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BENEFITS OF FLUORIDATION ALTERNATIVES

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**A THESIS SUBMITTED IN PARTIAL REQUIREMENT FOR THE
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A handwritten signature in cursive script, appearing to read "Yin Shen Chiu Hou", written in dark ink.

SUMMARY

Fluoride has made a phenomenal contribution to dentistry for more than forty years and is undoubtedly the best weapon against dental caries. It has been shown that community water fluoridation is the most effective single method of preventing dental caries on a mass scale.

The lack of community water fluoridation is probably one of the reasons that contributes to the high prevalence of dental caries in Taiwan, the writer's country. Due to the fact that water fluoridation will not be implemented in the near future in Taiwan, the writer has reviewed some of the possible and practical alternatives to see if they could be applied in Taiwan.

The mechanisms by which fluorides, both systemic and topical act to inhibit dental caries is by its action on the plaque, saliva as well as tooth itself. The fluoride ions in plaque act mainly by affecting bacterial growth, glycolysis, glycogen synthesis and acid production. Plaque fluorides may also act as a reservoir of fluoride ions available for the remineralization of the early carious lesion. The mode of action of saliva fluoride is believed to be similar to that of dental plaque. Fluorides act directly on the tooth by enhancing remineralization and decreasing the solubility of tooth structure as well as by preventing the colonization of bacteria on the tooth surface.

Due consideration must at all times be given to the risks of the ingestion of excessive fluoride. Studies have shown that the total daily fluoride intake should not exceed 0.1mg/kg body weight as there

is evidence that fluoride intake above this level could lead to the occurrence of dental fluorosis.

School water fluoridation has produced a maximum 40% caries reduction without objectionable dental fluorosis at fluoride concentration of 4.5 times the optimum level recommended for community fluoridation.

Home use fluoride tablets or drops taken from birth can reduce caries by 50-80%. There has been a decline in the home use of fluoride tablets due to the problems of compliance.

However, the problems of compliance associated with home use of fluoride tablets can be largely overcome by using supervised fluoride tablets programmes in schools. The effectiveness and feasibility of supervised school-based fluoride tablets programmes have been demonstrated in several studies. Percentage reductions in caries have ranged from about 20-36% after two or more years of fluoride ingestion. Wei and Campbell (1978) have reported a reduction of 81% after three years' trial.

Fluoridated salt has produced a 39% caries reduction in deft after eight years of introducing 250ppm fluoride into cooking and table salt.

Fluoridated milk has been used for many years in Switzerland, where it has been reported that milk fluoridated at 1ppm reduces dental caries up to 30%. Fluoridated milk could be useful in a school-based programme in which an optimal daily dosage is provided at one time and

the problem of compliance can also be overcome. However, the costs of fluoridated milk for distribution in school are likely to be much greater than corresponding costs for a school-based fluoride tablets programme.

Mouthrinsing with fluoride solution is a feasible and effective method for the prevention of dental caries in schoolchildren. The findings of more than 30 studies in different countries indicate that the incidence of dental caries can be reduced by about 35% when the procedure is used daily, weekly or fortnightly. Because there is no evidence of a notably greater effectiveness from the daily procedure and because daily rinsing makes greater demands on participants and supervisory personnel, a weekly programme of mouthrinsing with 0.2% sodium fluoride is recommended as the preferred school-based procedure.

In children, a caries reduction of 20-30% after three years' regular use of fluoride toothpaste has been reported. Toothpaste containing 0.76% sodium monofluorophosphate, 0.4% stannous fluoride, or 0.25% sodium fluoride have been used. After reviewing the literature on the use, effectiveness, safety, cost benefit and cost effectiveness of the alternatives to water fluoridation, the writer has recommended the following programmes that could be applied in Taiwan.

- (1) School water fluoridation at fluoride concentration 4.5 times the optimum recommended for community water fluoridation.
- (2) Supervised school-based fluoride tablets programmes using 2.2mg NaF tablets daily (6 days/week).
- (3) Supervised weekly 0.2% NaF mouthrinsing programme in schools. For individuals, the writer strongly recommends the use of fluoride toothpaste as a routine part of self care.

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1 INTRODUCTION

1.1 GENERAL BACKGROUND OF FLUORIDE IN DENTISTRY

Fluorine is the most electronegative of all chemical elements and is therefore always combined chemically in the form of fluoride. There is an abundance of fluoride in soil, air, water and food. Fluoride is absorbed into the body mainly from the stomach and excreted in the urine.

Fluoride has not only notable chemical qualities but also physiological properties of great interest and importance to human health. Research into the biology of fluoride has been very extensive during the last few decades, especially after it was demonstrated in the 1930s. The discovery of the relationship of mottled enamel, dental caries and fluoride was one of the starting points of research into fluoride and can be ranked as one of the classic epidemiological studies of chronic disease in the history of medicine.

Fluoride illustrates strikingly the classical medical concept that the effect of a substance depends on the dose. Fluoride has been found to be beneficial in the prevention of dental caries in small quantities, but long time exposure to higher quantities may have deleterious effect on teeth, and single, gram doses cause acute toxic effect or may even be lethal.

The precise way in which fluoride inhibits dental caries is not finely understood. However, there is sufficient evidence to suggest that fluoride acts in several ways both before and after tooth eruption. If fluoride is present in an optimum concentration during tooth

development it results in the formation of enamel with improved crystallinity which is more resistant to acid attack. On the other hand, fluoride is also effective when applied topically to enamel after eruption.

More recent research clearly shows that other actions of fluoride, such as remineralization of initial or pre-carious lesions and antimicrobial effects, are also important.

1.2 FLUORIDE AND DENTAL CARIES

Dental caries is a chronic disease. Three conditions must be present for dental caries to occur:

- 1) There must be a susceptible host. Any tooth will develop caries if challenged sufficiently, all persons with teeth must be considered susceptible.
- 2) Acid-producing bacteria must be present in plaque.
- 3) There must be a diet suitable for bacterial fermentation.

In correspondence with these conditions, our efforts to prevent dental caries have focused upon attempts to:

- 1) increase the resistance of teeth with various fluorides
- 2) lower the number of bacteria in contact with the teeth by mechanical means or reduce their cariogenic activity with chemical agents, and
- 3) modify dietary practices by urging people to eat cariogenic foods less frequently.

Today, the most feasible way to prevent dental caries is to increase the resistance of teeth to decay, and the most practical way to accomplish this goal is by the proper use of fluorides. Fluorides have been and continue to be the best weapon to defend our teeth against dental caries.

Fluoridation of community water supplies is the least expensive and most effective way to provide fluoride to large groups of people. It has been proven that fluoride at 1ppm level produces the greatest protection against dental caries with the least risk of fluorosis.

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

However, due to political, economic, geographical or technical reasons, there is still a large proportion of the world's population does not have access to community water fluoridation. Therefore, it is important to learn more of the effects of various types of fluoridation alternatives with the possibility of extending benefits to non-fluoridated areas. Several methods have been suggested as the alternatives to water fluoridation, such as school water fluoridation, fluoride tablets, fluoridated salt, fluoridated milk, professional or self-applied topical fluorides.

School water fluoridation has produced maximum 40% caries reduction at fluoride concentration of 4.5 times the optimum level recommended for community water fluoridation.

Fluoride tablets or drops taken from birth can reduce caries by 50-80%. School-based studies have reported 36% caries reduction after eight years of tablet use. This figure is further improved if the child slowly dissolves the tablet in the mouth before swallowing it. Fluoride tablets and drops as systemic supplements should not be prescribed when the water contains over 0.7ppm fluoride.

Fluoridated salt was first suggested in 1946 as an alternative to water fluoridation and since then it has been reported that fluoridated salt

produces 39% caries reduction in deft after eight years of introducing 250ppm fluoride into cooking and table salt.

Fluoridated milk has been used for many years in Switzerland, and at present received reasonable impetus in Great Britain with the establishment of the Borrow Dental Milk Foundation. It has been reported that milk fluoridated at 1ppm reduces dental caries up to 30%.

Topical fluoride products can be divided into two broad categories: professional and self-applied products. Professionally applied fluoride products are those medicaments typically dispensed by dental professionals in the dental office setting and usually involve the use of high-F-concentration products - that is, from 5000 to 19000ppmF per ml of product. Self-applied F products are usually bought and dispensed by patients but at the recommendation of dental personnel. These products include fluoride toothpaste and mouthrinses and typically are low-F-concentration products in the range of from 200 to 1000ppm or 0.2 to 1.0mgF per ml of product.

A daily mouthrinse with 0.05% solution of sodium fluoride reduces the incidence of caries by 30-40%. Fluoride compounds other than sodium fluoride, such as stannous fluoride, acidulated phosphate fluoride (APF) and amine fluoride, are effective but cost more and taste worse.

In children, a caries reduction of 20-30% after three years' regular use of fluoride toothpaste has been reported. Toothpastes containing 0.76% sodium monofluorophosphate, 0.4% stannous fluoride, or 0.25%

sodium fluoride have been used. Concentrations are designed to provide 1000ppm fluoride.

Topical fluoride application by dentists or hygienists as either a solution, gel or varnish has long been used in caries prevention. It has been shown that professionally applied topical fluoride containing 2.0% sodium fluoride, 8% or 10% stannous fluoride and 1.23% acidulated phosphate fluoride can reduce the incidence of dental caries by 30-40%.

1.3 AIM OF THESIS

An increasing caries prevalence, together with the low level of dental care, make it extremely important to establish caries preventive programmes in Taiwan, the writer's country.

Water fluoridation commenced on an experimental basis in Taiwan in 1972. In the fluoridated village of Chung-Hsing, caries prevalence in five-year-olds changed from 6.5 dft in 1971 to 6.3 dft in 1978 after six years' fluoridation at 0.6ppmF. Because the results did not show a great decrease in the dft score, the antifluoridationists used this result coupled with antifluoridation propaganda, and hence water fluoridation on a large scale was not implemented in Taiwan. The question of personal freedom of choice is another reason for water fluoridation not being accepted by the general public in Taiwan.

However, the caries experience of five-year-olds in the control, non-fluoridated village of Tsao-Tun increased from 6.4 dft in 1971 to 8.5 dft in 1978. The increase is probably due to the rise in sugar consumption, a result of increasing economic prosperity.

Knowing the merit of fluorides, especially water fluoridation and taking into consideration that water fluoridation will not be implemented universally in Taiwan in the near future, the writer wishes to review some of the possible and practical alternatives to water fluoridation.

Special attention will be given to their use, effectiveness, safety, cost benefit and their cost-effectiveness.

After reviewing the literature, recommendations will be made by the writer for the most appropriate alternatives for application in Taiwan.

2 BACKGROUND OF FLUORIDATION ALTERNATIVES

It has been noted that a significant caries reduction will be achieved for life-long residents in areas where fluoride content of water supply has been adjusted to approximately 1ppm and that this is the most cost-effective means available for attaining substantial caries reduction on a community basis.

However, there exist political, economical, geographical and other reasons which make this benefit unavailable to a large proportion of the world's population.

Alternatives to water fluoridation have been suggested, eg school water fluoridation, fluoride tablets or drops, fluoridated salt, fluoridated milk and the use of fluoridated mouthrinses and toothpastes.

2.1 SCHOOL WATER FLUORIDATION

Children who live in areas without public water supplies cannot benefit from optimally fluoridated drinking water. One effective way to bring them these benefits is to fluoridate their school water supplies. Higher than optimal fluoride concentrations for community fluoridation were suggested for school fluoridation to compensate for the part-time and belated exposure.

At fluoride concentrations of 4.5 times the optimum recommended for community fluoridation, school water fluoridation has produced significant caries reductions without dental fluorosis (Horowitz et al 1972). To date it seems that school water fluoridation has mainly been implemented in the United States.

Interim data from two long-term studies provide information on the optimal concentration of fluoride for school fluoridation. In one study, 4.5 times the optimum concentration of fluoride was used (Horowitz et al 1968) and in the other, seven times the optimum (Heifetz et al 1978). In both studies, caries reduction of 35-40% were found after eight years. Because only a small additional benefit has been obtained to date by fluoridating at the higher level, the recommended level for school fluoridation remains at 4.5 times the optimum for community fluoridation.

It has been estimated that as of March 1983, 500 schools with 200,000 children were utilizing school-water fluoridation system (Heifetz et al 1983). A few schools in Brazil and Thailand also practise school fluoridation (FDI & WHO Joint Working Group 1985).

2.2 FLUORIDE TABLETS OR DROPS

In communities with insufficient fluoride in drinking water, fluoride tablets or drops are recommended for children for the prevention of dental caries.

Fluoride tablets or drops can be given daily at home and were started before school age or given at school, on school days only, usually without additional supplementation during holidays. The effectiveness of the use of fluoride tablets at home is very much harder to investigate because it is difficult to choose a comparable control group and there is frequently a marked fall-off cooperation; these difficulties do not usually arise in school-based trials.

A variety of fluoride tablets and drops are commercially available (Table 1 and Table 2). Fluoride drops are preferred for infants, young children and individuals who have problems handling tablets. Fluoride drops are available without vitamins in the following doses: 0.125mgF/drop, 0.25mgF/drop and 0.5mgF/ml; whereas drops with vitamins are available in the following doses: 0.25mgF/ml, 0.5mgF/0.6ml and 0.5mgF/ml. Fluoride tablets for older children are available without vitamins in the following doses: 0.25mgF, 0.5mgF or 1mgF. The 1mgF tablet can be obtained as neutral sodium fluoride (NaF) or as acidulated phosphate fluoride (APF). Tablets with vitamins are only available in 0.5mgF or 1mgF doses.

Multiple clinical trials have shown that fluoride tablets used postnatally can provide an alternate method of reducing caries to

TABLE 1: Fluoride available in tablet form with or without vitamins.

SOURCE: Wei 1985. p 60

Form	Dose	Brand Name	Company	Quantity
Tablet	*0.25 mg F (0.55 mg NaF)	Luride 0.25 Lozi-Tabs ^{0*}	Hoyt	120
	0.5 mg F (1.1 mg NaF)	Luride 0.5 Lozi-Tabs ^{0*}	Hoyt	120/1200
	1 mg F (2.2 mg NaF)	Fluorineed	Hanlon	100/1000
		Fluoritab [*]	Fluoritab	100
		Flura ^{†*}	Kirkman	100
		Flura-Loz ^{†*}	Kirkman	100
		Karidium [*]	Lorvic	180/1000
		Luride Lozi-Tabs ^{0*}	Hoyt	120/1000
		Luride-SF Lozi-Tabs ^{0*†}	Hoyt	120
		Phos-Flur [*]	Hoyt	120/500
Tablets with Vitamins	0.5 mg F (1.1 mg NaF)	Adeflor Chewable 0.5 mg	Upjohn	100/500
		Caritab Softab	Stuart	100
		Poly-Vi-Flor Chewable 0.5	Mead Johnson	100
	1 mg F (2.2 mg NaF)	Adeflor Chewable 1 mg	Upjohn	100/500
		Dentavite Chewable	Reid-Provident	100
		Florvite	Everett	100/1000
		Flura-Vite with Fluoride	Kirkman	100
		Mulvidren-F Softab	Stuart	100
		Poly-Vi-Flor Chewable	Mead Johnson	100/1000
		Poly-Vi-Flor with Iron	Mead Johnson	100/1000
		Tri-Vi-Flor	Mead Johnson	100/1000
		Vi-Daylin Chewable.	Ross	100
		Vi-Penta F Chewable	Roche	100
		Vita-Flor	Rugby	100/1000
		Vi-Daylin/F & Iron Chewable	Ross	100

*Ionic fluoride dose is given first. Dosage of fluoride compound appears in parens.

⁰ - Sugar and saccharin-free[†] - Dye-free^{*} - ADA approved

Based on information from:

- (1) Facts and Comparisons
- (2) Physicians Desk Reference
- (3) Accepted Dental Therapeutics

TABLE 2: Fluoride supplements available in liquid form with or without vitamins

SOURCE: Wei 1985. p 59

Form	Dose	Brand Name	Company	Quantity
Drops	*0.125 mg F/Drop (.275 mg NaF/Drop)	Karidium* Luride*	Lorvic Hoyt	30/60 ml 30 ml
	0.25 mg F/Drop (0.55 mg NaF/Drop)	Fluoritab Flura Drops* Pediaflor	Fluoritab Kirkman Ross	19 ml 24 ml 50 ml
	0.5 mg F/ml (1.1 mg NaF/ml)	Pediaflor	Ross	50 ml
	0.25 mg F/ml (0.55 mg NaF/ml)	Abdec with Fluoride Baby Vitamin Poly-Vit Fluoride Poly-Vi-Flor 0.25 mg. Tri-Vi-Flor 0.25 mg. Tri-Vi-Flor 0.25 with Iron Vi-Daylin F ⁰ Vi-Daylin F ⁺ Iron Vi-Daylin/F ADC Vi-Daylin/F ADC + Iron	Parke-Davis Rugby Mead Johnson Mead Johnson Mead Johnson Ross Ross Ross Ross	50 ml 50 ml 50 ml 50 ml 50 ml 50 ml 50 ml 50 ml
Drops with Vitamins	0.5 mg F/0.6 ml (1.1 mg NaF/0.6 ml)	Adeflor Vi-Penta F Infant Vi-Penta F Multivitamin	Upjohn Roche Roche	30 ml/150 ml 30 ml 30 ml
	0.5 mg/ml (1.1 mg NaF/ml)	Dentavite Florvite Pediatric Florvite + Iron Pediatric Ped-Vite with Fluoride Polysorbin F Poly-Vi-Flor 0.5 mg Poly-Vi-Flor with Iron Polyvite with Fluoride Tri-Bay-Flor Trisorbin F Tri-Vi-Flor 0.5 mg	Reid-Provident Everett Labs Everett Labs Three P Reid-Provident Mead Johnson Mead Johnson Geneva Generics Bay Reid-Provident Mead Johnson	50 ml 50 ml 50 ml 50 ml 50 ml 30 ml/50 ml 50 ml 50 ml 50 ml 50 ml 30 ml/50 ml
	0.2% F 1 mg F/5 ml APF	Phos-Flur* NaF Rinse Acidulated Oral Rinse and Systemic*	Hoyt Orachem Pharm.	250/500 ml 500 ml

*Ionic fluoride dose is given first. Dosage of fluoride compound appears in parens.

