mellberg & Ripa, 1983 page 196

Study	Fluoride agent	Initial age (years) of subjects	No applications per year	Duration of study (years)	Percent reduction DMFT	DMFS
Downs and *Pelton* [153]	2% NaF	6–18	4	1	0	0
Galagan and *Vermillion* [154]	2% NaF	7–16	4	1	9	0
Muhler [155,156]	8% SnF_2	6–17	2	1	35	31
				2	46	35
				2 5	54	49
Horowitz and *Heifetz* [157,48]	8% SnF_2	7–9	1	1	17	10
				2	20	13
				3	21	21
Szwejda [124]	10% SnF_2	8–9	1	3	14	20
	1.23% APF solution		1	3	19	23
	APF gel		1	3	9	4
	APF prophylaxis paste		1	3	1	+2

Table 11: Effect of professionally applied topical fluoride on primary teeth of children living in optimally fluoridated communities.

<u>Source:</u> Mellberg & Ripa, 1983 page 197

Study	Fluoride agent	Initial age (years) of subjects	No. applications per year	Duration of study (years)	Percent reduction DEFT	DEFS
Fluoride-deficient communities						
Jordan et al.[158]	2% NaF	6–12	1	1	5	+3
			2	1	15	10
			3	1	40	17
Ast [159]	2% NaF	2–7	4	1		22
Jordan [160]	2% NaF	4–6	1	3	34	
Wittich [161]	2% NaF	3–6	2	2		22
Sundvall-Hagland et al [162]	2% NaF	3–5	4*	1		34
				2		23
				3		12
Compton et al.[163]	8% SnF_2	2–4	1	1		28
Salter et al.[52]	8% SnF_2	6–7	1	1	45	42
Burgess et al [164]	8% SnF_2	2–4	1	1		15
				2		25
Optimally fluoridated communities						
McDonald and *Muhler* [165]	2% NaF	3–12	4	1	21	12
	4% SnF_2	3–12	4	1	57	37
Schutze et al [166]	APF prophylaxis paste	3–5	2	2		+16

*Treated first year only

Table 12: Effect of professionally applied topical fluoride on primary teeth of adults living in fluoride deficient or optimally fluoridated communities.

Source: Mellberg & Ripa, 1983 page 197

Study	Fluoride agent	Initial age (years) of subjects	No. applications per year	Duration of study (years)	Percent reduction DMFT	DMFS
Fluoride-deficient communities						
Arnold et al.[167]	1% NaF	17–23	1	1	0	0
Klinkenberg and *Bibby*[2]	1% NaF	18–40	5	1	47	45
Rickles and *Becks*[168]	2% NaF	22–34	2	2	19	37
Kutler and *Ireland*[169]	2% NaF	20–42	4	1	0	0
Carter et al.[170]	2% NaF	19–39	4	1	12	
Muhler[171]	10% SnF_2	17–39	1	1	24	16
Harris et al.[172]	10% SnF_2	30 1*	1	1		15(7)**
Scola and *Ostrom*[47]	SnF_2 multiple therapy***	17–24	1	2	50	48
Optimally fluoridated communities						
Muhler et al.[66]	SnF_2 multiple therapy***	dental students	2	2.5	68	64

*Mean age.
**Two independent examiners.
***Includes prophylaxis with SnF_2-containing prophylaxis paste, topical application of 10% SnF_2 solution, and use of SnF_2-containing dentifrice.

Fluoride varnishes

With all currently used topical fluoride reagents about two-thirds of the fluoride acquired after treatment is lost within a day. The rapid loss of the soluble fluoride formed on teeth after topical fluoride therapy may be reduced by applying a waterproof sealant to the teeth. This procedure will enhance fluoride uptake for extended periods of time [Nikiforuk, 1985].

Several materials have been developed which are relatively simple to apply and permit an extended time of about 12-48 hours for fluoride fixation. One such product is 'Duraphat' and another is 'Fluor-protector' [Nikiforuk, 1985].

Duraphat contains 50mg of sodium fluoride per millilitre (2.2 per cent fluoride ion) in a alcoholic solution of natural varnishes. This fluoride varnish is applied to freshly cleaned and dried teeth, it sets when in contact with moisture and remains on the tooth surface fo up to 12 hours, thereby maintaining a close contact between fluoride and tooth. The initial uptake of fluoride after application of the fluoride varnishes is high but so is the subsequent loss of surface fluoride [Nikiforuk, 1985].

Results of clinical studies on deciduous teeth can be summarised in tables 13 and 14 below.

Table 13: Duraphat - Summary of clinical studies on deciduous teeth.

Source: Murray, 1989 page 177

Author	Year	Country	No. of Patients	Age	No. of Applications per year	Duration of study	% caries reduction
Hochstein *et al.*	75	GDR	94	3 4	1 5	2 yr	34
Murray *et al*	77	England	302	5-6	2	2 yr	7 4
Holm *et al*	79	Sweden	225	3	2	2 yr	44
Treide *et al*	80	GDR	110	Pre-school	4	21 m	26
Ulvestad*	78	Norway	103	7-11	2	2 yr	56*
Petersson	83	Poland	322	3	2	2 yr	9
Clark *et al*	85	Canada	703	6–7	3	20 m	7

* Includes first permanent molars --% reduction of approximal surfaces only

Table 14: Duraphat varnish - Summary of clinical studies on permanent teeth.

Source: Murray, 1989 page 178

Author	Year	Country	No. of Patients	Age	No. of Applications per year	Duration of study	% caries reduction
Heuser	68	FRG	224	13–14	1	15 m	30
Maiwald	73	GDR	82	11	1	23 m	10
			97	11	3	23 m	46
Hetzer	73	GDR	139	9–10	2	3 yr	18–43
Winter	75	FRG	165	6	1	2 yr	37
Koch	75	Sweden	60	15	2	1 yr	75
Murray *et al.*	77	England	302	5–6	2	2 yr	37
Leiser	77	FRG	366	10–12	2	3 yr	58
Maiwald *et al.*	78	Cuba	350	6–12	2	4½ yr	39
Koch	79	Sweden	200	14	2	2 yr	30*
Seppa *et al.*	82	Finland	62	11–13	2	3 yr	30
Holm	84	Sweden	109	5	2	2 yr	56**
Tewari *et al.*	84	India	645	6–12			73

* 30 per cent reduction compared with a positive control group using a 0.2% NaF mouthrinse weekly.
** 65 per cent reduction in fissure caries in first permanent molars.

Overall, the results of clinical trials with Duraphat varnish suggests that it is at least as effective as fluoride solutions and gels [Murray, 1989].

Fluor-protector is a fluoride coating material which contains polyurethane lacquer dissolved in chloroform and difluorosilane at a concentration of 2 per cent (weight), equivalent to 0.32 per cent fluoride ion in the liquid [Nikiforuk, 1985].

Fluor-protector is dispensed in 1ml ampules, each containing about 6.21 mg of fluoride. The material is applied to freshly cleaned, dried teeth by a small brush. The varnish dries rapidly to a thin, transparent coating [Nikiforuk,1985].

Fluorsilanes have been shown to increase fluoride penetration of the root surfaces and to enhance retention of surface fluoride [Nikiforuk, 1985].

Fluoride mouthrinses

Fluoride solutions such as sodium fluoride, stannous fluoride and APF which were high in fluoride concentration have been used by dentists and the method of application has been by painting or brushing the solution onto each tooth surface, one quadrant at a time [Mellberg & Ripa, 1983].

However, this was time comsuming so several products have been developed containing APF and SnF_2 which can be applied by the patient as a mouthrinse under the supervsion of dental personnel in a dental office [Mellberg & Ripa, 1983].

Self application of this type of mouthrinse in a dental clinic makes it much easier, less time consuming and less costly for dental office personnel, as their role is purely a supervisory one [Mellberg & Ripa, 1983].

Controlled release devices

Since many drugs are rapidly cleared from the blood stream, requiring a repeated dosage in order to maintain their therapeutic levels, devices have been developed in order to reduce the amount of drugs prescribed systemically. These devices control the release of drug, by releasing the drug slowly, thus overcoming the serum drug spiking effect brought about by the ingestion of drug supplements [Nikiforuk, 1985].

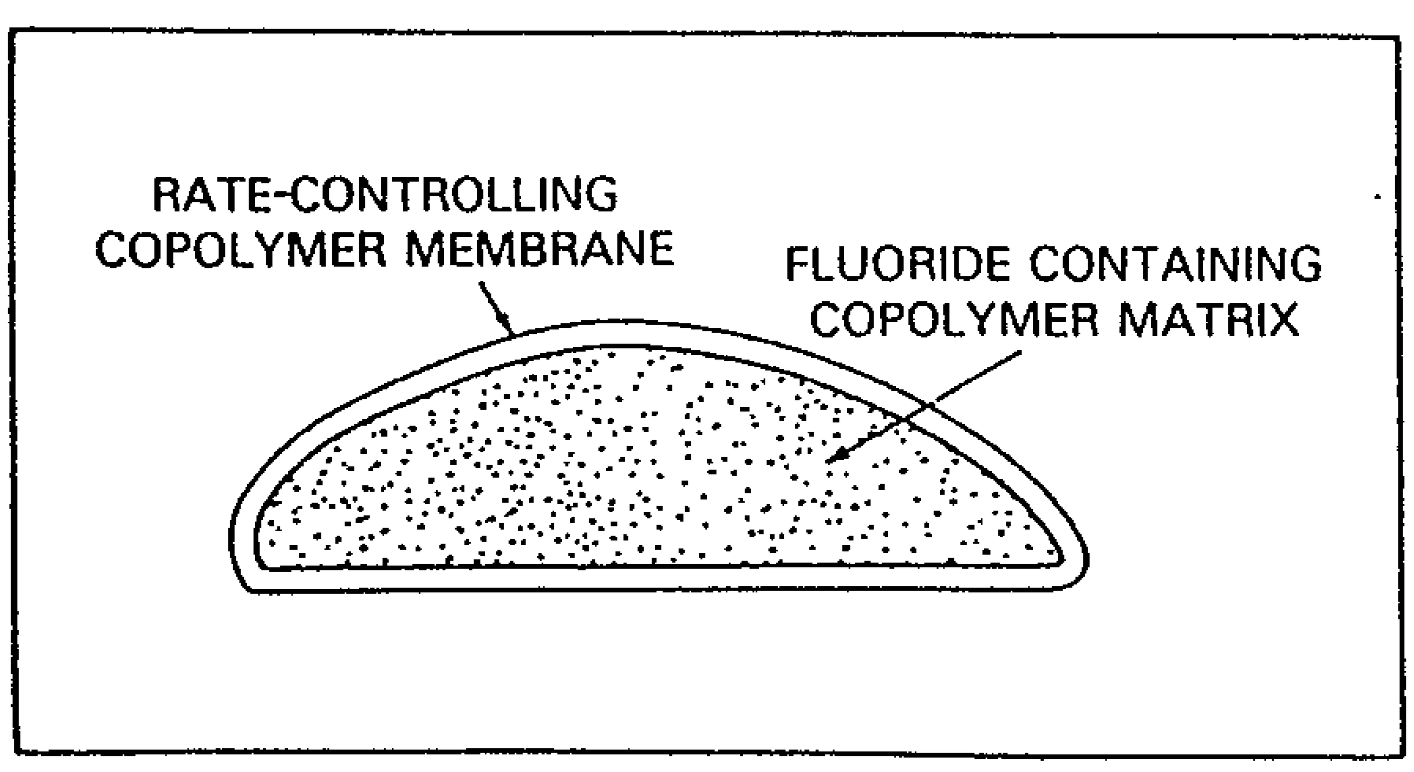
This technique has been recognised as having potential for a sustained release of fluoride from an intra oral device when controlling root caries in special groups [Nikiforuk, 1985].

Such a device has been developed as shown in figure 12 below.

Figure 12: A cross-section of an intraoral device for the controlled release of fluoride.

Source: **Nikiforuk, 1985 page 83.**

Controlled Release Fluoride



This device consists of a central depot of NaF intimately mixed with a plastic copolymer and surrounded by a rate-controlling membrane. Fluoride diffuses out at a controlled rate determined by the thickness of the membrane used and the exposed surface area of the device [Nikiforuk, 1985].

Clinical studies conducted by Mirth et al (1983) have shown a caries inhibition on all tooth surfaces of up to 42 per cent on sulcal surfaces and between 75-77 per cent on smooth surfaces. The rate of fluoride release has been 0.15 mg fluoride daily [Nikiforuk, 1985].

Slow release devices could play a major role in the prevention of dental caries. The devices could be incorporated into space maintainers, orthodontic appliances, partial dentures, crown and bridgework and also directly onto tooth surfaces [Nikiforuk, 1985].

Pit and fissure sealants

Numerous studies show that fluoridation of public water supplies and the use of fluoride preparations reduce caries significantly [Silverstone, 1978].

While the proximal sites show the greatest reductions, the occlusal surfaces of posterior teeth benefit the least [Backer Dirks et al., 1961].

Pit and fissure caries make up the bulk of caries. This is because occlusal fissures and buccal pits are obvious stagnation areas where plaque can accumulate. It is protected from cleaning by tooth brush bristles by the dimension of the fissures, resulting in lesions being formed on either side of the fissure walls, giving the appearance of two small, smooth surface lesion. Eventually the lesions increase in size coalescing at the base of the fissure the enamel lesion broadens as it approaches the underlying dentine [Murray, 1989].

Pit and fissure caries can be arrested by using sealants, the technique of fissure sealing is on in which the vulnerable biting surface is coated with a thin layer of plastic-type material to prevent the initiation and progression of caries [Silverstone, 1978].

The technique consists of two stages, the first is preparing the surface using an acid solution to etch the surface so that bonding of resins to tooth surface can occur, the second, is the application of a suitable sealant [Silverstone, 1978].

The first sealant clinical trials used cyanoacrylate based materials. These were subsequently replaced by dimethacrylate based products which were marketed, with the major difference between marketed sealants is their method of polymerisation [Ripa, 1993].

The first generation of sealants were initiated by ultra-violet light, the second generation were autopolymerized, and the third generation sealants used visible light. A recent innovation is the addition of fluoride to the sealants. Fluoride release to the saliva from fluoride sealant system is rapid [Ripa, 1993].

The first clinical trials of pit and fissure sealants used cyanoacrylates. These successful trials, Cueto & Buonocore (1967) and Ripa & Cole (1970), demonstrated the feasibility of sealing pits and fissures to prevent caries [Ripa, 1993].

However, one major problem with cyanoacrylates was that they were biodegradable and therefore were not suited for prolonged use in the oral cavity [Ripa, 1993].

Cyanoacrylates were eventually replaced by the more successful class of methacrylate sealants, and in particular the higher molecular weight dimethacrylate, which represents the reaction product of bis-phenol A and glycidyl methacrylate (BIS-GMA) which is a hybrid between a methacrylate and an epoxy resin [Bowen, 1982].

Most commercial sealants today are BIS-GMS dimethacrylate or urethane dimethacrylate based products [Ripa, 1993].

Roydhouse (1968) was perhaps the first to employ BIS-GMA in a sealant formulation. His studies, reported in 1968, showed that a blend of BIS-GMA and methyl methacrylate significantly reduced the incidence of occlusal caries after 3 years [Menaker, 1982].

Nuva-Seal is a modified BIS-GMA sealant developed by Buonocore et al (1967), they used a ultra-violet light sensitive catalyst, benzoin methyl ether. The sealant can be polymerised by ultra-violet light. In clinical trial conducted by Buonocore (1971) it was found that a single application of the sealant was almost completely effective in protecting occlusal surfaces from caries [Ripa, 1993].

In clinical trials, Horowitz et al (1974), reported on the effectiveness of Nuva-Seal in a two year clinical trial of school based children ranging in ages 10-14 years. After one year Horowitz and co-workers noted an 81 per cent caries reduction and an 88 per cent retention rate of the sealant [Ripa, 1993].

After a second year, the sealant showed a 67 per cent caries reduction and a 73 per cent retention rate. The sealant was shown to fail if the tooth was either carious or restored [Ripa, 1993].

Horowitz et al (1975), reported their four year results in 1975. After four years they found that there was a 50 per cent reduction in caries and all sites showed a complete retention of the sealant with a 16 per cent showing a partial retention of the sealant. For all sites remaining fully sealed there was a 99 per cent caries reduction [Ripa, 1993].

In a final report at the conclusion of a five year trial, Horowitz reported that there was a 92 per cent caries reduction with a 56 percent sealant retention rate [Ripa, 1993].

In the latter part of the 1960s and 1970s sealant research increased significantly. Several modifications and improvements were made in the methacrylate systems. As a result of this effort new sealants based on BIS-GMA or similar monomers have been developed and marketed under trade names such as Epoxylite 9075, Kerr pit and fissure sealant, Concise white sealant and Delton pit and fissure sealant [Menaker, 1982].

Epoxylite 9075 was used by Rock (1974), clinical trials showed a 35 per cent occlusal caries reduction [Ripa, 1993].

Two chemically polymerised BIS-GMA sealants are currently available and have produced good results in vitro and in vivo.

Concise enamel bond system and Delton, are fairly similar resins, the former being supplied with 37 per cent phosphoric acid as the etching agent whilst the latter employs a 35 per cent solution of phosphoric acid [Ripa, 1993].

Concise White enamel bond sealant, trialled by Thylstrup and Poulsen (1978) showed a 98 per cent caries reduction [Ripa, 1993].