⁰ - Sugar and saccharin-free

⁺ - Dye-free

* - ADA approved

Based on information from:

- (1) Facts and Comparisons
- (2) Physicians Desk Reference
- (3) Accepted Dental Therapeutics

children living in suboptimally fluoridated areas (Driscoll 1974). Glenn et al (1984) reported that fluoride tablets used prenatally have also been suggested as a means of providing the earliest possible caries-preventive benefit.

Nearly 60 studies have been published on the caries-preventive effect of fluoride tablets and drops reporting caries reduction of 50-80% for deciduous teeth, 39-80% for permanent teeth. Such a range should be expected, as there are great variations in population characteristics, caries prevalence, diagnostic criteria, type of fluoride preparation and dosage and also in initial age, duration and mode of tablet consumption.

Driscoll et al (1981) reported that the caries preventive effects on permanent teeth appeared to be lost following cessation of fluoride tablet supplementation.

2.3 SALT FLUORIDATION

Salt fluoridation as an alternative to water fluoridation was suggested more than 30 years ago, and the successful use of salt enriched with iodine to prevent goitre has led to studies in several countries using fluoridated salt for the prevention of caries.

Sodium fluoride was first added to salt in Switzerland in 1946. By 1967 three-quarters of domestic salt sold in Switzerland was fluoridated at 90mg of F per kg salt.

Several studies concerning the concentration of fluoride have been carried out in Switzerland, Columbia and Hungary. It was found that 90mg of F per kg of salt only produced limited caries preventive effect.

Marthaler et al (1978) concluded that the caries preventive effectiveness of 250mg of F per kg salt used in the Swiss canton of Vaud was greater than the reduction of approximately 25% observed following the addition of 90mg of F per kg salt in other Swiss cantons. Therefore, in 1981, the Swiss Academy of Medical Sciences recommended that fluoridated domestic salt should contain 250mg of F per kg instead of 90mg. Since April 1983, fluoridated salt containing 250mg of F per kg has been used throughout Switzerland.

Ericsson (1983) investigated the fluoride doses obtained with fluoridated salt under Swedish dietary conditions. Average daily doses were slightly above 0.5mgF in the 1-3-year-old children, 0.5-1mg in 4-12-year-old children and between 1mg and 2mg in the adults.

Toth (1976) reported the effectiveness of 250mg of F per kg in salt in Hungary after eight years of use. The results indicated a 39% caries reduction in deft in 6-year-old children in the test community, while caries experience increased by 7% in the control community children over the same period.

In summary, the caries preventive effectiveness of fluoridated salt is impressive. It is thought that when the concentration of fluoride in salt is such that excretion levels of urinary fluoride are similar to those found in communities with optimally fluoridated water, the caries preventive effects are similar.

2.4 MILK FLUORIDATION

Among the collective methods for caries prevention as an alternative to water fluoridation, the possibility of milk fluoridation was first mentioned by Ziegler (1956). Because milk is recommended as a good food for infants and children, it was therefore considered to be a suitable vehicle for supplementing children's fluoride intake in fluoride-deficient areas.

In the few studies carried out with fluoridated milk, there is no agreement concerning the optimum fluoride concentration. Concentrations of 1.0, 2.5 and 4.23ppm have all been used or recommended (Rusoff et al 1962; Ziegler 1964; British Dental Journal 1969). In none of these situations was the milk fluoride concentration determined on the basis of physiological measurements, such as urinary fluoride excretion (FDI 1984).

The following reductions in caries have been reported:

36.3% (Imamrira 1959); 35% and 76% for those aged 6-9 years and six years at the beginning of experiment (Rusoff et al 1962); 14.8-31% in the primary teeth and 64.2-65.2% in permanent molar teeth (Wirz 1964 and Ziegler 1964); 31.2% DMFT and 43.1% DMFS reduction in permanent teeth (Wei et al 1984).

Although the results have been encouraging, milk fluoridation has certain disadvantages. Duff (1981) reported the binding of added ionic fluoride to milk-calcium or milk-protein occurs after addition, making milk an unsatisfactory carrier of ionic fluoride.

Also, the amount of milk consumed by children, particularly among those in different socio-economic groups, varies considerably. Unlike consumption of water, the consumption of milk tends to decrease as a child grows older, whereas the need for fluoride to prevent dental caries increases with age.

2.5 FLUORIDE MOUTHRINSES

Mouthrinses are chemical substances that are swished around the oral cavity and then expectorated for cosmetic (breath freshness) and/or therapeutic purposes. The basic ingredients in a liquid mouthrinse formulation are water, alcohol, flavouring oils and colouring materials. Other components may include humectants, astringents, emulsifiers, antimicrobial agents, sweeteners and therapeutic substances.

The concept of a fluoride containing therapeutic mouthrinse was established in the 1940s, but failed to have an effect on caries.

Weisz (1960) reported success with a sodium fluoride mouthrinse used by his patients at home. However, the amount of fluoride used in the rinse was considered by the American Dental Association to be too high and, therefore, unsafe for home use. Subsequent studies did result in significant caries reductions with a neutral 0.2% sodium fluoride mouthrinse.

The two most common fluoride rinsing techniques combine two variables, fluoride concentration and rinsing frequency with low potency/high frequency technique or high potency/low frequency technique.

Low potency/high frequency technique is the method recommended for home use. Fluoride rinsing is indicated for patients with banded, bonded or removable appliance; and removal appliance; and for patients with reduced salivary flow whose teeth are highly susceptible to decay. High potency/low frequency technique is the method usually used for

school-bases programmes. Neutral preparations of sodium fluoride are recommended over other agents. A 0.2% solution is used on a weekly basis, while 0.05% solution is used daily. A summary of fluoride rinse and expectorate technique is illustrated in Table 3.

Results of clinical trials of mouthrinsing with fluoride solutions containing sodium fluoride are shown in Table 4. The data indicates that sodium fluoride mouthrinses are safe and effective with regard to reducing the incidence of caries.

This conclusion was also substantiated at an International Workshop on Fluorides and Dental Caries Reductions (Forrester and Schulz 1974), where the recommendations indicated that sodium fluoride rinses, in either neutral or acidulated form, were safe and efficacious. Also, the Council on Dental Therapeutics of the American Dental Association has classified as "Accepted" both neutral sodium fluoride and phosphate acidulated fluoride solutions as effective agents for use in reducing the incidence of caries (American Dental Association, Council on Dental Therapeutics 1975).

TABLE 3: Summary of fluoride rinse and expectorate techniques

SOURCE: Ripa 1981. p 478

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

TABLE 4: Results of clinical trials of mouthrinsing with fluoride solutions containing sodium fluoride (NaF)

SOURCE: Murray and Rugg-Gunn 1982. p174

Study	F concentration (ppm)	Rinsing frequency	Age at baseline	Test group		Length of trial (mths)	DFMS Caries increment		Per. cent caries reduction
				No. completing trial			Control	Test	
Bibby et al. (1946)	1000*	3/wk	18-21	31		12	5.6	6.1	9 (increase)
Roberts et al. (1948)	45*	2/wk	12	187		12	2.4	3.0	25 (increase)
Torell and Ericsson (1965)	225	1/day	10	160		24	10.0	5.1	49
Torell and Ericsson (1965)	900	1/2 wk S	10	172		24	10.0	7.9	22
Koch (1967)	2225	1/2 wk S	10	85		36	21.1	16.1	23
Koch (1967)	2225	3.7/yr S	7	117		36	6.2	4.6	25
Koch (1967)	225	2.9/yr S	8-10	114		24	4.9	4.8	2
Horowitz et al. (1971)	900	1/wk S	6	129		20	1.3	1.1	16
Horowitz et al. (1971)	900	1/wk S	11	117		20	2.9	1.7	44
Brandt et al. (1972)	900	2/wk S	11-12	94		21	7.0	4.0	43
Moreira and Tumang (1972)	450	3/wk S	7	50		24	7.5	4.0	47
Moreira and Tumang (1972)	450	1/wk S	7	50		24	7.5	5.7	25
Moreira and Tumang (1972)	450	1/2 wk S	7	50		24	7.5	5.8	23
Aasenden et al. (1972)	200†	1/day S	8-11	114		36	12.3	9.0	27
Heifetz et al. (1973)	3000	1/wk S	10-12	126		24	7.5	4.7	38
Rugg-Gunn et al. (1973)	225	1/day S	11-12	222		34	10.2	6.6	36
Gallagher et al. (1974)	1800	1/wk S	10-11	306		24	4.4	2.9	34
Maiwald and Padron (1977)	900	1/2 wk S	6	100		88	11.6	5.1	56
De Paola et al. (1977)	1000**	1/day S	10-12	158		24	7.6	4.4	41
Luoma et al. (1978)	200‡	1/day S	11-15	32		24	6.3	4.2	32
Ripa et al. (1978)	900	1/wk S	7-12	750		24	3.2	2.6	20
Ringelberg et al. (1979)	250	1/day S	11	179		30	6.3	4.8	23

S, School only.
* pH 4.0.
† Rinse swallowed (1 mg F).
** pH 4.4.

2.6 FLUORIDE TOOTHPASTE

The first fluoride compound to be used in a toothpaste formulation was sodium fluoride. Initial studies since 1945 showed no effects of fluoride to dental caries. Through further investigations on the compatibility of fluoride compounds with conventional constituents of toothpaste, it was found that the abrasive system of calcium carbonate and phosphate inactivated the sodium fluoride by formation of calcium fluoride. In a subsequent study by Torell and Ericsson (1965) using 0.24% sodium fluoride, there was a cumulative caries reduction of one surface saved per child per year.

Koch (1967) published results of a study testing a toothpaste formulation containing 0.22% sodium fluoride. In the study for three years of once a day brushing it was found that the reductions of new caries surfaces for the 8-10 year group and the 11-12 year group were 40% and 48% respectively.

Other fluoride compounds which have been tested for caries inhibitory properties when incorporated into a toothpaste includes stannous fluoride, acidulated phosphate fluoride, sodium monofluorophosphate and amine fluoride.

Stannous fluoride-containing toothpastes have been subjected to extensive clinical investigation. The most well-known stannous fluoride toothpaste contains 0.4% stannous fluoride and calcium pyrophosphate as the cleaning and polishing agent. Calcium pyrophosphate was selected because it was found to be more compatible

with stannous fluoride. Many clinical studies have been published concerning 0.4% stannous fluoride-calcium pyrophosphate toothpaste. It is readily apparent that such toothpastes are effective in reducing the incidence of new surfaces. The variations in the magnitude of reducing caries are most likely a result of different degrees of usage, different criteria of examiners, and the relative incidence between caries of smooth surfaces and pit or fissure surfaces. It is generally agreed that effectiveness is greater on smooth surfaces.

Sodium monofluorophosphate-containing toothpastes have been extensively evaluated in laboratory and clinical investigations. The most well-known toothpaste contains 0.76% sodium monofluorophosphate and dicalcium phosphate dihydrate as the cleaning and polishing agent.

Finn and Jamison (1963) carried out the first clinical trial involving the use of sodium monofluorophosphate in a toothpaste. The result of this trial suggested that this compound might be more effective than stannous fluoride. Numerous investigations with this compound have since then been reported. The property of not being readily inactivated by calcium permits sodium monofluorophosphate to be used in a variety of toothpaste-abrasive formations without loss of efficacy. In contrast, stannous fluoride and sodium fluoride are incompatible with such common cleaning and polishing agents as calcium carbonate and dicalcium phosphate because of the formation of insoluble and inactive calcium fluoride. So, monofluorophosphate has become the preferred chemical form of fluoride in most of the major commercial fluoride toothpastes used throughout the world.

A toothpaste containing an amine fluoride compound was selected for clinical evaluation because laboratory and animal investigations had indicated that this compound might provide better anticariogenic and antibacterial activity than sodium fluoride. Marthaler (1974) reported a 33% in caries reduction after a six year study of using 0.4% cetylamine hydrofluoride containing toothpaste.

3 MECHANISM OF CARIOSTATIC ACTION OF FLUORIDE

The mechanisms by which fluorides inhibit cariogenesis have not been completely understood but, clearly, more than one mechanism is involved and both topical and systemic exposures are important.

3.1 EFFECTS ON ENAMEL

3.1.1 Effects of fluorides on the solubility of enamel

It is generally accepted that caries results from demineralization of the mineral phase of tooth by bacterial acids. It follows that solubility of tooth minerals might be expected to affect the caries process.

Solubility studies of intact enamel obtained from teeth of individuals living in fluoridated and non-fluoridated areas indicate a trend towards lesser solubility in the fluoridated groups (Isaac et al 1958; Jenkins 1963). Using apatites that contain well-defined levels of fluoride from 0-3.4%, Moreno et al (1977) concluded that fluoride concentrations of 4000-8000ppm were required to produce a significant decrease in enamel solubility. Such concentrations of fluoride, although higher than detected by the usual imprecise methods of collecting outer enamel, may be reached in the molecular layers of surface enamel in fluoridated zones.

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

The composition and structure of enamel surface does not remain constant. Carbonate and magnesium at the surface of the enamel are probably leaked out slowly and fluoride tends to accumulate by ion exchange. When the pH at the enamel surface falls, such changes will be accelerated. Hallsworth et al (1973) reported that during incipient carious attack, carbonate and magnesium are removed preferentially and fluoride uptake increases. Thus, the resistance of enamel will correspondingly change.

It is possible, therefore, to increase the fluoride concentration in enamel either while the apatite crystals of the tooth are forming (systemic fluoride administration) or after the enamel is formed and the tooth erupted into the mouth (topical administration).

Although differences in solubility of enamel with fairly modest changes in fluoride content have been observed, Moreno et al (1977) reported that the maximum cariostatic effect would be reached when about 50% of the hydroxyl groups are replaced by fluoride.

3.1.2 Effects of fluorides on enamel demineralization

Apart from other mechanisms, fluoride in solution has been shown to influence demineralization, both in rate and appearance.

Larsen (1973) showed that enamel is eroded when subjected to demineralizing solutions without fluoride. However, when the solution was supersaturated to fluorapatite (FAP), a surface layer could be seen on the microradiogram.

Moreno and Zahradnick (1974) also stress the important role of fluoride for the preservation of the surface layer.

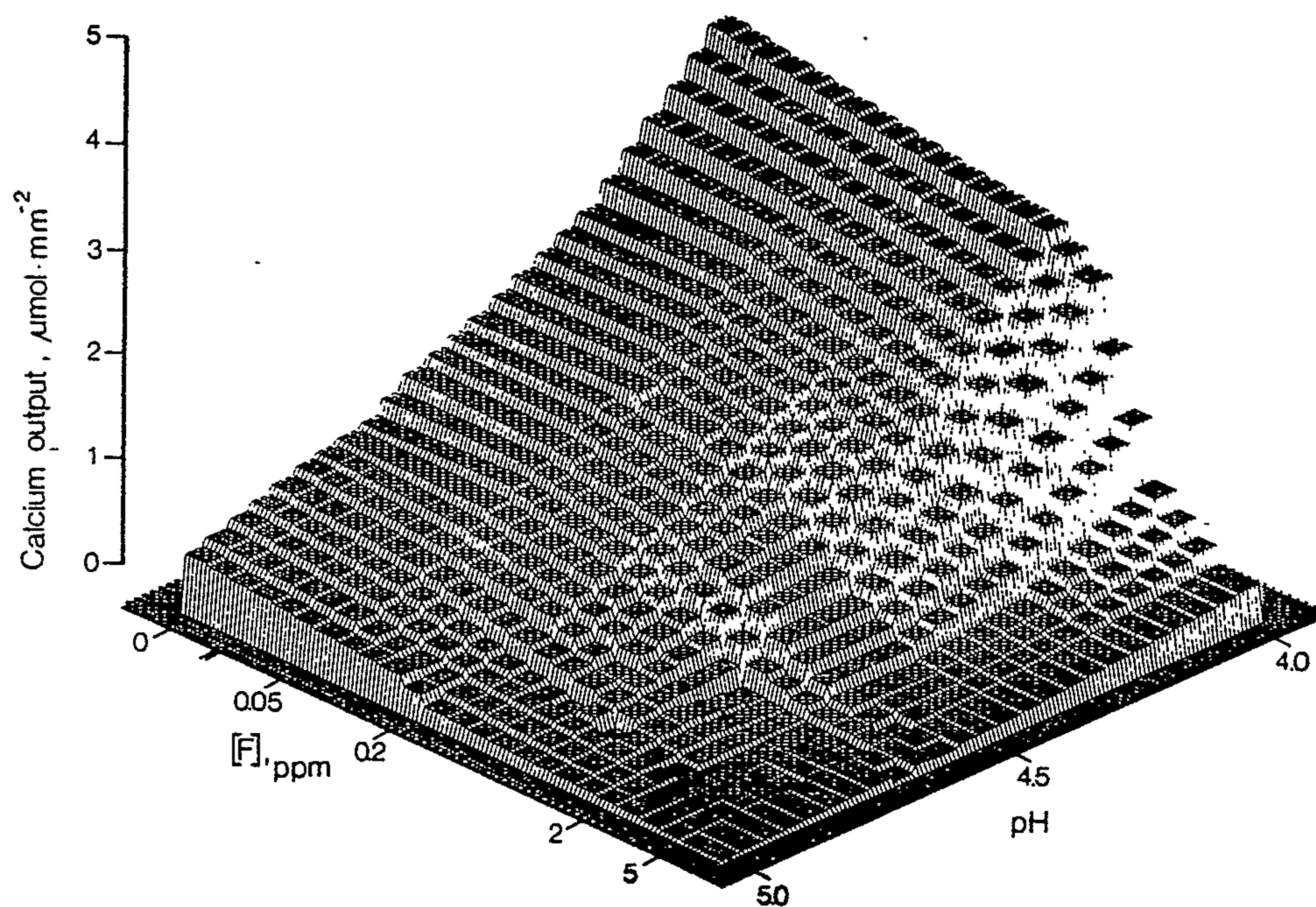
Cate and Duijsters (1983) concluded that during a pH drop, demineralization can be inhibited by fluoride. A second conclusion is that the rate of demineralization seems to be affected to a greater extent when the solution becomes supersaturated to CaF_2 as opposed to fluorapatite.

The effect of fluoride on the rate of demineralization at conditions relevant to the oral situation is given in Figure 1 (Cate and Duijsters 1983).

Ostrom et al (1977) showed that the enamel was not demineralized when 100ppm fluoride was included in the 3% sucrose rinse normally used to induce caries.

FIGURE 1: Calcium output as a function of pH and fluoride concentration in the demineralizing solution initially containing 2.2mM $\text{Ca}(\text{NO}_3)_2$, 2.2mM KH_2PO_4 and 50mM acetic acid.

SOURCE: Cate and Duijsters 1983. p 195



3.1.3 Effects of fluorides on enamel remineralization

There is abundant evidence in the literature to show that small carious lesions can be arrested or reversed, a process referred to as remineralization. Similarly, in vitro studies have shown that various types of experimental caries-like lesions can also be remineralized by exposure to either oral fluid or synthetic calcifying fluids (Silverstone 1983). One factor common to many of the results obtained on the remineralization of either enamel caries, artificial caries, or acid-etched enamel, is that the presence of fluoride ions greatly enhances the degree of remineralization achieved, and reduces the time period necessary for this mechanism to occur.

Remineralization basically affects a small lesion by two processes. In the first process, the lesion is reduced in size. In the second phase, the remineralized lesion becomes more resistant to progression. Thus, although the lesion is initially reduced in size, it is the latter mechanism that is probably most significant with respect to clinical prevention of the lesion.

One of the more important actions of fluoride is likely to be its ability to increase the formation of apatite during remineralization. Brown et al (1977) have suggested that during remineralization the outer layer of the apatite crystal may take up F ions so that it acquires the property of fluorapatite. Also, Feagin et al (1971) described the minerals that deposit during the remineralization are less soluble than the deposits from the same solution that do not contain fluorides.

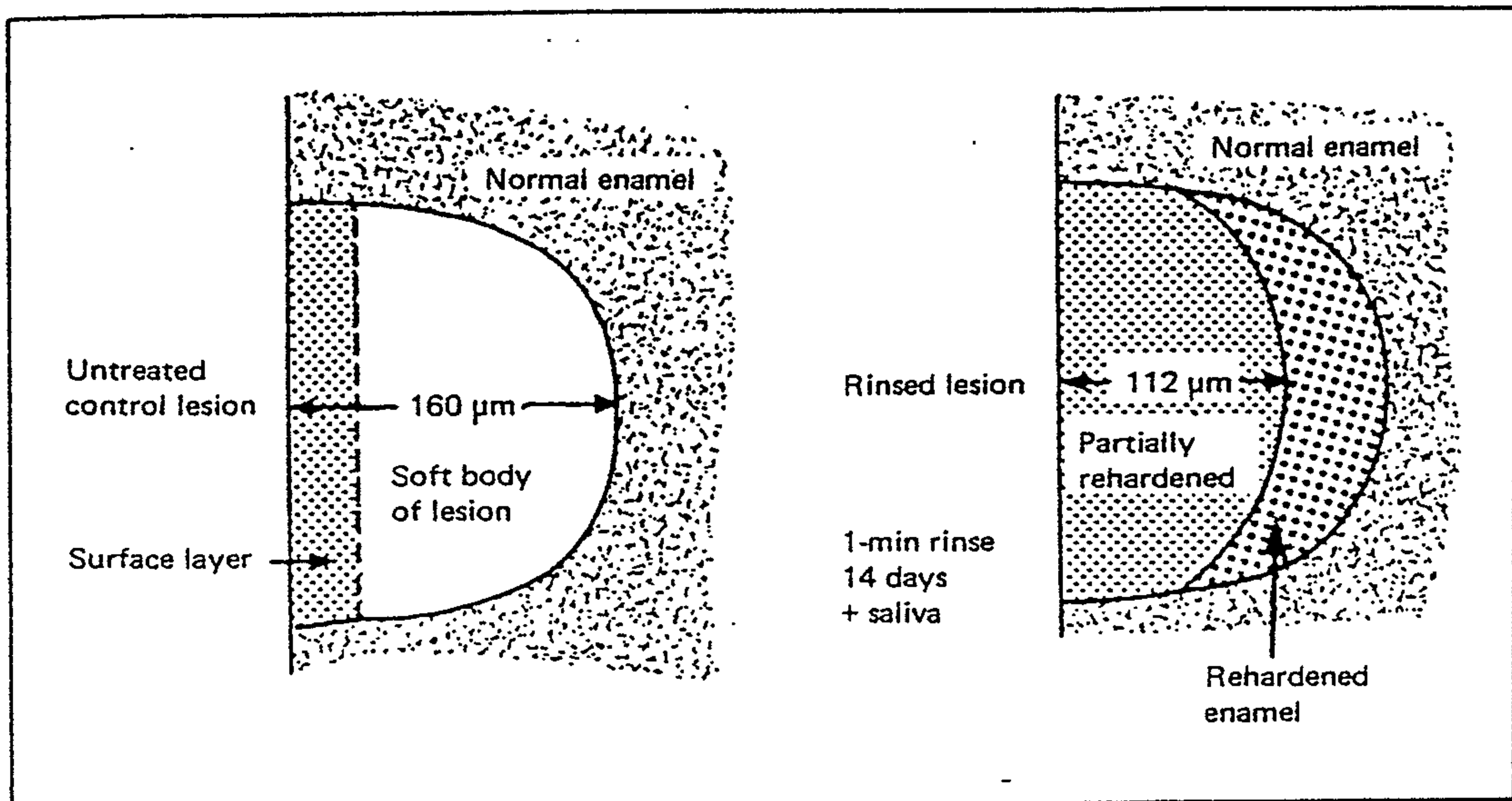
A diagrammatic representation of the remineralization of an early carious lesion is shown in Figure 2.

In vitro remineralization experiments, Silverstone et al (1981) have reported that the entire body of white spot lesion does not have to be remineralized for it to become protected. A lesion can become arrested if the surface zone alone is remineralized.

Although fluoride is important in enhancing remineralization, it is not necessary to use high concentrations. Recent clinical studies have supported the frequent supply of low concentrations of fluoride rather than the infrequent use of high concentrations. In this respect the widespread use of fluoridated toothpastes is likely to have had a highly significant effect in reducing caries experience. The recent findings of lower caries incidence in many western nations have also been accomplished in regions where water fluoridation was either minimal or totally lacking. In such areas, fluoridated toothpaste must have been a major contributor in the frequent supply of low fluoride levels so as to enhance remineralization of lesions.

FIGURE 2: A diagrammatic representation of the remineralization of an early carious lesion following the repeated use of fluoride in a rinse.

SOURCE: Nikiforuk 1985. p57



3.2 EFFECT OF FLUORIDE ON TOOTH MORPHOLOGY

The size and morphology of teeth in humans and experimental animals can be influenced by ingestion of fluoride.

Copper and Ludwig (1965) measured the buccolingual and mesiodistal diameters and cusp depth of lower first permanent molars of children in fluoridated and non-fluoridated areas. The results showed the diameters were about 2% smaller and the cusp depths were 5% smaller in the fluoridated areas. Such changes in morphology would tend to decrease the caries susceptibility of teeth by making them more self-cleansing.

Aasenden and Peebles (1974) also reported that molars in subjects consuming fluoridated water or supplements had shallower fissures and fewer carious lesions than molars in a non-fluoride control group.

Paynter and Crainger (1956) found that in rats fed 6ppm F in their diet, the size of molar teeth was reduced and the proportion of molars with rounded fissures was higher than the controls. These results were confirmed by Kruger (1968, 1970) who observed a reduction in the thickness of enamel and dentin and this resulted in smaller teeth with wider fissures.

3.3 EFFECTS ON SALIVA

Jenkins and Edgar (1977) reported that the fluoride was present as two forms in the saliva - as free fluoride ions and bound to bacteria, epithelial cells or inorganic constituents at neutral pH but in forms which were readily ionizable in an acidic medium.

According to Bruun et al (1982), the basal fluoride concentrations found in saliva was reported to range from 0.5-2.6mu and believed to increase with systemic ingestion or after various applications of topical fluorides.

Jenkins and Edgar (1977) also found that the whole saliva samples contained higher fluoride levels than simultaneously collected submandibular and parotid samples.

Ekstrand et al (1986) reported that in the case of ingestion of fluoridated drinking water, the source of salivary fluoride is likely to be the hard tissues with transfer of fluoride occurring via the blood. Duckworth et al (1987) reported that in the case of topical fluorides, the fluoride reservoir of the saliva may be from sources in the mouth like the plaque.

Various studies (Svanberg and Rolla 1982, Svanberg and Westergen 1983) have shown a significant reduction in the number of viable microorganisms in the presence of fluorides in whole saliva.

Featherstone et al (1985) have also suggested that the continuous presence and redistribution of fluoride by saliva may be important in caries prevention as it would be available during each acid attack of the teeth from acids produced by fermenting carbohydrates.

Also, the release of free fluorides, calcium and phosphate ions in any acidic medium would make saliva an important reservoir of these ions by replenishing fluoride which is lost from plaque to the tooth structures.

Hence, salivary fluorides like plaque fluorides may be a contributing factor towards the prevention of dental caries.

3.4 EFFECT ON PLAQUE

3.4.1 Fluoride Concentration in Plaques

Wide variations of fluoride concentrations in plaque have been reported. Jenkins and Edgar (1977) reported that the level of fluoride (ppm, dry weight) in scrapings from dental plaques was in the range of 15-64ppm. The distribution of fluoride in plaque apparently is not uniform since its concentration is related to the thickness of deposit. Birkeland et al (1971) reported that thick or heavy plaque usually had a lower fluoride concentration than thin plaques. This may be related to the rate of plaque growth or slow rate of fluoride diffusion from the surface inwards.

The plaque fluoride originates from prolonged day-to-day contact with the low levels of fluoride in the saliva and gingival fluid. The concentration of fluoride in plaque from communities with fluoridated drinking water is about twice as high as in non-fluoridated communities.

After the use of fluoride mouthrinses or toothpastes, plaque fluorides can reach 100ppm for periods of minutes, although it may remain elevated for several hours or more.

3.4.2 . Plaque Fluoride and Acid Production

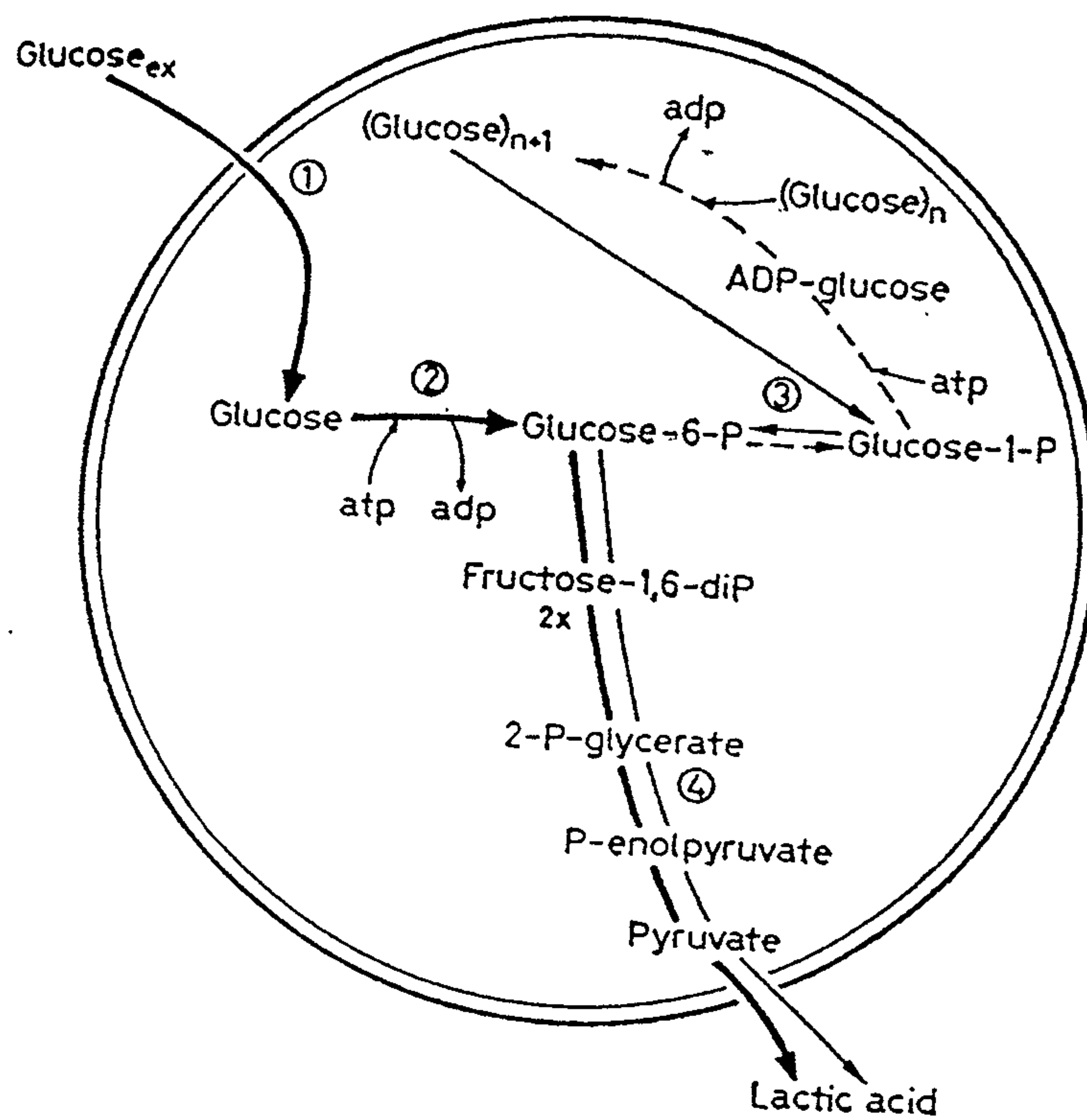
It is a well accepted fact that the degradation of carbohydrates by plaque bacteria into acid which in turn causes demineralization of tooth substance is one of the most important aetiological factors in the carious process. There is sufficient evidence that fluorides derived from topical fluorides (Geddes and McNee 1982) or water fluoridation (Jenkin et al 1969; Agus et al 1980) may decrease the acidogenic potential of plaque though the exact mechanism of action was not known.

Hamilton (1977) suggested that fluoride could inhibit acid production by inhibiting any or all of the following stages of carbohydrate metabolism (glycolysis) by the bacteria, ie the bacterial phosphatase which are involved in degradation of sugar phosphate; cation transport which is closely associated with carbohydrate metabolism or the enzyme enolase in bacteria (Figure 3). Enolase is highly sensitive to fluoride inhibition and may be partially inhibited by 0.5-1ppm fluoride.