Delton Pit and fissure sealant was clinically trialled over a one year period by Houpt and Sheykhaleslam (1978) and was assessed as being 90 per cent effective in occlusal caries prevention [Ripa, 1993].

A recent innovation is the use of fluoride containing sealants, when the sealant material is applied to the occlusal surface apart from arresting and preventing the spread of pit and fissures, it also releases fluoride very slowly to the tooth environment. The release is usually short lived, normally seven days, exhibiting a 'burst effect' only [Ripa, 1993].

The use of fissure sealants can reduce the incidence of occlusal caries drastically. Since occlusal caries accounts for approximately 50 per cent of the total caries experience, and since the occlusal site is the least to benefit by fluoride, fissure sealants play an important role in the overall caries prevention regimen [Silverstone, 1978].

Fluoride restorations

As soon as early caries lesions have been detected they are attacked with the dentists' drill to remove diseased tissues and hopefully arrest further progression of the carious lesion. The cavity is then filled with a restorative material [Murray, 1989].

It appears that the interface between a restoration and the dental tissue is susceptible to demineralisation, whenever leakage of bacteria, fluids, molecules, or ions can occur between the cavity wall and the restorative material applied to it. This clinically undetectable leakage around restorations has come to be referred to as 'microleakage' [Murray, 1989].

Bacteria accumulates more readily on restorations surfaces, Glantz (1969), with the possible exception of porcelain, Newcomb (1974), than on other surfaces such as enamel. The surface finish of a restorative material may influence the degree of plaque formation [Murray, 1989].

A more highly polished surface will be less prone to plaque formation because it is easier to keep clean. While restorations with overhanging or defective cervical margins form retention sites for plaque [Murray, 1989].

Subgingival restorations margins produce more plaque accumulation Silness (1980) and result in poorer gingival health than margins which are level with the gingival crest or in supragingival position [Murray, 1989].

So choice of restorative materials to be used is very important, several of which include:

Amalgam Alloy, is the material most commonly used in restorations of posterior teeth. Even though freshly packed amalgam restorations have been shown to leak, this problem is short lived as cavity seal improves when the restorations have been in the mouth for some time Nelson et al (1952). This phenomenon has been attributed to the formation of corrosion products at the amalgam/dental tissue interface. Thus, the corrosion of the alloy, a property long deplored by clinicians, may be responsible for its success in giving long clinical service [Murray, 1989].

The initial leakage around an amalgam restoration can be minimised by applying a thin layer of cavity varnish to the walls and floor of the cavity before packing the amalgam. This will prevent leakage until corrosion products form and block the microspace between restoration and cavity wall [Murray, 1989].

Silver amalgams containing SnF_2 have been shown to be of potential value for minimising caries adjacent to dental restorations. Studies conducted by Souganidis et al (1979) showed that the use of 1 per cent SnF_2 in fine-cut silver amalgam can be of potential value for minimising caries adjacent to dental restorations. Electron microscope analyses of enamel and dentine along the enamel-dentinal junction showed a significant uptake and retention of fluoride to distances of 100 μm of the amalgam/cavity interface [Suoganidis et al., 1979].

Copper content alloy, materials with reduced corrosion resistant properties pose many problems because of the reduced corrosion which may affect the long term cavity sealing ability of the restorations [Murray, 1989].

Cast gold inlays, are an alternative to amalgam for restoration of posterior teeth. In any cast restoration the gap between restoration and tooth is filled by a cement, thus the cavity sealing ability of a gold inlay is really dependent on the seal of the cement used [Murray, 1989].

Composite resin materials, with greater wear resistance have been developed. However, they show poor resistance to recurrent caries at the cervical margins of the class II cavity, despite the fact that composites are bonded to the dentine via bonding resins. The problem being that material shrink as they set [Murray, 1989].
Adhesion between dentine and composite restorations has two potential benefits. The first, marginal leakage may be reduced, and, the second, if sufficient bond strength could be achieved, the need to cut retentive cavities would cease [Murray, 1989].

Glass ionomer cements, such as Vitrebond, Ketac-Fil and ChemFil II are fluoride releasing materials used as restorations, they release fluoride into the saliva [Koch & Hatibovic-Kofman, 1990].

Studies were conducted by Koch & Hatibovic-Kofman, (1990) where glass ionomer restorations were placed in the primary teeth of pre-school children. Samples of saliva were collected during various stages of the study in order to measure the amount of fluoride present. The concentration of fluoride was found to increase from 0.04 ppm before placement of restoration to 0.8 ppm after three weeks and even after one year the level of fluoride present in saliva was 0.3 ppm [Koch & Hatibovic-Kofman, 1990].

In vitro studies were also conducted where specimens were placed in deionised water for 16 weeks and the fluoride release being measured on a weekly basis. At 12 weeks the samples were exposed to fluoride toothpaste where it was found that the specimens actually absorbed fluoride from the toothpaste ad then slowly released it again. Thus it was concluded that glass ionomer cements can act as a rechargeable fluoride release device [Koch & Hatibovic-Kofman, 1990].

The amount of fluoride release is related to the fluoride content of both the material and storage medium [Walls 1986].

Fluoride release is accelerated under acidic conditions or at higher temperatures [Jones et al. 1987; Forsten 1990].

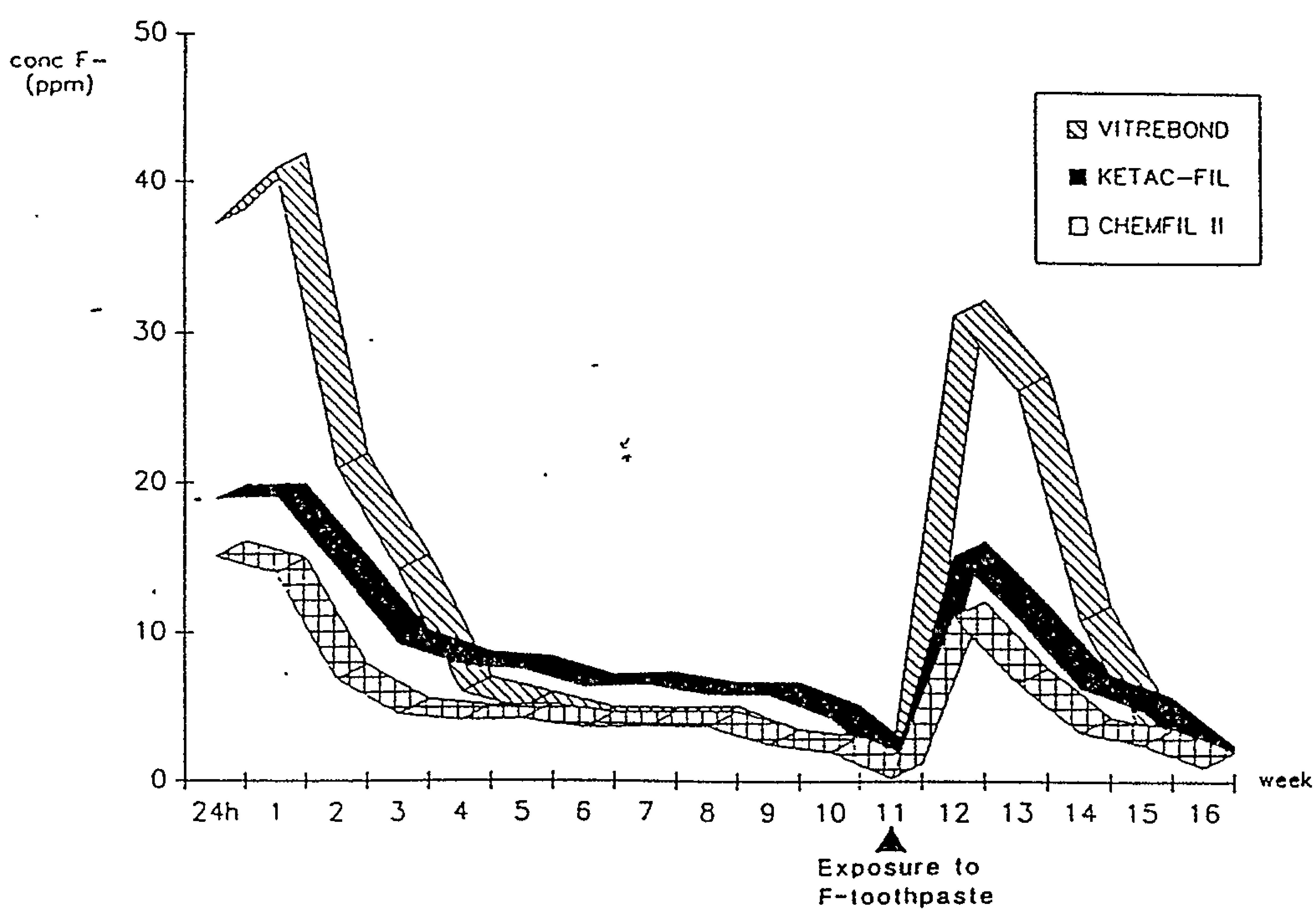
Swift (1988) evaluated the effect of mixing time on fluoride release. He found significantly greater amounts of fluoride released from glass ionomer cements after a short mixing time (5 minutes) than after a longer mixing time (10 minutes).