With decrease in pH (increase in hydrogen ion concentration) there is increased permeability of the bacterial cell wall to fluorides which results in a decrease in carbohydrate utilization.

FIGURE 3: Diagrammatic representation of the pathways involved in intact cells of *S. salivarius*.
Numbers indicated possible sides of fluoride inhibition.

SOURCE: Hamilton 1977. p263



Pathways: ----- glycogen synthesis
 ----- glycogen degeneration
 ----- exogenous glucose metabolism

3.4.3 Antibacterial Effect of Plaque Fluoride

Most of the dominant bacteria in the plaque can metabolize sugars/carbohydrates to acids. This includes Streptococci and Actinomyces, but also species within Bacteroides, Fusobacterium and Neisseria. The capacity to produce acid varies with the different bacterial species.

Under optimal conditions, some bacteria are able to produce acid faster than others. For example, the acid production rate of Streptococci is faster than that of Actinomyces and Streptococcus mutans has a higher acid-forming rate than Streptococcus sanguis and Streptococcus mitis.

Fluoride can affect microorganisms in several ways. Jenkins (1978) reported that at low concentrations it reduces acid formation, at higher concentrations it produces a larger reduction in acids and at very high concentrations, it completely inhibits bacterial growth.

Inhibition of growth of Streptococcus mutans was observed by Loesche et al (1973) using topical fluorides. Edgar (1981) suggested that high fluoride levels might disinfect the tooth and prevent recolonization of the organisms on the tooth.

Ericsson and Forsman (1969) reported that the formation of lactic acid from sugar was reduced to 10-20 minutes following rinses with 0.1% to 0.5% NaF, and the number of visible microorganisms in whole saliva diminished for several hours after rinsing with 0.1% to 0.5% SnF₂.

Brushing with monofluorophosphate dentifrice (0.1%F) reduced the number of salivary Streptococci in the mouth.

Gibbons and Van Houte (1973) also suggested that fluorides prevent the synthesis of extracellular glucans and fructans by *S. mutans* and *S. sanguis* during sucrose degradation which is of significance in the colonization of these bacteria to the tooth surface.

Marguis et al (1976) reported that certain strains of oral Streptococci undergo lysis in the presence of fluorides. Based on all the above, the fluoride concentration in plaque might contribute significantly in retarding the caries process by inhibiting acid production as well as by inhibiting bacterial growth, causing lysis of bacteria and perhaps preventing the colonization of bacteria to the tooth surface.

4 RISKS OF FLUORIDATION ALTERNATIVES

It is necessary to know what is a risk before discussing the risks of fluoridation alternatives. According to Rowe (1977), risk is the potential for realization of unwanted, negative consequences of an event. Both the probability of occurrence and the degree of magnitude are important when one is describing risk. Ideally, a biomedical therapy should be only of value to the patient, ie provide a benefit and should be devoid of any risks. Realistically, side effects that entail risks are associated with most biomedical treatments. Accepting the risk implies that a risk taker is willing to tolerate some risk in order to obtain a gain or benefit. The decision to accept a risk will depend upon the probability of its occurrence and its magnitude relative to the expected benefit.

Risks have been classified as physical, psychological, social and economic (Levine 1981). The risk of physical (or psychological) harm is obviously foremost in consideration. Does fluoride therapy carry the risk of physical (or psychological) harm? There have been relatively few physical problems reported from the therapeutic use of either topical or systemic fluorides. These are: gastrointestinal disturbance (nausea and vomiting) (Ekstrand and Koch 1980; Hoffman et al 1980); extrinsic staining of the teeth (Shannon 1978); gingival mucosal irritation (Muhler 1957) and dental fluorosis (Aasenden and Peebles 1974; Driscoll et al 1983). Of this list, a value judgement leads to the conclusion that the only serious one is dental fluorosis. This is because it is the only condition that is permanent and also that has the potential of causing psychological problems, depending upon its actual or perceived severity.

4.1 DENTAL FLUOROSIS

Dental fluorosis is a form of enamel and dentin hypomineralization resulting from the ingestion of excessive amounts of fluoride during tooth development. The severity of dental fluorosis ranges from barely noticeable, white specks covering only a small percentage of enamel surface to confluent pitting of the enamel surface usually accompanied by dark-brown staining.

Epidemiological studies carried out in the 1930s and 1940s by Dean and co-workers clearly established the relationship between the fluoride concentration in the drinking water and the prevalence of dental caries and fluorosis. Lifelong consumption of optimally fluoridated drinking water (0.7-1.2ppm, depending on the mean maximal daily temperature) reduced dental caries by 50% to 65% and produced only the mildest forms of dental fluorosis, which are not of aesthetic concern, in approximately 10% of the population.

The traditional system for classifying dental fluorosis was described by Dean in 1942. However, Dean's index has several shortcomings, such as only one single score, is given to a tooth rather than a separate score to each tooth surface and a "questionable" diagnostic category that is difficult to define or interpret precisely.

In an attempt to reduce some of the shortcomings of Dean's index, Horowitz et al (1984) developed a new index, the Tooth Surface Index of Fluorosis (TSIF). The descriptive criteria and scoring system for the TSIF are shown in Table 5. With the TSIF, a separate score is given to

each unrestored tooth surface. Two scores are assigned to anterior teeth (from the labial and lingual aspects) and three to posterior teeth (from the buccal, lingual and occlusal aspects). The TSIF contains no "questionable" category.

Renison et al (1985) reported that the prevalence of caries has declined 30% to 40% during the past 10-15 years, not only in the United States, but also in other industrialized countries. The decline in the caries prevalence has been particularly interesting because it has occurred in non-fluoridated as well as fluoridated areas.

Glass (1982) stated that fluoride in toothpastes, rinses and community water supplies provided the best possible single association to the decline in the caries prevalence.

Pendrys et al (1986) has reported that the prevalence of dental fluorosis is also increasing in both fluoridated and non-fluoridated areas. After surveying 336 children (8 to 16 years of age) in an optimally fluoridated community, Driscoll et al (1983) concluded that although the overall prevalence and severity of dental fluorosis have not changed significantly in the past 40 years, 8-10 year old children had distinctly more fluorosis in the permanent first molars and incisors than had children 13-16 years of age. The fluorosis was almost entirely the milder forms, which do not involve pitting or staining of the enamel.

Because dental fluorosis is one of the earliest and most sensitive indicators of fluoride toxicity, and because it can be produced in

TABLE 5: Descriptive criteria and scoring system for the Tooth Surface Index of Fluorosis (TSIF)

SOURCE: Horowitz et al 1984. p39

Numerical Score	Descriptive criteria
0	Enamel shows no evidence of fluorosis.
1	Enamel shows definite evidence of fluorosis, namely areas with parchment-white colour that total less than one-third of the visible enamel surface. This category includes fluorosis confined only to incisal edges of anterior teeth and cusp tips of posterior teeth ("snowcapping").
2	Parchment-white fluorosis totals at least one-third of the visible surface, but less than two-thirds.
3	Parchment-white fluorosis totals at least two-thirds of the visible surface.
4	Enamel shows staining in conjunction with any of the preceding levels of fluorosis. Staining is defined as an area of definite discoloration that may range from light to very dark brown.
5	Discrete pitting of the enamel exists, unaccompanied by evidence of staining of intact enamel. A pit is defined as a definite physical defect in the enamel surface with a rough floor that is surrounded by a wall of intact enamel. The pitted area is usually stained or differs in colour from the surrounding enamel.
6	Both discrete pitting and staining of the intact enamel exist.
7	Confluent pitting of the enamel surface exists. Large areas of enamel may be missing and the anatomy of the tooth may be altered. Dark-brown stain is usually present.

permanent teeth (other than third molars) only by excessive fluoride intake during the first five years of life, questions are being raised regarding the factors that influence the dietary fluoride intake of infants and young children and the effect of supplemental sources of ingested fluoride.

4.1.1 Optimal Fluoride and Fluoride Intake Associated with Dental Fluorosis

In the 1940s - before the introduction of fluoride tablets, fluoride-containing toothpastes and the widespread water fluoridation - epidemiological studies established that an optimal fluoride intake was the amount of fluoride ingested by individuals in communities where the drinking water contained approximately 1ppm fluoride.

McClure (1943) estimated that children up to 12 years of age who consumed drinking water containing 1ppm fluoride had dietary fluoride intakes of approximately 0.05mg/kg body weight. This finding was supported by Ophang et al (1985), who indicated that the dietary fluoride intakes of average six-month-old and two-year-old children in fluoridated cities (>0.7ppm) are approximately 0.05mg/kg body weight.

Forsman (1977) reported that a daily fluoride intake of 0.1mg/kg body weight was associated with the development of dental fluorosis in human beings. The findings that dental fluorosis is associated with fluoride intakes that are approximately twice those found in optimally fluoridated communities was supported by Dean's studies (1946) in which it was shown that dental fluorosis becomes significant, when the community water fluoride level is approximately 2ppm.

Angmar-Mansson and Whitford (1982) found that disturbance in incisor enamel mineralization in rats were associated with plasma fluoride peaks of 5umol/l that occurred once or twice daily. Angmar-Mansson and Whitford (1984) also reported that when the plasma fluoride levels were maintained relatively constant at 3.3-4.7umol/l for one week or at 1.5-3.1umol/l for eight weeks, disturbances in enamel mineralization

were consistently observed in rats. Plasma fluoride concentrations of 1.5-3.1 $\mu\text{mol/l}$ are similar to those reported for human beings in areas where the drinking water contains 2ppm fluoride. Thus, to some extent, the development of dental fluorosis depends not only on the daily intake of fluoride, but also on the pattern of plasma fluoride levels that result from ingestion of fluoride.

4.1.2 Dietary Fluoride Intake

The dietary fluoride intake of infants and young children has been estimated by several investigators. Ophang et al (1985) reported the dietary (foods and drinking water) fluoride intakes of six-month-old and two-year-old children based on the analysis of "market basket" food collections made in 20 cities by the Food and Drug Administration USA (Table 6). Average six-month-old and two-year-old children in fluoridated (>0.7 ppm) cities had mean dietary fluoride intakes of 0.418mg/day (0.052mg/kg body weight) and 0.621mg/day (0.050mg/kg body weight) respectively. In 11 market baskets collected in cities with municipal water supplies that contained greater than 0.7 ppm fluoride, the drinking water contributed more than 50% of the dietary fluoride intake. In no instance did the dietary fluoride intake exceed 0.08mg/kg body weight. These intake levels, on the basis of body weight, are nearly identical to those found by Dabeka et al (1982) for three and six-month-old children based on an analysis of 334 Canadian commercial infant foods and food consumption data from the Nutrition Canada Survey. This data suggests that average infants and young children who reside in fluoridated cities have dietary fluoride intakes that are similar to the optimal intake of 0.05mg/kg body weight and that are below the intake associated with the development of dental fluorosis (0.1mg/kg body weight).

However, the type of milk or formula being fed has a major impact on dietary fluoride intake. Human and cow's milk contains less than

TABLE 6: Dietary fluoride intake of average six-month-old (infant) and two-year-old (toddler) children who reside in cities with various water fluoride levels.

SOURCE: Ophang et al 1985. p70

Water Fluoride Level (ppm)	Dietary Fluoride Intake	
	(mg/day ^a)	(mg/kg body weight)
Infant		
> 0.7	0.418 ± 0.054 (11)	0.052 ± 0.007 (11)
0.3 to 0.7	0.314 ± 0.059 (6)	0.039 ± 0.007 (6)
< 0.3	0.226 ± 0.023 (5)	0.028 ± 0.003 (5)
Toddler		
> 0.7	0.621 ± 0.039 (11)	0.050 ± 0.003 (11)
0.3 to 0.7	0.386 ± 0.037 (6)	0.031 ± 0.003 (6)
< 0.3	0.207 ± 0.036 (5)	0.017 ± 0.003 (5)

^aAll values are given as mean ± SEM (number of samples).

0.10ppm fluoride, while commercial formulas may obtain much higher fluoride levels.

Dabeka et al (1982) reported that daily dietary fluoride intake can vary between 0.02 and 0.18mg/kg body weight, depending on the infant's age, the type of milk or formula being fed and whether the milk or formula is given in a fluoridated or non-fluoridated community.

Changes in the milk feeding patterns of infants during the first year of life significantly affect the fluoride intake. Martinez et al (1981) found that 42% of two-month-old infants were breast-fed; 62% were fed formula; and only 2% were fed cow's milk or evaporated milk. By the age of one year, however, 7.5% were breast-fed; 11% were fed formula; and 87% were fed cow's milk or evaporated milk. Thus, while some infants may be receiving high fluoride intakes early in life because of their consumption of commercial formulas diluted in the home with fluoridated water, by the age of one year, this intake will affect relatively few children. In addition, the increased incidence of breast feeding (Martinez et al 1981) coupled with the reduced fluoride content of ready-to-feed commercial formulas since 1979 means that significantly fewer infants are being exposed to high fluoride intakes from formulas than were exposed in the 1970s. Therefore, if formula feeding is a contributing factor to the increased incidence of dental fluorosis, it is no longer as important as it was in the past.

4.1.3 Fluoride Intake through Fluoride Tablets or Drops

In 1972, the Committee on Nutrition of the American Academy of Paediatrics recommended a supplemental dose of 0.5mg of fluoride daily from birth to three years of age and 1.0mg of fluoride daily after three years of age if the drinking water contains less than 0.5ppm fluoride. This schedule was widely used by paediatricians and dentists in the 1970s.

Aasenden & Peebles (1974) have reported that daily administration of 0.5mg fluoride tablets to children older than three years of age effectively reduces the incidence of caries, but it produces a significant increase in dental fluorosis. Table 7 illustrates the index of enamel fluorosis and percentage distribution by degree of severity. Although most of the fluorosis was classified as "mild" and "very mild" and was of no aesthetic concern, in some children the fluorosis was classified as "moderate". It appears that a fluoride tablet of 0.5mg/day beginning at birth is at the very borderline of the tolerate limit.

So, in 1982, the Council on Dental Therapeutics of American Dental Association made a new recommendation on the fluoride supplementation schedule as shown in Table 8.

TABLE 7: Index of enamel fluorosis and percentage distribution by degree of severity.

SOURCE: Aasenden and Peebles 1974. p323

	Mean index	Percentage distribution				
		Normal	Questionable	Very mild	Mild	Moderate
I, F supplement	0.88 $\pm$ 0.08*	16.0	17.0	34.0	19.0	14.0
II, No F supplement	0.07 $\pm$ 0.02	82.8	12.9	3.2	1.1	0
III, F water	0.40 $\pm$ 0.06	37.0	30.4	21.7	8.7	2.2

* Standard error.

Note: No severe fluorosis was observed.

TABLE 8: Fluoride supplementation schedule of the Council of Dental Therapeutics, American Dental Association.

SOURCE: Ophang et al 1987. p71

Age (Years)	<i>Concentration of Fluoride in Drinking Water (ppm)</i>		
	<i>< 0.3</i>	<i>0.3 to 0.7</i>	<i>> 0.7</i>
Birth to 2	0.25 ^a	0	0
2 to 3	0.50	0.25	0
3 to 13	1.00	0.50	0

^aMilligrams of fluoride per day.

This schedule provides graded doses of fluoride from birth to 13 years of age, depending on the fluoride content of drinking water and the age of the child. In 1979 the American Academy of Paediatrics altered its recommendation to a supplementation schedule that is identical to the schedule of ADA's Council on Dental Therapeutics, except that the tablets are continued to age 16. American Academy of Paediatrics, Council on Nutrition (1986) reviewed recent information on fluoride and concluded that no further changes in the supplemental schedule are necessary. The schedule also emphasizes that no practitioner should give a prescription for fluoride tablets without being aware of the fluoride content of the drinking water.

When the recommended doses of fluoride tablets or drops for six-month-old and two-year-old children are added to the dietary fluoride intakes calculated from the analysis of market basket food collection the results shown in Table 9 are obtained.

No supplemental fluoride is recommended for six-month-old infants who consume water containing 0.3 to 0.7ppm fluoride. Since the dietary fluoride intake for these children is less than optimal, the fluoride supplementation schedule may be slightly conservative in this area. The total daily fluoride intakes are adjusted to 0.051 to 0.059mg/kg body weight after adding the supplemental fluoride intake. These intake levels are similar to the optimal intake of 0.05mg/kg body weight and are similar to the dietary fluoride intakes of infants and toddlers who reside in areas where drinking water contains more than 0.07ppm fluoride.

TABLE 9: Effects of fluoride supplements on total daily fluoride intake.

SOURCE: Ophang et al 1987. p72

Water Fluoride Level (ppm)	Dietary ^a (mg)	Supplement ^b (mg)	<u>Total Intake</u> (mg) (mg/kg body wt)	
Infant (Six months old)				
> 0.7	0.418	—	0.418	0.052
0.3 to 0.7	0.314	—	0.314	0.039
< 0.3	0.226	0.25	0.476	0.059
Toddler (Two years old)				
> 0.7	0.621	—	0.621	0.050
0.3 to 0.7	0.386	0.25	0.636	0.051
< 0.3	0.207	0.50	0.707	0.057

4.1.4 Ingestion of Fluoride-containing Toothpaste

The ingestion of fluoride-containing toothpaste during toothbrushing is of particular concern in young children (those aged five years or younger) because of their inability to control the swallowing reflex and because the crowns of the permanent teeth are undergoing calcification and are susceptible to the development of dental fluorosis.

Dowell (1981) interviewed mothers of three-year-old children to determine the age at which the use of toothpaste was started. Some 46% of the mothers reported starting toothbrushing their children by the age of 12 months and, by the age of one month, 8% had initiated toothbrushing.

Palmer and Prothero (1981) reported similar findings in a survey of the parents of 17-month-old and three-year-old children. The parents indicated that 29% of the 17-month-old children and 55% of the three-year-old children were brushing at least twice a day. The parents of 23% of the three-year-old children also indicated that their children swallowed most of the toothpaste during brushing, and 24% of the parents reported that their children ate toothpaste at other times.

Barnhart et al (1974) reported that the ingestion of toothpaste during toothbrushing decreases with age as control of the swallowing reflex is gained and children younger than five years of age will ingest 26%-35% of the toothpaste used. Children two to four years of age used an average of 0.86g of toothpaste per brushing and ingested approximately

35% of the toothpaste per brushing. If a toothpaste containing 0.1% fluoride were used, 0.3mg of fluoride would be ingested per toothbrushing.

The total daily fluoride intake of an average two-year-old child from foods, beverages, properly prescribed fluoride tablets or drops and ingested toothpaste (assuming two brushings per day) is shown in Table 12. In areas where the drinking water contains less than 0.3ppm fluoride, the quantity of fluoride ingested from toothpaste is nearly three times that derived from dietary sources. On the basis of body weight, an average two-year-old child who brushes twice daily with a fluoride-containing toothpaste and who is provided with the recommended doses of fluoride tablets or drops has a total fluoride intake similar to that associated with the development of marginal dental fluorosis (0.10mg/kg body weight). Therefore, fluoride ingested in toothpaste has the potential for impacting significantly on dental caries and fluorosis. Renson et al (1985) concluded that it is important to note that the decline in dental caries that has been observed in most industrialized countries has not occurred, or has occurred to a much smaller extent, in countries where the use of fluoridated toothpaste is less common.

It is the responsibility of paediatricians and dentists to counsel parents on the proper use of fluoride toothpastes by the young children. Parents should carefully supervise toothbrushing by their younger children, instruct them to use only a pea-sized quantity of toothpaste and teach them to avoid swallowing the toothpaste.

TABLE 10: Effect of dentifrice ingestion on total daily fluoride intake of average two-year-old children (toddlers)

SOURCE: Ophang et al 1987. p74

Water Fluoride Level (ppm)	Dietary ^a (mg)	Supplement ^b (mg)	Dentifrice ^c (mg)	Total Intake	
				(mg)	(mg/kg body w
> 0.7	0.621	—	0.60	1.221	0.098
0.3 to 0.7	0.386	0.25	0.60	1.236	0.100
< 0.3	0.207	0.50	0.60	1.307	0.105

4.1.5 Ingestion of Fluoride Mouthrinses

Ericsson et al (1969) reported that fluoride retention after the use of mouthrinses in children age six and over was about 20%. Wei et al (1983) found that preschool children usually swallow as much as 30-40% of the rinse. The younger the age group the greater the percentage of the rinse swallowed. The volume of the mouthrinse and its duration have also been shown to influence the degree of retention. Birkeland (1973) found that in older children significantly more fluoride was ingested when using 10ml than 7ml of mouthrinse, and that adults swallowed more mouthrinse when longer rinsing time was used.

Based on 7ml of an 0.1% fluoride solution a maximum fluoride can be ingested. Kindergarten children may swallow 40% or 2.8mg fluoride and older children 20% or 1.4mg fluoride. These figures should be borne in mind when considering the age at which fluoride mouthrinses should be introduced as well as the concentration of fluoride and their place in multiple fluoride regimens.

4.2 ACUTE FLUORIDE POISONING

Dowell (1981) reported the estimated toxic dose of fluoride was 5-10mgF/kg of body weight, with gastrointestinal symptoms having been noted following ingestion of 3-5mgF/kg of body weight in young children. The lethal dose for humans is reported to be 32-60mgF/kg of body weight (Goodsman and Gilman 1980), but fatalities in children have been reported at doses of 16mgF/kg of body weight.

Based on these criteria, Table 11 and Table 12 assemble the approximate amounts of various commercial fluoride agents which would have to be ingested to produce toxicity and death, respectively. An examination of these data shows quite a large safety range in children and adults for most commercial NaF containing mouthrinses. Table 11 compares the potential toxicity of the fluoride content. It can also be seen from this table that acute fluoride toxicity could be expected in a young child between one and two-year-olds who swallowed 70 fluoride tablets. Under normal circumstances, effervescent fluoride mouthrinse tablets would only be used under supervision in the surgery. However, it can be seen from Table 11 that there is a potential risk if numbers of these particular tablets were prescribed or dispensed for use at a home where very young children were present; such tablets would be unlikely to be given to the patient in a container with a child-proof lid. Monsour and Kruger (1984) reported some 20 children needed to be hospitalized for poisoning from fluoride tablets in Brisbane between 1978 and 1983.

TABLE 11: Toxic doses of various fluoride agents.**SOURCE: Monsour and Kruger 1985. p83**

Fluoride source	Toxic quantity by age and weight					
	1 year 6.0 kg	2 years 12.5 kg	5 years 18.5 kg	10 years 30.5 kg	16 years 46.5 kg	Adult 70 kg
NaF (mg)	66.3	138.2	204.5	337.1	513.9	773.7
1.1 mg NaF tablets (No.)	60	126	186	306	467	703
2.2 mg NaF tablets (No.)	30	63	93	153	234	352
1.23% F topical gel (ml)	2.4	5.1	7.5	12.4	18.9	28.5
5% SnF ₂ topical gel (ml)	2.5	5.2	7.6	12.6	19.2	28.9
0.2% NaF topical wash (ml)	33.2	69.1	102.2	168.6	256.9	386.9
0.05% NaF mouthwash (ml)	132.6	276.3	408.9	674.2	1027.8	1547.3
50 mg NaF effervescent tablets (No.)	1	3	4	7	10	15
10% SnF ₂ prophylaxis paste (gm)	1.2	2.6	3.8	6.3	9.6	14.5
0.8% MFP toothpaste (gm)	28.4	59.2	87.6	144.5	220.3	331.6

*Calculated on a dose of 5 mg F/kg body weight.

TABLE 12: Lethal doses of various fluoride agents.**SOURCE: Monsour and Kruger 1985. p83**

Fluoride source	Lethal quantity by age and weight					
	1 year 6.0 kg	2 years 12.5 kg	5 years 18.5 kg	10 years 30.5 kg	16 years 46.5 kg	Adult 70 kg
NaF (mg)	424.4	884.2	1308.6	2157.5	3290.3	4951.6
1.1 mg tablets (No.)	386	804	1189	1961	2990	4502
2.2 mg tablets (No.)	193	402	595	981	1495	2251
1.23% F topical gel (ml)	15.6	32.5	48.1	79.3	121.0	182.1
5% SnF ₂ topical gel (ml)	15.9	33.1	48.9	80.7	123.0	185.1
0.2% NaF topical wash (ml)	212.2	442.1	654.4	1078.8	1644.7	2476.0
0.05% NaF mouthwash (ml)	848.8	1768.3	2617.2	4314.8	6578.3	9902.7
50 mg NaF effervescent tablets (No.)	8	18	26	43	66	99
10% SnF ₂ prophylaxis paste (gm)	7.9	16.5	24.5	40.3	61.5	92.6
0.8% MFP toothpaste (gm)	181.9	379.0	560.9	924.7	1409.8	2122.2

*Calculated on a dose of 32 mg F/kg body weight.

4.2.1 Symptoms of Acute Fluoride Poisoning

The symptoms of acute fluoride poisoning usually involve excessive salivation, nausea, cramps in the abdomen and vomiting. Diarrhoea may occur several hours after the ingestion of fluoride compounds. In the early stages of acute fluoride poisoning, highly corrosive hydrofluoric acid may be produced in the stomach and this may damage the gastric mucosa, particularly in infants, resulting in ulceration and haemorrhage. Such damage may lead to the presence of blood in the vomitus. With the absorption of a large amount of fluoride, there will be a sudden drop in blood calcium and this may precipitate muscle excitability, hyperactive reflexes, painful spasms, weakness and tetanic contractures. Respiration may also be stimulated at least initially, but in extreme cases respiration will subsequently be depressed (Spoerke et al 1980). As the condition becomes critical with large doses, there may also be a fall in blood pressure possibly due to central vasomotor depression as well as a direct toxic effect on cardiac muscle. When death occurs, it is usually a result either of respiratory depression or cardiac failure. Hodge (1965) stated that patients surviving for four or more hours have a much improved prognosis because fluoride is rapidly excreted in the urine, thereby continuing to decrease blood and tissue concentrations below fatal levels.

4.2.2 Management of Acute Fluoride Poisoning

Different individuals will respond differently to a given dose of fluoride. The primary objective following the ingestion of a large dose of fluoride is to prevent the absorption of the fluoride from the gastrointestinal tract. This is best achieved by firstly inducing vomiting, for example, with 10-15ml of ipecacuanha syrup or by physical means. Induced vomiting is contraindicated if the patient is comatose, convulsing, or has lost the gag reflex. Following induced vomiting, treatment should be directed towards binding as much of the residual fluoride as possible with calcium, for example, by having the patient drink milk, lime water (0.15% calcium hydroxide), or calcium chloride solution (5ml per litre of water). Following this regimen, medical advice should be sought and if necessary the child should be hospitalized for further management and observation.

5 BENEFITS OF FLUORIDATION ALTERNATIVES

A benefit is an axiological concept representing anything received that causes a net improvement to occur to the recipient (Rowe, 1977). When a patient seeks care, it is with the expectation of receiving a benefit (Levine 1981). In the case of fluoride therapy, the traditional and most direct benefit is the prevention of dental caries.

Baylink et al (1983) reported controlled fluoride ingestion may be beneficial to bone metabolism in both healthy and diseased individuals. In addition to obvious treatment benefits, there are also economic and psychosocial ones associated with fluoride therapy.

Recent research has increased our understanding of the nature of the caries lesion to include processes of both demineralization and remineralization (Silverstone, 1985). With this expanded interpretation of the dynamics of caries formation is a broader recognition of the benefits provided by various types of fluorides. In addition to the prevention of lesions, fluoride is believed to be important in the arrest and reversal of incipient lesions. Thus, the benefits of the use of fluorides includes not only preventing a disease, but also treating it.

In this section, the effectiveness of caries reduction of various types of fluoridation alternatives are discussed. The cost-benefit and cost-effectiveness analysis are also included.

5.1 ANTICARIOGENIC EFFECTIVENESS OF FLUORIDATION ALTERNATIVES

5.1.1 Anticariogenic Effectiveness of School Water Fluoridation

Horowitz et al (1972) reported that 40% fewer DMF surfaces was found in Elk Lake, Pennsylvania, USA, after 12 years of school fluoridation at 5ppm, (4.5 times the optimum recommended for community fluoridation). The results showed a different effectiveness according to the time of tooth eruption (Table 13). Earlier erupting teeth that were already in place when the children began to attend school showed 31% fewer DMF surfaces. Whereas surfaces of later erupting teeth that received both topical and systemic exposure to the fluoridated water developed 57% fewer DMF surfaces. The rate of extractions per 100 teeth decreased by 65% during the 12-year period of study and no objectionable dental fluorosis resulted from the procedure.

Heifetz et al (1978) carried out another study of school fluoridation at 6.3ppm in Seagrove, North Carolina, USA. After eight years of school fluoridation at seven times the recommended optimum for community fluoridation produced only marginally greater benefits than at 4.5 times the recommended concentration.

One major disadvantage of school fluoridation is that its implementation is limited to geographic areas where both school and home water supplies of the school children have uniformly low concentrations of fluoride. If some students drink nearly optimal concentration of fluoride in water at home and others only trace levels, it is impossible to determine the proper concentration for the school water supply.

TABLE 13: Average DMF surface scores by eruptive status among school children in Elk Lake, PA. Before (1958) and after 12 years (1970) of school fluoridation.

SOURCE: Stallard 1982. p158

YEAR	DMFS		
	IN ALL TEETH	IN EARLY ERUPTING TEETH	IN LATE ERUPTING TEETH
1958 (N=1030)	13.51	9.03	4.47
1970 (N=1149)	8.13	6.23	1.91
% Diference from 1958	40	31	57

5.1.2 Anticariogenic Effectiveness of Fluoride Tablets and Drops

Summaries of 20 trials into the effect of fluoride tablets or drops on the deciduous dentition are given in Table 14. The initial age of the subjects and the length of time the tablets were taken varied, making it difficult to draw conclusions on the effectiveness accurately. Nevertheless, it would appear that a 50-80% caries-preventive effect was consistently observed in studies where the initial age was two years or younger. In the three studies in which no effect was found, the children were initially aged three years or older.

Granath et al (1978) suggested that while buccolingual surfaces may benefit if the commencement age is over two years, the effect on approximal surfaces is very much less if the commencement age is two years or over. This suggests that the topical effect is greater on the more exposed buccolingual surfaces than on the accessible approximal surfaces.

Summaries of 32 trials into the effectiveness of fluoride tablets in preventing caries in the permanent dentition are given in Table 15.

In four studies where fluoride tablets were taken from birth to at least seven years, reductions ranged from 39% to 80%.

Thylstrup et al (1979) examined the 7-year-old children who had received a total 0, 1-800, 800-1600 and more than 1600 0.25mgF tablets (one per day) shortly after birth. A significant inhibition of dental caries in the primary dentition was recorded only for those who, in

TABLE 14: Caries-preventive effects of fluoride tablets on deciduous teeth.

Source: Murray 1986. p86

Study	F compound ^b	Daily dosage (mg)	Initial age of subjects (years)	No. of subjects in F group	Duration of F intake (years)	Caries reduction (%) ^c		Statistical significance
						deft	deft	
Arnold et al. (4)	NaF	0.5-1	Birth-6	121	1-12	Comparable to water F		NR
Pollack (46)	NaF+V	1	3	100	2	80		NR
	NaF+V	1	4	111	2	20		NR
Ziemnowicz-Glowaka (58)	NaF	0.8	3	139	2		26	NR
Lutomska & Kominska (39)	NaF	0.6	3-4	154	2	No significant effect		NR
Kamocka et al. (33)	NaF	0.75 ^e	3	64	3	0		NS
	NaF	0.75 ^e	4	79	3	0		NS
Leonhardt (38)	NaF+V	1+	3	Not known	2	38		NR
	NaF+V	1+	4	Not known	2	30		NR
Hennon et al. (24-26)	NaF+V	0.5-1	Birth-5½	85	3		63	S
	NaF+V	0.5-1	Birth-5½	54	4		68	S
	NaF+V	0.5-1	Birth-5½	60	5		66	S
Margolis et al. (40)	NaF+V	0.5-1	Birth	149	4-6	76		S
	NaF+V	0.5-1	4	77	0-2	29		NS
Hoskava (30)	NaF	0.25-1	Prenatal	78	4	93		S
	NaF	0.25-1	Birth-1	151	4	54		S
Kailis et al. (32)	NaF	?	Prenatal	50	4-6	82		S
	NaF	?	Birth	92	4-6	56		S
Stolte (54)	?	1	3	130	3	11		NR
Prichard (47)	NaF	?	Prenatal	176	6-8	70		S
	NaF	?	Birth	282	6-8	40		S
Hamberg (21)	NaF+V (drops)	0.5	Birth	342	3	57		NR
	NaF+V (drops)	0.5	Birth	342	6	49		NR
Kraemer (34)	CaF ₂	1	4	170	2	22		NR
	CaF ₂	1	5	82	2	18		NR
Schützmannsky (50)	NaF	1	Prenatal	100	1	13		S
	NaF	0.25-1	Prenatal	100	9	30		S
	NaF	0.25-1	Birth	100	9	14		S
Aasenden & Peebles (1)	NaF+V ^f	0.5-1	Birth	87	8-11		78	S
Fanning et al. (17)	NaF	Not	1	581	5	33		NR
Andersson & Grahnén (3)	NaF	0.25-0.5	1	127	5 ^g	31		S
Hennon et al. ^h (27)	NaF+V	0.5-1	1	44	5		47	S
	NaF+V	0.5	1	47	5		37	S
Granath et al. (19)	NaF	0.25-0.5	2	48	2-4		46 BL	NS
							51 AP	S
	NaF	0.25-0.5	2-3	123	1-2		33 BL	NS
							1 AP	NS

^a Based on Driscoll (10) and Binder et al. (7).^b V-vitamins.^c BL-buccolingual; AP-approximal surfaces.^d S-statistically significant; NS-statistically non-significant; NR-no statistical test reported.^e Tablets given only on school days.^f A NaF+V combination was given up to 3 years of age. Beyond this age, some children received NaF+V, while others received only NaF.^g Aged 8-10 years at examination.^h In area with 0.8-0.8 mg of F⁻/litre in the water supply.