This then means that glass ionomer cements might be looked upon as a rechargeable slow release fluoride system and thus making glass ionomer restorations of considerable benefit in the prevention of caries [Koch & Hatibovic-Kofman, 1990].

The fluoride concentration of the three glass ionomer cements when immersed in distilled water can be shown in figure 13 below.

Figure 13: Fluoride concentration at different times in distilled water in which glass ionomer cement specimens had been immersed.

<u>Source:</u> Koch et al. 1990 page 257



We can summarise the results of the studies conducted by Koch & Hatibovic-Kofman, (1990) of the three glass ionomer cements in tables 15 and 16 below.

Table 15: Fluoride concentration in unstimulated saliva before and after placement of glass ionomer restorations.
Source: Koch et al. 1990 page 255

Material	No. of children	Fluoride concentration in unstimulated saliva in ppm ($\bar{x}$)			
		Before placement	After		
			3 weeks	6 weeks	1 year
Vitrebond	10	0.04	0.8	0.4	0.3
Ketac-Fil	5	0.06	0.9	0.5	0.3
ChemFil II	4	0.05	0.6	0.4	0.2

Table 16: Glass-ionomer cements tested for fluoride release-absorption-release.

Source: Koch et al. 1990 page 255

Material	Manufacturers	Batch no.	No. of samples	Test specimen weight (g)	
				$\bar{x}$	SD
Vitrebond	3M[1]	7510	5	0.29	± 0.01
Ketac-Fil	ESPE, W. G.	03753	5	0.29	± 0.03
ChemFil II	DeTrey	3/7/89	5	0.29	± 0.04

4.1.4.2 Self Applied Topical Fluorides

The traditional application of topical fluoride involves a dentist or dental hygienist treating one patient at a time. This one-to-one approach is time consuming and too costly to satisfy the requirements of most public health programs.

To bring the benefits of topically applied fluoride to more people at a reasonable cost, procedures have been developed for self application of fluoride. Some of the methods developed include toothbrushing with a fluoride solution, gel or prophylaxis paste, mouthrinsing with a fluoride containing mouthrinse and using mouth trays with drops of a fluoride gel.

Fluoride mouthrinses, together with fluoride gels, soluble tablets and dentifrices may be described as self administered caries preventive agents and will be discussed below.

Fluoride solutions

Fluoride solutions including Naf, SnF_2 and APF, can be applied in one of several ways, either by brushing or mouthrinsing. Solutions can be applied with a toothbrush directly to the teeth, such as 0.1 per cent sodium fluoride or 0.5 per cent sodium fluoride, zirconium fluoride, ferric fluoride [Mellberg & Ripa, 1983].

Fluoride dentifrices

Dentifrices were initially introduced as a cosmetic product to be used in conjunction with a toothbrush for the purpose of cleansing and polishing the teeth and as a breath freshener [Nikiforuk, 1985].

Dentifrices have become a vehicle for the delivery of therapeutic agents, such as fluorides, in order to inhibit dental caries [Nikiforuk, 1985].

Dentifrices are a mixture of an abrasive or polishing agent, a detergent, binders, flavouring agents and substances necessary to facilitate their preparation and use [Nikiforuk, 1985].

The composition of dentifrices can be shown in table 17 below.

Table 17: Components in typical dentifrice formulations.
<u>Source:</u> Mellberg & Ripa, 1983 page 219

Component	Range in formulation (%)
Abrasive	40-50
Humectant	20-40
Detergent	1-2
Binding agent	0.5-2
Flavour, colour, etc	1-4
Fluoride	0.1
Water	20-30

The most frequently used dentifrices are in the form of pastes, although gel formulations are becoming more common. Abrasive substances comprise about one half of the volume of dentifrices. Most commonly used dentifrices contain calcium pyrophosphate (obtained by heating dicalcium phosphate, sodium phosphate or silica gel) abrasives [Nikiforuk, 1985].

Therapeutic dentifrices contain, in addition to the above, one or more chemicals intended to reduce the incidence of oral dental disease [Nikiforuk, 1985].

Fluoride prophylaxis pastes

Prophylaxis pastes are self-applied by the patient with a toothbrush. The fluoride is incorporated into a prophylaxis paste by combining it with an abrasive such as zirconium silicate or silicon dioxide [Mellberg & Ripa, 1983].

Woods (1976) reported a 76 per cent reduction in caries incidence of primary teeth of children brushing with a stannous fluoride-zirconium silicate prophylaxis paste three times a year [Mellberg & Ripa, 1983].

Fluoride mouthrinses

Pioneering clinical trials of mouthrinsing by Bibby at al (1946) and Roberts et al (1948) using acidified sodium fluoride solutions did not show significant results. Successful laboratory studies and clinical trials with neutral sodium fluoride solutions in the 1950s and 1960s led to the introduction of weekly or fortnightly supervised rinsing with neutral 0.2 per cent NaF solutions and in combinations with other fluoride methods in non-fluoridated areas [Torell & Ericson, 1965; Horowitz et al., 1986].

Fluoride mouthrinses were effective in children living in areas with sub-optimal water fluoride concentrations and also in children receiving inadequate fluoride therapy [Weiz, 1960; Torell & Ericson, 1974].

Fluoride mouthrinses have been shown to have additional benefits in optimally fluoridated communities [Driscol et al., 1982].

Fluoride gels

Fluoride gel products available for self application include NaF (5,000ppm), APF (5,000ppm) and SnF_2 (1,000ppm). The fluoride concentration of sel-applied products is lower than that of products applied by a professional [Petersson, 1993].

Self administration of gels is performed using trays or direct brush-on techniques. Clinical trials of the self-application of fluoride gels (neutral or acidulaed Naf containing 5,000ppm fluoride) in school children who lived in fluoride deficient communities were recently reviewed by Ripa (1991). All studies were conducted under supervision, the gels were applied in custom or stock mouthtrays and all studies showed some caries reduction [Petersson, 1993].

For products available for non-supervised home use, none of which have been tested under supervision and Ripa (1991) suggested that further clinical trials of self applied APF and NaF gels were needed due to limited clinical evidence of their effectiveness on root caries [Petersson, 1993].

Only one clincal trial of SnF_2 (1,000ppm fluoride) gel on controlling dental caries has been conducted Boyd et al (1985). The study however, was not rigorously designed, it used a small sample and the duration of the study was too short, therefore the results are inconclusive [Petersson, 1993].

No clinical trials of the effects of sel-applied fluoride gels (5,000ppm fluoride) on children living in both fluoridated and non-fluoridated communities in which the gel is brushed on the teeth rather than applied in a tray have been published [Petersson, 1993].

Both professionaly and self-applied fluoride gel programmes are now less commonly used as public health communty measures because of the relatively high cost with gel tray applications and professional supervision, when compared to weekly fluoride mouthrinsing, which is much cheaper and the procedures much simpler [Petersson, 1993].

Self applied fluoride gels are still practial for use in special groups of patients who are highly susceptible to caries attack, such as those undergoing orthodontic treatment and those with xerostomia related to radiation therapy of the head or neck [Petersson, 1993].

Stratemann and Shannon (1974) as well as Shannon and West (1979) have reported a reduction in the incidence of demineralisation in patients with the daily use of a glyceric-based 0.44 per cent SnF_2 gel (1,000ppm fluoride) in addition to their usual oral hygiene procedures [Petersson, 1993].

Several investigators have reported the successful use of self-applied topical fluoride methods to prevent or control rampant caries in patients who have developed radiation induced xerostomia [Petersson, 1993].

In a clinical study by Wescott et al (1975), the patients were asked to apply 0.4 SnF_2 gel to all tooth surfaces with a toothbrush on a daily basis, while in other studies by Driezen et al (1977), the daily use of 1 per cent NaF gel was applied in mouth trays.

Al-Jaburi et al (1991) found that the daily use of 0.4 per cent SnF_2 was significantly more effective in preventing root caries in head and neck cancer patients than the 1 per cent NaF gel [Petersson, 1993].

4.2 COST ANALYSIS

The two primary objectives of dental public health are to prevent or control oral diseases and to promote oral health through organised community efforts [Young & Striffer, 1969].

Any community-based or national program with these objectives, is a public health program and most public health programs are publicly funded [Horowitz et al., 1979].

Certain analytical techniques of evaluation should be applied before deciding how to use funds for preventive or promotional oral health programs [Horowitz et al., 1979].

Many studies and evaluations of agents and methods for the prevention of dental caries have been conducted during the past 35 years. Most of these studies have dealt with methods of delivering fluorides to populations or groups of individuals, and many of the clinical trials have been replicative [Horowitz et al., 1979].