TABLE 15: Caries-preventive effects of fluoride tablets on permanent teeth.

Source: Murray 1986. p88

Study	F compound ^b	Daily dosage (mg)	Initial age of subjects (years)	No. of subjects in F group	Duration of F intake (years)	Caries reduction (%)		Statistical significance
						DMFT	DMFS	
Stones et al. (55)	NaF	1.5	6-14	125	2	0		NS
Bibby et al. (6)	NaF	1	5-14	133	1			NR
	NaF	1	5-14	119	1		Nil Tentative finding: "possible"	NR
Niendenthal (44)	NaF	1 ^d	6-7	251	3	22		NR
Wrzodek (56)	NaF	1 ^d	6-9	8381	3	21		NR
	NaF	1 ^d	6-9	13585	4	22		NR
Arnold et al. (4)	NaF	0.5-1	Birth-6	121	1-15	Comparable to water F		NR
Krusic (35)	CaF ₂	Not known	8-15	480	1-3	70		NR
Pollack (46)	NaF + V	1	6-7	300	2	38		NR
Ziemnowicz-Glowaka (58)	NaF	0.8 ^d	3-6	704	2		33	S
	NaF	0.8 ^d	5-6	204	3		28	S
Jez (37)	CaF ₂	Not known	7-11	7200	2½	0		NR
Krychalska-Karwan & Laskowa (36)	NaF	Not known	Grammar school	134	4		5	NR
Minoguchi et al. (42)	NaF + V	0.25	Birth-6	75	6	36		NR
Grissom et al. (20)	NaF	1 ^d	6-11	178	2		34	S
Kamocka et al. (33)	NaF	0.75 ^d	3	64	3	17		NS
	NaF	0.75 ^d	4	79	3	60		S
Leonhardt (37)	NaF	1	6	398	4	32		NR
Hippchen (28)	NaF	1	7	429	3	25		NR
	Not known	1	6	500	3	32		NR
Schützmannsky (49)	NaF	0.75 ^d	6	580	4		25	NR
Berner et al. (5)	NaF	0.75 ^d	6	197	6		27	NR
	NaF	0.5-1 ^d	5-7	105	3		84	NR
							(except 1st molar)	
							...33...	NR
							(1st molar)	
De Paola & Lax (9)	NaF	1 ^d	7-9	158	4	16		NR
	NaF	1 ^d	7-9	160	6	20		NR
	NaF	1 ^d	7-9	109	7	24		NR
	APF	1 ^d	6-8	130	2		23	S
Giradi-Vogt (18)	NaF	1	6	Not known	3	31		NR
Stolte (54)	Not known	1	3	150	3	69		NR
Marthaler (41)	NaF	0.5-1 ^d	7	450	1-8	36	47	S
Hamberg (27)	NaF + V	0.5	Birth	342	7	70		NR
Schützmannsky (50)	NaF	1	Prenatal	100	1	6		NS
	NaF	0.25-1	Prenatal	100	9	43		S
	NaF	0.25-1	Birth	100	9	39		S
Aasenden et al. (2)	APF	1 ^d	8-11	109	3		30	S
	NaF	1 ^d	8-11	114	3		27	S
Plasschaert and König (45)	NaF	1	7	208	2		38	S
Aasenden & Peebles (7)	NaF + V ^e	0.5-1	Birth	100	8-11		80	S
Binder (7)	NaF	0.25-1	Birth-14	3084	8-14	43		S
Margolis et al. (40)	NaF + V	0.5-1	Birth	56	7-10	58		S
	NaF + V	0.5-1	4	31	3-6	14		NS
Andersson & Grahnén (3)	NaF	0.25-0.5	1	127	5 ^f		40	S
Stephen & Campbell (52)	NaF	1 ^d	5 1/2	54	3		81	S
Driscoll et al. (12)	APF	1 ^d	6-7	150	6		28	S
	APF	2 ^d	6-7	135	6		29	S

^a Based on Driscoll (10) and Binder et al. (8).

^b V-vitamins

^c S-statistically significant; NS-statistically non-significant; NR-no statistical test reported.

^d Tablets given only on school days.

^e A NaF + V combination was given up to 3 years of age. Beyond this age, some children received NaF + V, while others received only NaF.

^f Aged 8-12 at examination.

total, received from than 1600 tablets and used them continuously through the years. No difference in caries was observed in the permanent dentition.

In the four studies conducted in school (initial age 6-7 years) and lasting at least five years, the following reductions in caries have been reported: 27% (Schützmannsky 1965), 20-24% (Berner et al 1967), 36% (Marthaler 1969) and 28-29% (Driscoll et al 1978). The only study conducted in the UK was by Wei and Campbell (1978) where an 81% reduction was reported after a 3-year trial in Glasgow children initially aged 5½ years old.

Widenheim et al (1986) evaluated the preeruptive effect of NaF tablets on caries in proximal surfaces of permanent molars and premolars. The material consisted of 47 subjects who had consumed fluoride tablets for a minimum of five years between ½ and 6 years of age in accordance with recommendations from the National Swedish Board of Health and Welfare (F⁺-group) and 69 comparable children who had never consumed such tablets (F⁻-group). Two confounding factors, ie, salivary counts of *Streptococcus mutans* and *Lactobacilli*, were estimated and used for correction of crude caries differences. The results showed a statistically significantly higher caries prevalence in the F⁻-group compared to the F⁺-group when the children were 14-yr-old, 4.4 VS 2.9 DFS, corresponding to a caries reduction of about 34%. After correction for confounding, this was reduced to 24%, representing a non-significant difference of 1.1 DFS but still indicating preeruptive effect. At age of 17, the difference in caries prevalence was statistically not

significant, 7.1 VS 5.6 DFS. A main finding was that the caries reduction diminished with time.

Although the anticariogenic effectiveness of fluoride tablets or drops is encouraging, it has been generally claimed that fluoride tablets can only be of very limited use because it demands continuous effort on the part of the parents.

Seow et al (1986) reported that there had been a decline in the use of fluoride tablets in recent years in Brisbane, the only non-fluoridated capital city in Australia. A similar decrease was also recently reported in Sweden (Widenheim 1982). Several reasons may account for this decline in the use of fluoride tablets, such as the difficult problems of ignorance, inconvenience, cost and patient non-compliance. These problems are even more compounded in the low socio-economic groups where lower educational levels, incomes and poorer attitudes of the parents may lead to less knowledge and acceptance of fluoride tablets compared with the high socio-economic groups. Also, changes in attitude to fluoride tablets may have occurred amongst dental or other health professionals due to increasing concern over dental fluorosis (Aasenden & Peebles 1974, Silverstein 1983) as well as the awareness of rinsing background levels of fluoride and the decreased levels of caries prevalence in the younger age groups (Carr 1983). These changes in attitude of health professionals may lead to less promotion of fluoride tablets than previously.

5.1.3 Anticariogenic Effectiveness of Salt Fluoridation

Most experiences with salt fluoridation has been accumulated in Switzerland. By 1977, 77% of salt purchased for the domestic population of 5.5 million contained 90mgF/kg salt.

However, it was soon accepted that the original estimates of salt intake, upon which calculations of fluoride concentrations in salt were based, were too high and the ingestion of fluoride too low. In more recent investigations the level of fluoride has been raised to 200, 250 and 350mgF/kg salt.

Marthaler et al (1978) concluded that the caries-preventive effectiveness of 250mgF/kg salt used in the Swiss canton of Vaud was greater than the 25% reduction observed following the addition of 90mgF/kg in other Swiss cantons.

Toth (1976) reported the effectiveness of 250mgF/kg salt fluoridation in Hungary after eight years' use. The results (Table 16) indicated a reduction of 39% in deft in 6-year-old children in the test community, while caries experience increased by 7% in the control community children over the same period. Toth (1978) observed that 5-to-6-year-olds in the same test community had 2.8 deft, compared with 6.0 deft in the control community, and 1.4 deft in children of the same age living in a fluoridated area. These results indicated that a substantial caries reduction occurred after the introduction of salt fluoridation, but this was less than occurred with water fluoridation.

TABLE 16: Caries experience (deft) for 6-year-old children living in test and control communities in Hungary after 8 years' salt fluoridation (at 250mgF/kg)

SOURCE: Murray and Rugg-Gunn 1982. p79

	EXPERIMENTAL	CONTROL
1964	6.8	8.6
1974	4.1	9.2
DIFFERENCE	-2.7 (-39.5%)	+0.6 (+7.1%)

In 1964, a study was initiated in four Columbian communities (Mejia et al 1976). In the village of Montebello, NaF was added to domestic salt (at 200mgF/kg), while in Armenia CaF₂ was added to domestic salt (at 200mgF/kg), in San Pedro drinking water was fluoridated at 1ppm and Don Matias remained as the control community. After eight years' study, the reduction in DMF between 1964 and 1972 was 50% in Montebello (NaF in salt), 48% in Armenia (CaF₂ in salt), 60% in San Pedro (water fluoridation) and 5% in the control town Don Matias (Table 17).

TABLE 17: Comparison of DMFT mean and percentage difference between the baseline figures (1964) and the final examination (1972) in four Colombian communities.

SOURCE: Murray 1986. p76

Age (years)	Armenia				Montebello				Don Matias				San Pedro			
	DMF		% Differ- ence		DMF		% Differ- ence		DMF		% Differ- ence		DMF		% Differ- ence	
	1964	1972	1964	1972	1964	1972	1964	1972	1964	1972	1964	1972	1964	1972	1964	1972
6	0.71	0.35	50.70		0.75	0	100.00		1.00	0.93	7.00		1.13	0.23	79.64	
7	2.33	0.36	84.55		2.35	0.60	74.47		2.29	2.62	-14.41		2.40	0.35	85.41	
8	3.71	1.43	61.45		3.80	1.05	72.37		4.33	3.75	13.39		3.75	0.83	77.86	
9	5.26	2.05	61.02		3.86	1.86	51.81		5.31	5.15	3.01		4.66	1.59	65.88	
10	5.70	2.47	56.66		5.33	2.23	58.16		6.96	6.91	0.72		6.21	2.91	53.14	
11	9.73	3.97	49.93		7.08	3.63	48.73		9.93	10.13	-2.01		7.80	3.65	53.20	
12	9.44	4.96	47.76		8.59	4.50	47.61		10.72	11.03	-2.89		9.48	4.10	56.75	
13	12.29	7.33	40.36		10.54	5.38	48.95		13.08	14.26	-9.02		11.05	6.47	41.45	
14	9.68	8.15	15.80		9.60	7.44	22.50		15.57	16.43	-5.52		12.89	7.23	43.91	
Total	6.74	3.48	48.37		6.30	3.17	49.68		8.63	8.24	4.52		6.65	2.66	60.00	

5.1.4 Anticariogenic Effectiveness of Milk Fluoridation

There are few clinical longitudinal studies on the effect of fluoridated milk. Imamura (1959) in Yokohama, Japan, added 2-2.5mgNaF to milk or soup served daily in school meals. After four years a 36.3% caries reduction was observed in the fluoride group. Rusoff et al (1962) in the USA examined 65 children, aged 6-9 years at the beginning of the experiment and after 3½ years' consumption of school milk containing 3.5ppm fluoride. The caries reduction was 35% in the whole group and 76% for subjects aged six years at the beginning of fluoridation. Wirz (1964) and Ziegler (1964) in Switzerland distributed milk containing 1ppmF to 749 test children, using 553 children as controls, whose age at the beginning of the experiment was between 9-44 months. The caries reduction after six years ranged from 14.8% to 31.5% in the primary teeth and about 64.2% to 65.2% in permanent molar teeth. Banoczy et al (1983) in Hungary, distributed 0.4mgF to 3-5 year age group and 0.75mgF to 6-9 years group. The caries reduction in 3-5 years old group after 3 years was 74% and statistically significant ($p < 0.001$).

In children 7-9 years old the caries reduction of the permanent first molar was less and statistically not significant. A slight reduction of DMFS mean values in the front teeth of this group could be observed. Stephan et al (1981) using adequate pretrial stratification and double blind methodology, supplemented 200ml school milk daily with 1.5mgF (7 parts/ 10^6) supplied to 94 test children for 200 days per annum, using 93 children as controls. All children were aged 4.5-5.5 years at the beginning of the experiment. After five years 50 test and 56 control children could be re-examined. Significant differences with 31.2% DMFT

and 43.1% DMFS reductions in permanent tooth caries incidence were obtained.

Legett et al (1987) carried out a two and three year study to examine the effect of chocolate-flavoured milk in the caries incidence of elementary school children. For the two year group, 77.2% fewer decayed teeth and 76.6% reduction in decayed surfaces were obtained. But analysis of data for the three-year group did not show significant differences between test subjects and control subjects.

5.1.5 Anticariogenic Effectiveness of Fluoride Mouthrinses

Sodium fluoride has been the most frequently tested fluoride compound, such solutions would tend to have a neutral pH. Table 18 is the summary of clinical trials of neutral sodium fluoride mouthrinses from 1971-1982. Table 19 summarizes the results of two clinical trials which direct comparisons were made of the efficacy of daily acidulated phosphate fluoride (APF) and neutral pH rinses, which contained equal concentrations of fluoride ion. There was no significant advantage to the use of APF in these studies, and poor acceptance of the taste of the acidulated rinse was reported. Frankl et al (1972) supported the conclusion that APF rinses have the same degree of cariostatic activity as neutral pH rinses.

Table 20 shows the results of two clinical trials in which daily stannous fluoride rinses were tested at concentration of 100, 200 and 250ppm. Compared to placebo-treated control children, those rinsing with stannous fluoride developed about 20-40% fewer caries lesions during the trials, or about the same level of protection given by daily or weekly rinsing with sodium fluoride. Thus, the available clinical indicates that the anticaries effect of stannous fluoride rinses is roughly the same as that of sodium fluoride rinses.

Ringelberg et al (1979) reported that amine fluoride rinses showed no superiority over neutral sodium fluoride rinses when used according to the same regimen. In summary, alternative compounds to NaF have a less pleasant taste and have not been shown to be more effective than neutral NaF solution. Sodium fluoride, therefore, is the compound of choice at present.

TABLE 18: Results of clinical trials of mouthrinsing with neutral sodium fluoride solutions.

SOURCE: Wei 1985. p77-78

Study	F Concentration (ppm)	Rinsing Frequency	Age at Base-line	Number Completing Trial	Length of Trial (Months)	DMFS Caries Increment			% Difference
						Control	Test	Δ	
Horowitz et al. (1971) ¹⁰	900	1/week S	6	129	20	1.3	1.1	0.2	16
(Same trial)	900	1/week S	11	117	20	2.9	1.7	1.2	44
Brandt et al. (1972) ¹¹	900	2/week S	11-12	94	21	7.0	4.0	3.0	43
Moreira & Tumang (1972) ¹²	450	3/week S	7	50	24	7.5	4.0	3.5	47
(Same trial)	450	1/week S	7	50	24	7.5	5.7	1.8	25
(Same trial)	450	1/2 week S	7	50	24	7.5	5.8	1.7	23
Aasenden et al. (1972) ¹³	200	1/day S	8-11	114	36	12.3	9.0	3.3	27
Heifetz et al. (1973) ¹⁴	3000	1/week S	10-12	126	24	7.5	4.7	2.8	38
Rugg-Gunn et al. (1973) ¹⁵	225	1/day S	11-12	222	34	10.2	6.6	3.6	36
Gallagher et al. (1974) ¹⁶	1800	1/week S	10-11	306	24	4.4	2.9	1.5	34
Maiwald & Padron (1977) ¹⁷	900	1/2 week S	6	100	88	11.6	5.1	6.5	56
DePaola et al. (1977) ¹⁸	1000	1/day S	10-12	158	24	7.6	4.4	3.2	41
Ripa et al. (1978) ¹⁹	900	1/week S	7-12	750	24	3.2	2.6	0.6	20
Ringelberg et al. (1979) ²⁰	250	1/day S	11	179	30	6.3	4.8	1.5	23
Heifetz et al. (1982) ²¹	900	1/week S	10-12	97	36	3.6	2.3	1.3	38
	900	1/week S	10-12	102	36	4.4	3.4	1.0	24
(Same trial)	225	1/day S	10-12	88	36	3.6	1.9	1.7	47
	225	1/day S	10-12	107	36	4.4	2.9	1.5	34
Driscoll et al. (1982) ^{*22}	900	1/week S	12-13	81	30	2.6	2.0	1.6	22
	900	1/week S	12-13	81	30	1.9	0.9	1.0	55
(Same trial)	225	1/day S	12-13	102	30	2.6	1.9	0.5	28
	225	1/day S	12-13	102	30	1.9	0.9	1.0	50

S = School only

*0.84 ppm F in drinking water

TABLE 19: Results of clinical trials comparing neutral and acidulated phosphate fluoride mouthrinses.