It is likely that much time, effort and money have been wasted on unnecessary replication of trials of preventive methods that an initial analysis of cost-benefit relations would have revealed to be uneconomical [Horowitz et al., 1979].

4.2.1 Cost-benefit analysis

Cost-benefit analysis is a formal and systemic way to choose among alternative investents in public projects [Klarman, 1974; Prest & Turvey, 1965].

It is an essential component of public financing, by guiding decision making, cost-benefit analyses aims to do in the public health sector what supply and demand analysis accomplishes in the private sector [Klarman, 1972].

The goal of public policy should be to adopt those projects or programs of service which yeald the greatest benefit for a given expenditure, or of which the value of benefits most greatly exceeds the value of costs [Horowitz et al., 1979].

Cost-benefit analysis attempts to measure the benefits of a program strictly in monetary terms and to relate the benefits to the cost of achieving them [Klarman, 1972].

An important point in cost-benefit anlysis is that both the cost and benefits are measured in monetary terms, which may reder the analysis complex because any benefits are difficult, if not impossible, to value monetarily [Horowitz et al., 1979].

One may measure a reduction in the incidence of dental caries and assign a monetary value to the protection based on the cost of restoration, but it is not a simple matter to measure the monetary benefit to a child or a school system if that child makes fewer trips from school to a dentist for emergency dental service, or the monetary benefit to the child of not having a toothache [Horowitz et al., 1979].

Simple cost-benefit analysis often generate those unmeasurable, intangible or indirect benefits. When an item cannot easily be assigned a market price, it is likely to be omitted from calculations of the cost-benefit, even though it may be important. For this reason, a program with valuable indirect or intangible benefits may be eliminated from consideration among competing programs because its total benefits have been underestimated [Klarman, 1972; Fein, 1967].

A list of some of the indirect or intagible benefits includes:

1. Freedom from pain
2. A dentition completely free of decay
3. Improved occlusion
4. Social acceptibility
5. Psychological value of retaining teeth
6. Fewer unsightly restorations
7. Less time missed from work or school
8. Avoidance of extractions or operative dentistry

Whenever investment decisions are being considered, society must weigh the desirability or necessity of sacrificing present benefits (income or consumption) to gain future benefits (income or consumption) [Horowitz et al., 1979].

An investment is not considered worthwhile unless the potential in is greater than the present sacrifice [Fuchs, 1972].

As future gains may take some time to become manifest, they are worth less in present values of inflation. Thus a ten-dollar benefit that will not accrue for 10 years is less valuable than a ten-dollar benefit that can be derived today [Horowitz et al., 1979].

Methods of discounting should be used to allow for this 'decreased value' of future benefits [Klarman, 1972].

Using the monetary values of present costs to calculate the value of future benefits will result in giving too much weight or value to the future benefits. This error will cause an understated cost-benefit ratio.

Nelson and Swint (1976) applied discounting corrections, using a net present value rate (NPV), in their hypothetical cost-benefit analysis of fluoridation in Houston, Texas.

In a similar sense, present benefits should also be weighed more heavily than future benefits in determining social value of an investment [Horowitz et al., 1979].

In essence, then, as Oswald (1977) has stated: 'cost-benefit analysis compares the estimated financial returns and outlays of competing projects. The chosen project is the one with the greatest difference between returns and outlays, allowances having been made for the lapse of time before the benefit occurs'. The procedure is often complicated because, as Oswald (1977) goes on to say; 'heath is of course difficult if not impossible to evaluate in monetary terms' [Horowitz et al., 1979].

4.2.2 Cost-effectiveness analysis

In order to avoid the dilemma of assigning costs to indirect and intangible benefits, one may use cost-effectiveness analysis to determine the least expensive way of achieving a stated objective [Klarman, 1972; Grainger, 1973].

In cost-effectiveness analysis, benefits may be measured in physical terms and need not be assigned a monetary value. For example, the objective of a program may be to decrease the incidence of dental caries in children by an average of one tooth surface per year. In chosing among alternative methods for accomplishing that objective, the aim is to minimize the cost of attaining it [Horowitz et al., 1979].

The data on costs are the same for both cost-benefit and cost-effectiveness analysis. Cost-benefit analysis usually cuts across diverse objects of public expenditure to help in making broad decisions, whereas cost-effectiveness analysis helps in choosing among alternative ways of achieving a desired outcome [Klarman, 1974].

A cost-benefit analysis might be used by a ministry of health to help determine whether to build a new hospital, institute a permanent school-based screening program for hearing deficiencies or establish a maternal and child health program [Horowitz et al., 1979].

In contrast, a cost effectiveness analysis would be used to determine the most effective way to achieve the objective of reducing the prevalence of dental caries among high-school students by 40 per cent. Thus, cost-effectiveness analysis is the procedure of greatest interest to us in deciding among caries preventive regimens [Horowitz et al., 1979].

Before we begin to look at cost-effectiveness we should attempt to give some form of definition to the concepts, clinical-effectiveness and community-effectiveness which we are going to discuss in cost-effectiveness analysis.

1. Clinical-effectiveness of caries preventives; is the degree of caries protection as determined under ideal conditions in carefully controlled clinical trials of agents or methods [Horowitz et al., 1979].

2. Community-effectiveness of caries preventives; is the degree of caries protection as determined under field conditions in realistic evaluations of agents or methods [Horowitz et al., 1979].

4.2.2.1 Clinical effectiveness

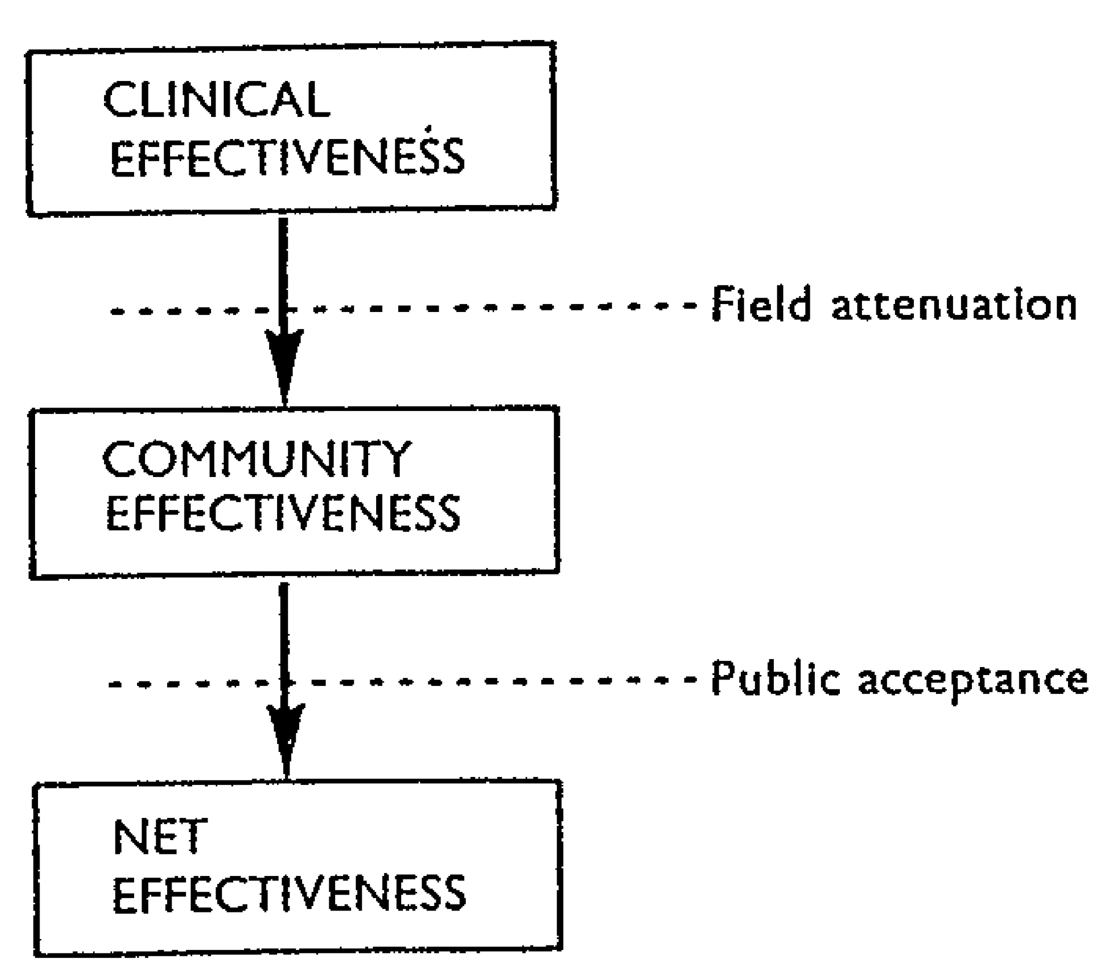
Clinical effectiveness is determined as experimental clinical trials which are conducted under ideal conditions that give an agent or procedure the greatest chance of showing its effectiveness [Horowitz et al., 1979].