SOURCE: Wei 1985. p79

Study	F Concentration		Rinsing Frequency	Age at Base-line	Number Completing Trial	Length of Trial (Months)	DMFS Caries Increment			% Difference
							Control	Test	Δ	
Aasenden et al. (1972) ¹³	200	NaF	1/day S	8-11	114	36	12.3	9.0	3.3	27
	200	APF	1/day S	8-11	109	36		8.7	3.6	
Heifetz et al. (1973) ¹⁴	3000	NaF	1/day S	10-12	126	24	7.5	4.7	2.8	38
	3000	APF	1/day S	10-12	133	24		5.5	2.0	27

S = School only

TABLE 20: Results of clinical trials of mouthrinsing with stannous fluoride solutions.

SOURCE: Wei 1985. p79

Study	F Concentration (ppm)	Rinsing Frequency	Age	Number Completing Trial	Length (Months)	DMFS			% Difference
						Control	Test	Δ	
McConchie, et al. (1977) ²⁸	100	1/day S	10	199	36	5.8	4.6	1.2	20
	200	1/day S		204	36	5.8	4.8	1.0	17
Radike, et al. (1973)* ²⁹ (Examiner #2)	250	1/day S	8-13	348	20	3.0	2.0	1.0	33
						2.8	1.6	1.2	43

S = School only

*Fluoridated water supply

In 1975, a weekly fluoride mouthrinsing programme was initiated in the Three Village Central School District, Long Island, New York. After two years, a 20% reduction in caries prevalence (dfs/child) of the primary teeth was reported. After three years of rinsing, however, the reduction in caries prevalence for the permanent teeth was 40% compared to only 17% for the primary teeth in the same children. The results indicate that the effect of topical fluoride therapy to the primary teeth is less than that for the permanent teeth.

Stannous fluoride, acidulated sodium fluoride and neutral sodium fluoride mouthrinses have been tested in children residing in communities with optimal water fluoridation. The results of their studies, presented in Table 21 suggest that an additive effect can be realized from fluoride rinsing by children already benefiting from community water fluoridation. This impression is further substantiated by the finding of De Paola and co-worker (1977), who found that children with prior exposure to systemic fluoride had the same percentage of caries reduction when either an acidified sodium fluoride or an ammonium fluoride mouthrinse was used, compared to children with no history of systemic fluoride exposure.

Leske and co-workers (1985) reported that the benefits of fluoride mouthrinsing persist after children discontinue their participation in a school-based fluoride mouthrinsing programme. After participation in the programme for six to seven years (179-203 scheduled rinses) followed by discontinuation of rinsing for six months to 2½ years, there was a 57.1% reduction in the DMFS prevalence. The greatest percentage reduction, 81.3%, occurred on proximal surfaces. The post

TABLE 21: Effect of fluoride mouth rinses on the permanent teeth of children residing in optimally fluoridated communities.

SOURCE: Mellberg and Ripa 1983. p253

Study	Initial age (years) of subjects	Type of rinse	Rinsing frequency	Duration of study	Percent reduction DMFT DMFS
Radike et al.	8-13	0.1% SnF ₂	once/day	20 months	33-43*
Laswell et al	8-9	0.044% NaF APF, pH 4	once/day	28 months	23
	8-9	0.25% NaF APF, pH 4	once/week	28 months	46
Heifetz et al.	10-11	0.2% NaF + APF gel-tray**	once/week	30 months	30

*Two examiners.

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

treatment caries protective benefit of fluoride mouthrinsing increased directly with the duration of past participation in the programme.

Haugejorden et al (1985) compared caries prevalence in two groups of 21 years old, 6-7 years after discontinuation of school-based preventive programmes consisting respectively of fortnightly rinsing or brushing 3-5 times per year with NaF solutions. The results revealed significantly lower means DMFS score in the rinsing than in the brushing group ($p < 0.001$).

5.1.6 Anticariogenic Effectiveness of Fluoride Toothpaste

Clinical trials of toothpaste containing sodium fluoride, acidulated phosphate fluoride, stannous fluoride and sodium monofluorophosphate are listed in Tables 22, 23, 24 and 25. From the 93 clinical trials, up to 1981, the effectiveness of fluoride-containing toothpaste on caries reduction have been justified.

Glass (1981) carried out a clinical trial using 0.76% sodium monofluorophosphate (NaMFP) in a calcium carbonate base. Regular use by children of this toothpaste resulted in significantly lower (44%, $p < 0.01$) caries increments than those observed for the control group. The reduction in caries incidence during the study period was so great that it resulted in a significant reduction in caries prevalence at the end of 30-month brushing period (31%, $p < 0.01$).

Rule et al (1984) carried out a double blind clinical trial to determine the anticaries activity of a toothpaste containing 0.78% sodium monofluorophosphate in a silica gel abrasive base compared with a placebo under conditions of supervised brushing. After 12 months, the 996 subjects examined showed that the group using the test toothpaste had significantly ($p < 0.05$) lower DMFT (25%) and DMFS (19.1%) increments than the group using the placebo. After 24 months the 876 subjects examined showed that the test group continued to have significantly lower DMFT (24.5%) and DMFS (24.7%) increments than the placebo group. Surface protection after 24 months ranged from 22.1% for occlusal to 37.1% for interproximal surfaces.

Hanachowicz (1984) carried out a 3-year clinical trial in France just after fluoride toothpaste was allowed to be sold on the mass market. The mean caries reduction, after using 1.2% sodium monofluorophosphate (NaMFP) toothpaste in an aluminium oxide trihydrate base, were found: 26% for DMFT, 27% for DMFS and 39% for DMFS. The DMFS index for approximal, buccal-lingual and occlusal surfaces showed caries reductions of 32%, 25% and 22%, respectively. The trial demonstrated a highly significant effectiveness of 1.2% NaMFP toothpaste in a French population.

Ripa et al (1987) made a clinical comparison on the caries-inhibiting effect of two mixed $\text{NaF-Na}_3\text{PO}_3\text{F}$ toothpaste containing 1000 and 2500ppmF compared to a conventional $\text{Na}_2\text{PO}_3\text{F}$ toothpaste containing 1000ppmF. Results showed that the use of a mixed fluoride toothpaste ($\text{NaF/Na}_3\text{PO}_3\text{F}$) at a standard 1000ppmF concentration or at 2.5 times standard did not provide superior caries inhibition compared to a conventional $\text{Na}_3\text{PO}_3\text{F}$ toothpaste containing 1000ppmF.

TABLE 22: Clinical trials of sodium fluoride dentifrices

SOURCE: Murray and Rugg-Gunn 1982. p102-103

Investigators	% NaF + Abrasive		Unsupervised (U) or supervised (S) use	Duration of trial	No. of carious surfaces saved per year	Reduction in carious surface increment (%)	Level of statistical significance
Bibby (1945)	0.1	CaCO ₃	S	2 years	—	—	—
Winkler et al. (1953)	0.1	CaCO ₃	U	2 years	—	—	—
Muhler et al. (1955b)	0.15	CaCO ₃	S	18 months	—	—	—
Kyes et al. (1961)	0.22	Heat-treated Ca ortho- phosphate IMP + 5% anhydrous DCP	U	1 year	—	—	—
Torell and Ericsson (1965)	0.2	NaHCO ₃	U	1 year	—	—	—
Brudevold and Chilton (1966)	0.24		U	2 years	1-2	—	0.01
Peterson and Williamson (1968)	0.22	IMP	U	2 years	—	—	0.01
Koch (1967a)	0.22	Sec. Ca phosphate	U	2 years	—	—	0.05
Koch (1967b)	0.22	IMP	U	2 years	0.6	14	0.05
Weisenstein and Zacherl (1972)	0.22	Acrylic	S	3 years	3.2	40-48	0.001
Zacherl (1972a)	0.22	Acrylic	U	2 years	2.1	38	0.01
Reed (1973)	0.22	CaPP	U	21 months	0.7	25	0.05
	0.22	CaPP	U	20 months	1.1	28	0.05
	0.055	CaPP	U	2 years	0.15	7.5	
	0.11	CaPP	U	2 years	0.2	8.5	
	0.22	CaPP	U	2 years	0.4	20.0	0.05
Forsman (1974)	0.05	SiO ₂	U	2 years	0.2*	10-17*	NS
					0.8†	5-48†	NS
Stookey and Beiswanger (1975)	0.22	CaPP	U	27 months	0.8	25	0.05
Gerdin (1975)	0.22 (NaF)	Acrylic	S	2 years			'Test significantly better than control'
	0.24 (KF)	Acrylic	S				
Reed and King (1975)	0.22	CaPP	U	2 years	0.65	30	0.05
Edlund and Koch (1977)	0.22	SiO ₂	S	3 years	0.8	23**	0.05
Ennever et al. (1980)	0.22	CaPP	U	28 months	0.60	37	0.05
	0.22	CaPP			0.53	34	0.05
Zacherl (1981)	0.24 (pH 10)	SiO ₂	U	3 years	0.82 (0.35†)	41 23†	0.05
Beiswanger and Gish (1981)	0.24	SiO ₂	U	3 years	(0.22†)	15†	0.05

IMP, Insoluble metaphosphate; DCP, Dicalcium phosphate.

* Clinical examination.

† Radiographic examination.

** Versus MFP positive control. Placebo not included.

‡ Against SnF₂ positive control.

TABLE 23: Clinical trials of acidulated phosphate fluoride dentifrices

SOURCE: Murray and Rugg-Gunn 1982. p106

Investigators	Active ingredient (%conc.)	Abrasive system	pH	Duration (yrs)	Age	Use	Statistically significant reductions surfaces		
							saved	% redn	P
Brudevold and Chilton (1966)	0.22% NaF + 1.5% soluble orthophosphate	IMP	4.8-5.3	2	11-17	U	1-2	*	0.01
Peterson and Williamson (1968)		IMP	4.8-5.3	2	9-15	U	1	*	*
Slack et al. (1971)		IMP	*	3	11-12	U	—	—	—
Zacherl (1972b)		Calc. pyro.	5.5	1 $\frac{2}{3}$	7-14	U	—	—	—

U, Unsupervised use. * Information not given in paper.

TABLE 24: Clinical trials of stannous fluoride dentifrices

SOURCE: Murray and Rugg-Gunn 1982. p108-109

Investigators	% SnF ₂ + Abrasive		Unsupervised (U) or supervised (S) use	Duration of trial	No. of carious surfaces saved per year	Reduction in carious surface increment (%)	Level of statistical significance
Muhler et al. (1955a)	0.4	CaPP	U	1 year	1.48	49	0.0001
Muhler et al. (1955b)	0.4	CaPP	U	1 year	0.87	36	0.013
Muhler and Radike (1957) (Adults)	0.4	CaPP	U	2 years	0.84	34	0.005
Jordan and Peterson (1959)	0.4	CaPP	U	2 years	0.28	13	NS
			S	2 years	0.46	21	0.01
Muhler (1961)	0.4	CaPP	U	3 years	0.6	63*	0.0001
Kyes et al. (1961) (Adults)	0.4	CaPP	U	2 years	0.18	8	NS
Bixler and Muhler (1962)	0.4	CaPP	U	8 months	1.8	45	0.006
Muhler (1962a)	0.4	CaPP	U	3 years	0.41	22	0.0062
Muhler (1962b)	0.4	CaPP	S	2 years	1.2	46	—
Finn and Jamison (1963)	0.4	CaPP	S	2 years	No true placebo	No true placebo	—
Slack and Martin (1964)	0.4	IMP	U	Planned 3–4 years		Trial not completed	—
Gish and Muhler (1965)	0.4	CaPP	U	1 year	1.67–3.46	71**	0.00001
Torell and Ericsson (1965)	0.4	CaPP	U	2 years	1.16	22	0.01
Bixler and Muhler (1966)	0.4	CaPP	U	3 years	0.58 0.97	37† 58**	0.00001 0.00001
Brudevold and Chilton (1966)	0.4	IMP	U	2 years	1.08	25	0.05
	0.4	CaPP		2 years	0.2	4	NS
Halikis (1966)	0.4	IMP	U	15 months	1.04	27	0.07
Horowitz et al. (1966)	0.4	CaPP	U	3 years	0.33	17	0.01
	0.4	CaPP	S	3 years	0.42	21	0.01
Thomas and Jamison (1966)	0.4	CaPP	S	2 years	N/A	36	0.05
	0.4	IMP				37	
Jackson and Sutcliffe (1967)	0.4	CaPP	U	3 years	0.32	12	NS
James and Anderson (1967)	0.4	CaPP	U	3 years	1.22	29	
Muhler et al. (1967) (Adults)	0.4	CaPP	U	30 months	1.0	64**	0.001
Naylor and Emslie (1967)	0.4	IMP	U	3 years	0.49	14.5	0.001
Slack et al. (1967a)	0.4	CaPP	U	3 years	0.2	7	NS
Slack et al. (1967b)	0.4	IMP, SiO ₂	U	3 years	0.0 Clinical 0.3 Radiological	0 28	NS 0.01
Fanning et al. (1968)	0.4	IMP	U	2 years	1.28	21	0.001
Frankl and Alman (1968)	0.4	CaPP	U	3 years	—	No true placebo	NS
Mergele (1968a)	0.4	IMP	S	2 years	0.3	10	0.05
Mergele (1968b) (Water F 1.0 ppm)	0.4	CaPP	U	3 years	0.25	13	NS
Scola and Ostrom (1968) (Adults)	0.4	CaPP	U	2 years	1.13 1.35	42† 48**	0.001 0.001
Muhler (1970)	0.4	CaPP	U	1 year	1.18	29	0.05

TABLE 24 (cont): Clinical trials of stannous fluoride dentifrices

SOURCE: Murray and Rugg-Gunn 1982. p110

<i>Investigators</i>	<i>% SnF₂ + Abrasive</i>	<i>Unsupervised (U) or supervised (S) use</i>	<i>Duration of trial</i>	<i>No. of cariou surfaces saved per year</i>	<i>Reduction in cariou surface increment (%)</i>	<i>Level of statistical significance</i>	
Zacherl and McPhail (1970)	0.4	CaPP	U	30 months	1.0-0.76	40-44	0.05
Gish and Muhler (1971) (F water area)	0.4	CaPP	U	5 years	0.38	29	0.00078
Slack et al. (1971)	0.4	CaPP	U	3 years	0.76	18	0.01
	0.4	IMP	U	3 years	1.0	24	0.01
Zacherl (1972a)	0.4	CaPP	U	20 months	1.1	28	0.05
Zacherl (1972b)	0.4	CaPP	U	2 years	0.94	22	0.00037
Zacherl (1973)	0.4	CaPP	U	2 years	0.75	30	0.05
Beiswanger et al. (1978)	0.4	CaPP	U	2 years	No placebo	No placebo*	0.05
Fogels et al. (1979)	0.4	SiO ₂	U	3 years	0.41	15	0.01
	0.4	CaPP	U	3 years	0.40	15	0.01
Ringelberg et al. (1979)	0.4	CaPP	U	30 months	0.44	18	NS
Lu et al. (1980) (Adults)	0.4	CaPP	U	1 year (continuing)	0.23	33	0.05
Zacherl (1981)	0.4	CaPP	U	3 years	0.44	23	0.05

* Combined with topical F.

† Combined with prophylactic F.