The major factor to consider is that experimental trials are frequently done under artificial conditions and will rarely yield results which would prevail in a community, that is similar results would not be found when a regimen is applied in practice [O'Mullane, 1976].

Offensend and Merkhofer (1976) in a report, defined clinical effectiveness as the average percentage reduction in caries incidence that has been reported for a given method of prevention in studies conducted under carefully controlled clinical conditions as shown in figure 14 below.

Figure 14: Stages in the establishment of the effectiveness of a preventive measure

<u>Source:</u> Horowitz et al., 1979 page 108



A point estimate of an average reduction may be misleading because research findings may vary considerably according to such factors as age, caries susceptibility of participants and diagnostic criteria of examiners.

However, if many studies are conducted over a period of time then the mean caries reduction observed in all studies is probably as good a measure of its true clinical effectiveness as any other [Horowitz et al., 1979].

4.2.2.2 Community effectiveness

In a community, the ultimate effectiveness of a preventive method depends not only on its ability to prevent decay, but also on the number of persons who elect to use it. These persons include dental personnel (for agents which must be professionally applied), school personnel (for methods that require self-application under supervision) and the public in general, who must be willing participants in these programs [Horowitz et al., 1979].

The final impact or value of a regimen, its net effectiveness, may be determined only after the effects of field trials and public acceptance have been ascertained. Public acceptance may be affected by such factors as compatibility of a regimen with existing legislation, attitudes and habits of professional groups and the public, availability of personnel and community resources [Horowitz et al., 1979].

Two further concepts which should be cosidered in the cost-effectiveness analysis are efficiency, which was defined by the WHO (1971), as the effects or end results achieved in relation to the effort expended in terms of money, resources and time. This definition implies a comparison of outcome with input. If alternative preventive treatments are compared they may be ranked according to the magnitude of the difference between the benefit and the cost or by the ratio of the benefit to the cost which can be expressed as;

$$\text{Cost-benefit ratio} = \frac{\text{(Cost of care without new program)} - \text{(Cost of care with new program)}}{\text{(Cost of New program)}}$$

The other concept is equity, which refers to the fairness of the distribution of the effects of an activity [Klarman, 1972; Doessel, 1977].

Proposed method for cost-effectiveness analysis. If one wishes to rank alternative procedures for the prevetion of dental caries, it is desirable to look at each procedure identically. In making comparisons, we shall assume that our goal is to prevent one decayed, missing or filled (DMF) surface per person per year.

$$\text{Cost-effectiveness} = \frac{\text{Cost of procedure/person/unit of time}}{\text{Mean DMFS saved/person/unit of time}}$$

Effectiveness is expressed as the average number of tooth surfaces saved from decay per person per stated period.

The calculation of tangible costs for preventive dental programs is not difficult. Costs include facilities, dental equipment, supplies and salaries of personnel.

The cost of various preventive programs are usually independent of the caries activity of a community. The benefits however, are not, the higher the susceptibility to decay, the greater the absolute benefits of prevention [Horowitz et al., 1979].

In this analysis only direct costs of administering a regimen are included, these include:

1. Salaries and training of personnel.
2. Cost of expendable supplies such as fluoride agents, prophylaxis pastes, and paper products.
3. Capital costs of equipment such as lights, dental chairs.
4. Cost of maintenance and repairs to equipment.

Cost-effectiveness of systemic fluoride procedures can be taken as an example. We can apply the above analytical method of cost-effectiveness to two methods of delivering systemically applied fluorides to the community.

Case 1: Community water fluoridation

Community water fluoridation costs are usually expressed as the annual cost per person served by the water supply. Costs include the investment in equipment, whch may be depreciated over several years, annual operating costs for chemicals and other expendable supplies and the cost of maintenance and salaries [Horowitz et al., 1979].

Costs for community water fluoridation are affected by factors such as the size of the community, type of chemicals used and the type of equipment. The costs per capita of community fluoridation tends to vary inversly with the size of the population served, because in larger communities the costs are distributed over a larger proportion of the population, hence resulting in reduced costs per capita, whereas in smaller communities the costs per capita will be considerably higher [Horowitz et al., 1979].

A computation of cost-effectiveness for fluoridation of community water supplies can be shown as follows (for our computation we will assume that the increment of decay is 2DMF surfaces per person per year in a non-fluoride area).

Costs:

Capital	=	$ 0.05/person/year
Operating	=	$ 0.15/person/year
Total	=	$ 0.20/person/year

Effectiveness:

2DMFS x 50 % reductions = 1.0 DMFS saved/person/year

$$\text{Cost-effectiveness (per resident)} = \frac{\$\ 0.20/\text{person}}{1.0\ \text{DMFS saved/person}}$$

$$= \frac{\$\ 0.20}{1\ \text{surface saved}}$$

$$\text{Cost-effectiveness (per child)} = \frac{\$\ 0.60/\text{child}}{1.0\ \text{DMFS saved/child}}$$

$$= \frac{\$\ 0.60}{1\ \text{surface saved}}$$

It will take several years after the initiation of community water fluoridation for the effectiveness in the community to reach 50 per cent [Horowitz et al., 1979].

Case 2: School water fluoridation

For school water fluoridation the picture is slightly different, the equipment that is required consists of fluoride feeder, saturator, storage container and a colorimeter for fluoride analysis. There are some minor costs asociated with installation of equipment which can be as much as $2,000, Newbrun (1978). So our computation will look something like this:

Costs:

Capital	=	$ 0.40/child/year
Operating	=	$ 0.15/child/year
Labor	=	$ 0.95/child/year
Total	=	$ 1.50/child/year

These costs calculated based on a typical school with population of 500 pupils and the equipment cost being depreciated over 10 years.

Effectiveness:

2DMFS x 40% reduction = 0.8 DMFS saved/child/year

Cost-effectiveness:

$$= \frac{\$\ 1.50/\text{child}}{0.8\ \text{DMFS saved/child}}$$

$$= \frac{\$\ 1.90}{1\ \text{surface saved}}$$

School fluoridation is most suitabe for rural or isolated communties without central water supplies [Horowitz et al., 1979].

We can summarize the estimated cost-effectiveness of three methods of administering systemic fluoride: community water fluoridation, school-based administration of fluoride tablets and school fluoridation, in the table 18 below.

Table 18: Estimated cost-effectiveness of systemic fluoride procedures.

Source: Horowitz et al., 1979 page 113

Estimated cost-effectiveness of systemic fluoride procedures

Method	Percentage caries reduction*	DMFS saved per person per year†	Cost ($) per person per year	Cost ($) per surface saved
Community fluoridation 0·7–1·2 ppm F	50	1·0	0·20	0·20
1 mg F tablet daily in school	35	0·7	0·40	0·60
School fluoridation 4·5 × optimum	40	0·8	1·50	1·90

* Estimate represents maximum benefits attained when program has been operating for at least 12 years.

† Assuming normal increment of 2 DMFS/person/year in a non-fluoride area.

Cost-effectiveness of topical fluoride procedures, a comparison of the cost-effectiveness of various topically applied fluorides was conducted by Heifetz (1978) which he presented in a paper at a workshop at the University of Michigan [Horowitz et al., 1979].

His calculations were based on a hypothetical population of 8000 school children, he assumed children lived in an area with insignificant amounts of fluoride in the drinking water and experienced an average incidence of 2 DMF surfaces per year. The results of the analysis are show in table 19 below.

Table 19: Estimated cost-effectiveness of topical fluoride procedures.

Source: Horowitz et al., 1979 page 113

Estimated cost-effectiveness of topical fluoride procedures

Method	Percentage caries reduction	DMFS saved per person per year*	Cost ($) per person per year	Cost ($) per surface saved
Weekly mouth rinsing 0·2% NaF solution	25	0·5	0·50	1·00
Semiannual 'brush-in' 9% SnF_2 Zircate paste	25	0·5	1·23	2·50
One series of 2·0% NaF solution multiple-chair method	40	0·8	2·06	2·60
Annual APF gel (1·23% F) in preformed trays	40	0·8	3·60	4·40
Toothbrushing 5 × yr APF sol. (0·6%F)	20	0·4	2·23	5·60
Toothbrushing at home 0·1% fluoride dentifrice	20	0·4	4·00	10·00
Annual 8·0% SnF_2 solution in F area	20	0·2+	4·20	21·00
Daily APF gel (0·5% F) in custom trays	80	1·6	34·08	21·30

* Assuming normal increment of 2 DMFS/person/year in non-fluoride area.
Assuming normal increment of 1 DMFS/person/year in fluoride area.

The table shows costs per surface saved that range from $ 1.00 per weekly mouth rinsing with a 0.2 per cent NaF solution to $ 21.30 for daily self-application of a fluoride gel [Horowitz et al., 1979].

Programs of profesionally applied topical fluorides are usually most suitable in communities with an abundance of professional personnel and an extensive program of dental services in schools [Horowitz et al., 1979].

Methods of self-application of fluoride are generally most suitable where professional personnel are limited in numbers [Horowitz et al., 1979].

In summary, it may be impossible to conduct completelty accurate and valid analyses of cost-effectiveness, such exercises are often frustrating. However, if done carefully, these exercises can help us to set aside preconceived judgements on the value of certain regimens, to view our activities objectively as they affect target populations and to discover the real issues that should affect our decision making judgement in the future [Horowitz et al., 1979].

5 DISCUSSION

5.1 Introduction

The prevention and control of dental caries has been the major objective of dental public health over the past 20 years.

From studies and clinical trials, conducted during the 1940s in the United States, of fluoride added to the public water supply, it was found that fluorides could successfully be used to increase tooth resistance to acid attacks, fluorides could also be used to disrupt oral microflora thus reducing plaque formation and fluorides could arrest carious lesions which may have already been present.

Water fluoridation has gained wide acceptance, since then, as a means of combating root caries and has thus been adopted in many countries throughout the world and today the list is increasing.

5.2 Sources of fluoride delivery

Fluorides are naturally occurring in the environment, in things such as water, food and air. However, the amounts are often insufficient or may vary from region to region to be of any great benefit.

Therefore, fluoride has been added to the community water supply, in concentrations of 1.0 ppm, this being the figure generally recognised as having optimal effect on on root caries lesions, with the range lying somewhere between 0.7 ppm and 1.2 ppm. This figure is adjusted according to pre-existing fluoride levels found in the water supply.

Fluoridation of water supply, 'systemic', will guarantee that everyone in the community gains the benefits with minimal cost and effort to the individual. Systemic fluorides are very essential during the tooth development stage of children, primary dentition. So that by the time they develop their permanent teeth they have greater tooth resistance to caries with very few or no lesions evident.

The net result being healthier teeth in adult life with fewer dental problems and thus retaining their natural dentition into old age.

However, systemic fluoridation is not always practical, particularly in small rural or isolated communities, where there may not be a community water supply, so other means of introducing fluoride to the oral environment are necessary.

Some of the other methods of supplying fluoride to the oral environment include dietary fluorides and fluoride supplements such as tablets and drops, which can be administered either at home or school.

Dietary fluoride intake, such as in fluoridated salt or milk have been shown to reduce the rate of caries incidence, however, these face many problems in that not everyone in the community consumes these at the approximately same rate as they do with water.

The other source is fluoride supplements, given in the form of tablets and drops, either at home or school. These have been shown to have a systemic effect equalling that of water but as an added bonus they also tend to have a topical effect as they pass through the mouth being dissolved into the saliva which bathes the teeth.

While systemic fluoridation benefits the young much more than the adults, its effect will be lost if ingestion of fluoride ceases after permanent dentition is achieved. So the use of fluorides must continue and it has been shown that continuing to ingest fluoride systemically has little effect on caries once permanent dentition has been achieved, therefore, another source of introducing fluoride to the oral environment is required.

Topical fluorides have been suggested for application to maintain the ongoing benefits, topical fluoride preparations are numerous and can be divided into two main categories, those which are professionally applied by a dentist or dental auxiliary in a clinic, those which are self-applied at home or school.

In the professionally applied category we have the following topical fluoride preparations:

Fluoride solutions, such as sodium fluoride, stannous fluoride and acidulated phosphate which can be applied either by directly brushing onto tooth surface or using as a mouthrinse.

However, solutions when applied to each individual tooth surface with a brush have been found to be time consuming and thus costly to apply, making them less attractive than other methods. When used as mouthrinses they start to become more economical to apply as they can be applied by the patient, under professional supervision.

The major problem with solutions is that they remain on the tooth surface for a relatively short time, perhaps insufficient to allow the fluoride to be absorbed into the tissue. This has led to the development of fluoride gels, these are basically the same in formulation as solutions with the exception that they contain a gelling agent.

The benefit of gels being that they remain on the tooth surface much longer and can be applied much quicker using mouth trays.

Fluoride prophylaxis pastes, these are declining in popularity because of the reduction in the prevalence of dental caries and the amount of time and cost required for applying the prophylaxis in a dental clinic by a dentist makes it uneconomical. The tendency is towards using other fluoride agents which require less time and effort to apply and which are equally effective in the treatment of caries.

Fluoride varnishes, studies have shown that fluoride varnishes can give protection against caries with figures quoted as much as 70 per cent effectiveness. However, further trials may be required to determine the best method and frequency of application, and also to determine the duration of their cariostatic action.

A two year study conducted by Koch, Petersson, Ryden (1979) showed that the application of a fluoride varnish on a bi-annual basis was very effective, when compared to mouthrinsing on a weekly basis with a fluoride solution.

However studies conducted by Bruun, Bille, Hausen et al., (1985) and Kirkgaard, Petersen, Poulsen et al., (1986) found no significant difference in the effectiveness of fluoride varnishes when compared to rinsing with a 2 per cent sodium fluoride solution on a fortnightly basis.

So in view of results being mixed further long term clinical trials of fluoride varnishes are needed.

Fluoride mouthrinses

These have gained wide acceptance because they are easy to apply and less time consuming as they can be applied by the patient in a dental clinic under the supervision of dental personnel, they include neutral sodium fluoride, which was one of the early fluoride mouthrinses.

Birkeland, Broch, Jorksend (1977), in a 9 year study reported a 50 per cent caries reduction in school children ranging in ages 6 to 14 years, rinsing with a 0.2 per cent NaF solution on a fortnightly basis.

APF solutions have been shown to be just as effective as NaF by Aasenden (1972) and Heifetz (1973). However, this solution is not tolerated well by children because of its astringent taste. Caries reduction has been reported as much as 40 per cent in permanent teeth.

Stannous fluoride mouth rinses are as effective as NaF in caries reduction, however they are not tolerated well by young children because of their staining and astringent taste.

Controlled release devices are being seriously considered as a source of fluoride delivery to the oral environment because they can overcome the problem of quick release of fluoride to the oral environment as many other methods of fluoride delivery normally do, with the fluoride release lasting from several hours to several days.

With Controlled release devices fluoride can be slowly made available to teeth for as much as 35 days giving the tooth adequate time to absorb fluoride. The release rate being controlled by the thickness of the device membrane.

However, further work will be required with these devices as they have been known to cause irritation and presently are only used in special cases such as handicapped persons who are susceptible to rampant caries.

Sealants are most effective on occlusal surfaces of posterior teeth. They can be used to seal pits and fissures in areas that are difficult to clean, resulting in plaque accumulation and finally caries. They can be polymerised by ultra-violet light and some of the more recent ones by normal light.

They have shown caries reduction rates as much as 99 per cent as reported by Horowitz et al (1975) with a retention rate as high as 92 per cent.

Restorations are used to arrest further progression of caries lesions, when diseased tissue has been removed the cavity is filled with a restorative material, such as silver amalgam, sealing the cavity thus preventing further progression of the lesion. The material has a tendency to corrode thus sealing the microspace between the cavity wall and the restorative material preventing leakage of bacteria into the cavity.

Having looked at professionally applied topical fluorides, as sources of fluoride delivery we must now look at those that have been developed for self-application.

The high cost of applying topical fluorides at a dental clinic has resulted in the development and marketing of topical fluoride preparations intended for use at home by the patient.

These generally are much lower in fluoride concentration and require no supervision. They can be applied frequently on a daily basis and include dentifrices which can be applied by brushing. Dentifrices can contain any of the compounds NaF, SnF_2, APF, MPF in varying concentrations.

They also include mouthrinses, gels and prophylaxis pastes.

5.3 De- and re-mineralisation

When the tissue making up the root, dentine and cementum, are exposed to the oral environment, it faces dissolution by constant acid attack, resulting in de-mineralisation. The apatite structures thus become unstable causing gradual crumbling of the tissue. However, using fluorides we can prevent or at least reduce de-mineralisation and in turn promote re-mineralisation.

Cementum and dentine more readily take up fluoride than other tissues such as enamel. This is because of their larger surface areas and their tubular structures the calcium (Ca^{++}) ions react with fluoride forming a CaF which is found on the surface of cementum and dentine.

The cariostatic effect of CaF seems to be that it acts as a significant reservoir of fluoride ions which are directly deposited in areas of de-mineralisation thus reducing the loss of mineral by promoting re-precipitation of stable apatite structures (Ogaard et al., 1984).

So exposing root tissue to fluoride will result in a calcium fluoride layer being formed which makes the tissue more resistant to acid attack thus preventing dissolution of underlying dentinal tissue.

Use of topical fluoride enhances re-mineralisation of early caries lesions [Ogaard et al., 1984].

5.4 Pre- and post-eruptive ingested fluoride effects

Ingested fluoride is dissolved through the stomach and small intestine into the bloodstream. The fluoride is absorbed as the ion (F^-) and provided it is ingested in solution or easily soluble form, absorption will be rapid and complete.

The absorbed fluoride is transported through the body via the circulatory system and will be present in the extracellular fluid that bathes the mouth, and if fluoride is also ingested through the ingestion of supplements, it will be found in the saliva as well.

The presence of fluorides during the pre-eruption or primary tooth formation is essential because during the mineralisation phase of the tooth the fluoride becomes incorporated into the apatite crystals of the tooth making it more resistant acid attacks which will eventually will lead to caries.

The presence of fluorides during the pre-eruption or primary tooth formation is essential because during the mineralisation phase of the tooth the fluoride becomes incorporated into the apatite crystals of the tooth making it more resistant acid attacks which will eventually will lead to caries.

However, when the tooth has erupted and permanent teeth have formed the systemic effect of fluorides is of borderline significance relative to the post-eruptive effects. A substantial caries inhibition is obtained by post-eruptive administration of fluoride.

Since systemically applied fluorides are no longer as effective as when they were used for pre-erupted teeth we can use topical fluorides which have been shown to have the effect of maintaining the protection given to the tooth during the pre-eruptive stage by systemic fluorides by making the tooth more acid resistant, disrupting plaque formation and arresting early caries lesions.

5.5 Cariostatic efficacy of the combined use of fluorides

Dentists and dental auxiliaries have been prescribing as part of a preventive package the intake of systemic fluorides and topical fluorides in various forms.

Combining different fluoride regimens will ensure that maximum cariostatic efficacy is achieved. Particularly in communities who have suboptimal levels of fluoride in their water supply or don't have a fluoridated community water supply at all because of regional isolation.

For example, the use of fluoride tablets to achieve an optimal daily systemic intake may well be prescribed in association with topical fluoride applications of a professionally applied fluoride solution or gel, regular rinsing at home with a solution and use of a fluoride-containing dentifrice.

A very important basic question relates to the value of topical fluoride procedures in areas where the drinking water supplies contain fluoride at the optimal level. Studies conducted by Radike et al (1973) investigated the efficacy of moutrinsing with a 0.1 per cent SnF_2 solution on residents of a community which had water fluoridation with 1 ppm fluoride.

The study demonstrated that rinsing with the SnF_2 solution provided a small but significant added protection over and above that provided by the fluoridated drinking water.

Heifetz et al (1979) carried out studies to assess the combined effect of APF gel applied 3 times a year plus a weekly rinsing program with 0.2 per cent NaF fluoride solution as well as intaking fluoridated water.

From the studies it was concluded that topical fluoride applications will further enhance the caries inhibition provided by fluoridated drinking water.

The combined use of systemically administered fluoride in the form of an acidulated 1mg fluoride tablet, taken daily with a weekly rinse with 0.2 per cent NaF fluoride solution was evaluated by Horowitz et al, (1979). After 4 years there was a 35 per cent overall reduction in DMFS.

From this group of studies we can conclude that fluorides administered topically do indeed enhance the effect of systemically administered fluorides. However, there is no clear evidence that combining multi-regimens of topical fluorides agents alone provide any significant added benefit.

5.6 Clinical aspects of fluoride in caries prevention

Fluoride has been found to be the best chemical agent which can be used to control and prevent dental caries.

From studies conducted over the past 40 years it has been determined that there are several times during the development of a tooth when it is beneficial if it is exposed to fluoride.

These critical times are during formation of primary teeth until eruption has been achieved. Consumption of fluoride, systemically, in water, food or as supplements tends to give the best protection resulting in the development of a healthy, caries free tooth. However, upon eruption of primary teeth, the use of fluorides must be continued if benefits are to continue.

If fluoride consumption ceases then so does the protection and caries will soon start to develop. However, according to Thylstrup (1993) the continued use of systemic fluorides after tooth eruption does very little, so topical fluorides have been recommended for use, as they have been shown to give maximum protection against caries.

So the cariostatic efficacy of fluoride does persist beyond eruption, however the protection will not be indefinite and continued use of fluorides must persist.

Root caries has become an increasing problem in the adult population. From studies that have been conducted on the effects of fluoride on root caries, fluorides have been shown to be just as effective on root caries as it is on enamel caries. Various studies on the effects of systemic fluorides on root caries have shown that long-term consumption of fluoridated water has an inhibitory effect on root caries. Studies conducted by Banting and Stamm (1978) investigated the relationship between fluoridated water and root caries.

They compared their findings to those of other researchers (Hazen et al., 1972; Sumney et al., 1973) and concluded that a lifelong consumption of fluoridated water does indeed have an inhibitory effect on the occurrence of root caries.

Lifelong consumption of fluoridated water will ensure that there is a continuous supply of fluoride in the tissue surrounding the root, thus fluoride from this surrounding tissue is incorporated into the cementum which is being deposited throughout life. This fluoride serves to strengthen the cementum, making it more resistant to caries attack.

Systemic fluorides have been deemed to be effective in preventing root caries in susceptible patients rather than reducing root caries which are already present.

In order to reduce the number of caries already present we need to look at topical fluorides. Various studies have been conducted in order to determine the re-mineralisation and solubility effects of topical fluorides in root caries. Studies conducted by Johansen et al (1987) using self-administered topical fluoride gel, showed that the rate of new carious lesions decreased significantly and a high percentage of active root lesions were re-mineralised and were arrested.

Thus, the use of fluorides on roots will decrease the solubility of the root surface because we have a this layer of calcium fluoride and fluoridated hydroxyapatite which strengthen the root surface.

The effect of monofluorophosphate (MFP) dentifrices on root dentine have also been investigated by researches such as Sanchez and Mellberg (1988). They reported a significant mineral deposition on the surface and the deepest parts of the lesions, this is because dentine more readily uptakes fluoride than other dental tissues.

5.7 Cost benefit and cost-effectiveness

Dental public health programs are publicly funded, so before decisions are made on how public money should be spent and on which programs, certain analytical techniques need to be adopted which will help the decision making process ad ensure that the program selected will give maximum benefit with the least cost.

By carrying out an analysis we ensure that money is not wasted in replication of studies previously conducted by others and we only select those programs which will be most economical. Cost benefit analysis is a formal and systemic way to choose amongst alternative investment in programs.

The cost and benefit are measured in monetary values, however, intangible benefits must be discounted as they are too difficult to assign a monetary value to.
Cost effectiveness analysis, however, deals with the problems of having to assign monetary values to indirect or intangible benefits. The benefits are thus measured in physical terms instead.

6 CONCLUSION

This literary review on the use of fluorides for the prevention and control of dental caries of cementum and dentine has shown without a doubt that fluorides, both systemic and topical are effective in the prevention and control of dental caries in the dentine and cementum of the root.

The main mechanism by which systemic and topical fluorides act to inhibit caries is by its action on plaque, cementum and dentine.

In plaque, fluoride acts to disrupt bacterial metabolism, glycolysis and acid production. We have also found that plaque fluorides will act as a reservoir of fluoride ions which may be available for re-mineralization of early caries lesions.

Fluoride has also been found to act on dentine and cementum of the root by forming calcium fluoride which too acts as a reservoir of fluoride ions, it reacts with hydroxyapatite crystals to form fluoroaptite and thus resulting in a more stable crystal matrix.

There are many different types of systemic fluoride delivery, such as milk, salt, juices and water. The method which has been deemed to be best in terms of economics, ease of introduction and guarantee of success is water fluoridation and most important of all is that it requires very little community effort.

When looking more closely at the variuos methods of fluoride delivery, systemic fluorides, studies indicate that people who consume fluoridated water throughout their life generally show a reduction in root caries.

However, for the program to be successful, fluoridated water consumption must be commenced at an early age to be of most benefit and benefits will tend to become of marginal significance when post-eruption has been achieved.

Dietary fluoride supplementation, such as milk or salt have been trialled and found to be a good source of systemic fluoride delivery, however, these are far too dependend of peoples dietary habits or preferences.

Fluoride supplements is also another method of introducing fluorides systemically, in the form of drops or tablets. These have been very effective in communities residing in sub-optimal fluoride areas.

Topical fluoride applications will supplement fluoride intake and is particularly recommended for adults, mainly because they may not have had the early childhood benefits of water fluoridation, and it is also recommended for people living in areas with low levels of fluoride in their drinking water.

There are a large number of topical fluoride preparations, both self-administered,such as toothpastes, mouthrinses and professionally administered, gels, pastes, sealants, all containing varying concentrations of fluoride.

Topical fluorides give a post-eruptive benefit both in fluoridated and sub-optimally fluoridated communities. The overall effect being a caries resistant tooth surface and root.

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