** Combined with prophylactic+topical F.

TABLE 25: Clinical trials of sodium monofluorophosphate dentifrices

SOURCE: Murray and Rugg-Gunn 1982. p113-114

Investigators	% MFP + Abrasive	Unsupervised (U) or supervised (S) use	Duration of trial	No. of carious surfaces saved per year	Reduction in carious surface increment (%)	Level of statistical significance
Finn and Jamison (1963)	0.76 IMP	S	2 years	0.6	26	0.001
Goaz et al. (1963)	6.0 Solution	S	14 months	0.7	39	0.002
Torell and Ericsson (1965)	0.76 CaCO ₃	S	2 years	0.7	25	0.001
Naylor and Emslie (1967)	0.76 DCP + CaCO ₃	U	3 years	0.6	18	0.001
Frankl and Alman (1968)	0.76 IMP	U	3 years	0.6	8	0.05
Fanning et al. (1968)	0.70 IMP	U	2 years	1.2	20	0.001
Mergele (1968a) (Houston)	0.76 IMP	U	3 years	0.3	17	0.05
Mergele (1968b) (Austin)	0.76 IMP	S	22 months	0.6	20	0.001
Møller et al. (1968)	0.76 IMP + DCP	U	30 months	1.0	19	0.001
Kinkel and Stolte (1968)	0.76 IMP + silica	U	2 years	—	33	—
Thomas and Jamison (1970)	0.76 IMP	S	2 years	0.7	34	0.05
Zacherl (1972a)	0.76 Ca pyrophosphate	U	20 months	0.9	23	0.05
Kinkel and Raich (1972)	—	—	2 years	0.7	30.53	0.001
Hargreaves and Chester (1973)	2.0 Al ₂ O ₃	U	3 years	1.1	23	0.01
Lind et al. (1974)	2.0 Al ₂ O ₃	U	3 years	0.9	38	0.001
Andlaw and Tucker (1975)	0.76 Al ₂ O ₃	U	3 years	0.6	19	0.001
Downer et al. (1976)	0.76 IMP + APF topical applications	S	3 years	0.8	31	0.001
Peterson et al. (1975)	0.76 CaCO ₃	S	31 months	0.2	23	0.05
Mainwaring and Naylor (1978)	0.76 IMP	U	3 years	0.6	17	0.01
Shiere (1976)	0.76 CaCO ₃	S	2 years	0.7	23	0.05
Edlund and Koch (1977)	0.76 CaPO ₄ + CaCO ₃	S	3 years	No placebo group; NaF: SiO ₂ -containing dentifrice significantly better		
James et al. (1977)	2.0 Al ₂ O ₃	U	3 years	1.2	30	0.01
Howat et al. (1978)	0.76 Silica gel	S	3 years	0.7	26	0.05
Glass and Shiere (1978)	0.76 CaCO ₃	U	3 years	0.7	28	0.01
Naylor and Glass (1979)	0.76 + 0.13% CaGP	U	3 years	0.9	25	0.01
Hodge et al. (1980)	0.76 Al ₂ O ₃ + 0.1% NaF	S	3 years	0.6	22	0.05
Hodge et al. (1980)	0.76 + 0.1% NaF	S	3 years	0.65	24	0.01
Murray and Shaw (1980)	0.76 Al ₂ O ₃ (Low abrasivity)	U	3 years	0.6	34	0.001
Murray and Shaw (1980)	0.76 Al ₂ O ₃ (Normal abrasivity)	U	3 years	0.5	27	0.001

5.2 COST-BENEFIT and COST-EFFECTIVENESS ANALYSIS

The community will demand a health planner provides the best possible health services for their money. Since the planner will have to decide between various health-care strategies he will have to be able to estimate - (1) the cost of a proposed measure, and (2) the benefit likely to accrue from that measure - both in monetary terms. This is cost benefit analysis and is a well recognized procedure in public health planning. Whereas the cost of operating a preventive programme is largely independent on the caries activity of the population, the programme's benefits are not; the higher the susceptibility to decay, the greater the benefits of prevention.

According to Davies (1974), cost-benefit ratio is defined as the cost of implementation divided by the savings in costs of treatment.

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

A cost-benefit relation of fluoride in public health programmes is illustrated in Table 26. From this table, apart from community water fluoridation, the cost benefit ratios of school fluoridation and fluoride mouthrinsing are favourable.

In caries prevention it is frequently necessary to decide between alternative ways of achieving the same primary objective of caries prevention. It then becomes unnecessary to calculate the benefits in monetary terms and this can then be expressed in terms of the number of caries teeth or surfaces prevented. This is cost-effectiveness analysis which enables the planner to determine the least expensive of

TABLE 26: Benefit-cost relation of fluoride in public health programmes.

SOURCE: Rep. of the Committee of Inquiry into the fluoridation of water supplies, 1979-80, Melbourne, p74-77.

METHOD	ESTIMATE OF EXPECTED CARIES REDUCTION (PERCENTAGE)	APPROXIMATE YEARLY COST PER CHILD (US DOLLARS)	APPROXIMATE BENEFIT COST RATIO
Fluoridation of public water supply	60%	0.20	60.0
Fluoride tablets			
a. home use (daily)	50%	2.92	3.4
b. school use (180 days per year)	36%	1.44	5.0
Fluoride mouthrinsing	35%	0.38	18.4
Fluoridation of school water supply	40%	0.30	26.7

several alternatives of achieving a stated objective. For example, professional applications of topical fluorides are not cost-effective in public health programmes. A far greater number of people can benefit from a weekly fluoride mouthrinse programme than could benefit from a programme of equal cost which used professionals to apply topical fluorides.

For caries prevention, an estimate of efficiency is often obtained by evaluating the costs of various preventive techniques incurred for preventing one surface of tooth decay per child. To be meaningful, a cost-effectiveness analysis must have accurate effectiveness and cost data as inputs. The cost-effectiveness ratio is defined as cost (dollars) of procedure per child per year divided by 1.0 DMF surface saved per child per year.

The most thorough review of cost effectiveness of methods of caries prevention was achieved at a conference in Ann Arbor, Michigan, in 1978. Table 27 is taken from this publication and provides a guide to the order of efficacy of fluoride programmes. Table 28 lists factors which may be excluded from analysis.

Table 27 is compiled with the assumption of a caries increment of two DMFS per child per year in a fluoride deficient area, and the costing is given in US dollars as calculations were made on US wages and material costs. Because disease levels and resources will vary from community to community, a public health planner must estimate cost-effectiveness ratios based as much as possible on local information.

According to Table 27, weekly mouthrinses with 0.2% NaF solution is the most cost-effective methods among the alternative topical fluoride procedures. Most of the mouthrinsing programmes are school based.

Direct costs of school water fluoridation programmes in the US (in 1988 US\$) is shown in Table 29. They include the costs of fluoridators, testing equipment, engineering and installation. Table 30 (Garcia 1989) illustrates the direct annual personnel cost for school water fluoridation programmes in the US.

Costs for the fluoride supplement programmes, and details of the number of employees, type of personnel, and their salaries or wage rates are presented in Table 31 (Garcia 1989).

Direct annual costs of fluoride mouthrinse programmes in the US are shown in Table 32 and Table 33 (Garcia 1989). In Table 33, state five calculated personnel cost based on one-third of the time of one programme coordinator, who was paid \$24,069 annually. Thus, the total personnel cost reported represents approximately 5% of the total programme costs. By contrast, the programme in state 11 functions with a number of field workers, consultants, clerical help and a coordinator. For this programme, a large part of the total direct cost (73%) was due to personnel costs.

Fluoride toothbrushing programmes are quite popular in Scandinavian school systems. In the USA, however, very few states have supervised tooth-brushing with solutions and gels. Alabama has a pilot programme that includes 25 schools with an enrolment of 5000 children. A similar

TABLE 27: Ranking of alternative fluoride therapies according to estimated cost-effectiveness

SOURCE: Murray and Rugg-Gunn 1982. p254

<i>Procedure</i>	<i>Estimated per cent caries reduction</i>	<i>Annual cost (\$) per capita</i>	<i>Cost (\$) per 1 DMFS saved</i>	<i>Rank</i>
<i>Systemic</i>				
Public water fluoridation	50	0.20	0.20	1
Fluoride tablet distribution	35	0.40	0.57	3
School water fluoridation	40	1.50	1.88	3
<i>Topical</i>				
Weekly mouthrinse (0.2 per cent NaF)	25	0.50	1.00	1
Clinical application (multiple chair) (2 per cent NaF)	40	2.06	2.60	2
Clinical application (annual) (1.23 per cent F APF gel in tray)	40	3.50	4.40	3
Toothbrushing in school (5 x /yr) (0.6 per cent F solution)	20	2.23	5.60	4
Toothbrushing at home (0.1 per cent F toothpaste)	20	4.00	10.00	5
Daily self-application by tray (0.5 per cent F APF gel)	80	34.09	21.30	6

TABLE 28: Factors which are frequently excluded from cost-benefit analysis.

SOURCE: Murray and Rugg-Gunn 1982. p254

<i>Cost</i>	<i>Benefit</i>
1. Teachers' time supervising preventive measure	1. Repeat treatment (e.g. fillings) of teeth not included in DMF index
2. Subjects' time doing preventive measure	2. Subjects' (and parents') time and cost of attending surgery for treatment
3. Discounting of costs (benefits accrue later)	3. Freedom from pain, infection, etc.
	4. Post-treatment benefit
	5. Benefit to deciduous teeth
	6. Effect on gingival health of a complete dentition and unrestored teeth

TABLE 29: Direct costs of school water fluoridation programmes in the US, based on equipment replacement costs (in 1988 US\$).

SOURCE: Garcia 1989. p267

State	No. Schools	No. Students	Initial Capital Costs ('88\$)*	Capital Costs/		Costs of Chemical /Year	Oper. Costs/ Year**	Personnel Costs/ Year†	Other Costs	Cost/ Student/Year	
				(2%)	(4%)					(2%)	(4%)
1	4	2,500	8,100	630	729	300	400	200	500 ^a	0.81	0.85
2	103	28,896	154,500***	12,024	13,896	2,100	10,300	76,400		3.49	3.55
3	89	37,000	195,800	15,238	17,610	4,450	8,900	95,408	26,700 ^b	4.07	4.14
4††	134	48,500	241,200	18,772	21,694	16,000	NA	175,970	1,500 ^c	4.38	4.44
5	14††	3,300	24,500	1,907	2,204	896	1,400	10,710	400 ^d	4.64	4.73
6††	28	4,880	63,280	4,925	5,691	2,500	NA	40,000		9.72	9.88
All										Mean=\$4.52	\$4.60
										Median=4.23	4.29
										Range=0.81-9.72	0.85-9.88

*Includes equipment replacement cost, testing equipment, and installation.

†Annualized capital cost at 2% and 4% over 15 years.

**Cost of lab testing and routine maintenance and repair.

†See Table 14.

***No installation costs included; state employees install equipment.

††Source: Dr. R. Gerlach (1989).

‡‡Program discontinued Dec. 1988.

^a=travel \$350/year, postage \$150/year; ^b=travel, repair parts, \$300/school/year; ^c=all other costs; ^d=secretarial costs \$400/year.

TABLE 30: Direct annual personnel costs for school water fluoridation programmes in the US (in 1988 US\$).

SOURCE: Garcia 1989. p267

State	Type of Personnel	Cost (\$)	Total Cost/Year
State 1	Honorarium for program supervisor	200	200
State 2	2 full-time program representatives @ \$31,000/year	62,000	
	1 technician @ \$14,400/year	14,400	76,400
State 3	4 fluoride specialists and 1 support person \$922/school/year	82,058	
	1 school employee @ \$5.00/hour x 30 hours/year x 89 schools	13,350	95,408
State 4	1 engineer @ \$45,000/year (10% time)	4,500	
	6 technicians, appr. @ \$22,048/year (70% time)	92,603	
	1 clerk \$203.08/year	203	
	1 lab employee @ \$20,000/year	20,000	
	Administrative costs \$58,664/year	58,664	175,970
State 5	1 fluoridation technician @ \$765/school/year	10,710	10,710
State 6	1 engineer @ \$21,000/year (50% time)	10,500	
	1 technician @ \$22,000/year	22,000	
	Clerical \$4,000/year	4,000	
	Administrative costs \$3,500/year	3,500	40,000

TABLE 31: Direct annual costs of fluoride supplement programmes in the US (in 1988 US\$).

SOURCE: Garcia 1989. p265

State	No. Schools	No. Children	Age	Type & Dosage	Personnel Costs/ Year	Materials & Supplies/ Year	Other Costs/ Year	Total Costs/ Year	Costs/ Child/ Year
1	7	935	6-12	NaF (1 mg)	458	370		828	0.89
2	5*	657	4-5	NaF (1 mg)	NA†	756		756	1.15
3	49	10,751	5-14	NaF (1 mg)	17,264	5,805	1,200 ^a	24,269	2.26
4	12	3,000	5-12	NaF (0.5 mg)	5,278	2,000	1,500 ^b	8,778	2.93
5	—	9,721	4-5	NaF (1 mg)	39,290	12,000	1,200 ^c	52,490	5.40
All				Tabs or drops					
								Mean=\$2.53 Median=2.26 Range=0.89-5.40	

*Head Start programs affiliated with community health centers.

†=Travel; ^b=printing, clerical; ^c=postage.

Direct annual personnel costs:

State 1: 1 hygienist @ \$22,882/year (2% time), benefits included.

State 2: none reported; program is conducted by Head Start staff.

State 3: 2 hygienists @ \$17,264/year (50% time, no benefits.

State 4: 2 hygienists @ \$13.50/hour x 195.5 hours, no benefits.

State 5: 1 full-time coordinator @ \$36,000/year; 1 program director @ \$47,000/year (7% time), fringe benefits included.

TABLE 32: Direct annual costs of fluoride mouthrinse (0.2% weekly NaF) programmes in the US (in 1988 US\$).

SOURCE: Garcia 1989. p266

State	No. Schools	No. Children	Age or Grade	Personnel Costs/Year*	Materials & Supplies/Year	Other Costs/Year	Total Costs/Year	Costs/Child/Year
1	477	88,640	Gr. K-6	17,461	28,365		45,826	0.52
2	300	130,000	K-8	26,875	90,000		116,875	0.90
3	325	76,793	6-11 yrs	36,600	45,910		82,510	1.07
4	398	180,462	Gr. K-8	50,136	164,220		214,356	1.19
5	263	124,659	Gr. K-6	8,000	152,084		160,084	1.28
6	60	9,840	5-12 yrs	8,750	4,000		12,750	1.30
7	56	13,000	K-6	6,999	8,500	1,500 ^a	16,999	1.31
8	851	233,588	Gr. 1-6	69,500	245,700	46,800 ^b	362,000	1.55
9	136	36,155	Gr. K-6	37,125	12,405	9,960 ^c	59,490	1.65
10	137	26,907	7-14 yrs	15,400	29,060	1,200 ^d	45,660	1.70
11	1,537	358,263	Gr. K-8	467,458	170,900		638,358	1.78
All								
							Mean=\$1.30	
							Median=1.30	
							Range=0.52-1.78	

*See Table 12.

^a=printing costs; ^b=\$.20 per child, health department administrative costs; ^c=communications, travel, rent, and utilities; ^d=travel.

TABLE 33: Direct annual personnel costs for fluoride mouthrinse programmes in the US (in 1988 US\$).

SOURCE: Garcia 1989. p266

	State 1	State 2	State 3	State 4	State 5	State 6	State 7	State 8	State 9	State 10	State 11
Salaries											
# employed	4	1	1	8	1	2	None	4	1	NA*	None
Salaries	\$49,250	\$26,875	\$32,000	\$25,068	\$24,024	\$16,400		\$47,000	\$31,778		
(% effort)	10	100	100	25	33.3	25		33	25		
	\$18,927					\$18,600		\$24,000			
	33					25		100			
	\$11,545							\$20,000			
	20							75			
	\$9,905							\$20,000			
	20							75			
Subtotal	\$15,461	\$26,875	\$32,000	\$50,136	\$8,000	\$8,750	—	\$69,500	\$7,945	—	—
Contract											
# employed	3		1				5		16		25†
Wages	NA*		\$15/hr				\$13.50/hr		\$14.59/hr		\$8.90- \$17.50/hr
# hours			306.7				103.69		125.0		
Subtotal	\$2,000	—	\$4,600	—	—	—	\$6,999	—	\$29,180	—	—
TOTAL	\$17,461	\$26,875	\$36,600	\$50,136	\$8,000	\$8,750	\$6,999	\$69,500	\$37,125	\$15,400	\$467,458

*Information not available.
†Includes 1 coordinator, 5 field supervisors, 17 field consultants, 1 inventory specialist, and 1 secretary.

programme involving 40,117 and 81,472 children was carried out in Tennessee and Indiana. Table 34 illustrates the cost per student is US\$1.73, US\$1.80 and US\$0.75 in Alabama, Tennessee and Indiana, respectively.

TABLE 34: Estimated annual cost per person for tooth-brushing with solutions and gels in Alabama, Tennessee and Indiana.

SOURCE: Murray 1986. p108

	Alabama Projections for pilot programme 1982-83 school year	Tennessee Actual figures for 1981-82	Indiana 1981-82
Number of schools (classes)	25	(1605)	122 ^a
Number of children	5 000	40 117	81 472
Salary of personnel (US\$)	4 814	53 900	10 890
Cost of F agent (US\$)	960	6 420	
Type of agent	APF	APF	APF
Method of use	Brush-on	Self-applied Brush on	Self-applied Brush on
Concentration of agent	2.2% F ion	2.2% F ion	1.23% APF paste
Frequency	2 × yearly	2 × yearly	1 × yearly
Other costs, including supplies (US\$)	2 007	11 700 ^b	44 810 ^c
Time required (hours)	NA	6 420	NA
Per diem, mileage, telephone, etc. (US\$)	855	NA	4 620
Total cost (US\$)	8 637	72 020	60 320
Cost/student/year (US\$)	1.73	1.80	0.75

^a Indiana has 315 school corporations. The actual number of schools in each corporation ranges from 2-95.

^b Includes toothbrushes, paper products, and disposable garbage bags.

^c Includes F products.

Sources: Alabama—Dr N. L. Shory; Tennessee—Dr D. R. Collier; Indiana—Dr C. W. Gish.

6 DISCUSSION

Dental caries is a disease in which host, agent and environmental factors interact to produce irreversible destruction of the hard tissues of the teeth. There have been continuing efforts to develop methods of lowering the number of bacteria on teeth by mechanical means or by reducing their cariogenic activity with many different chemical agents. However, the use of fluoride remains the best defence against dental caries through its therapeutic action on the environment of the tooth, saliva and plaque, and on the tooth itself.

Fluorides act directly on the tooth by enhancing remineralization and decreasing the solubility of the teeth structure as well as by preventing the colonization of bacteria on the tooth surface.

The reservoir of fluorides in plaque may act in several ways - by affecting bacterial growth, glycolysis, glycogen synthesis, and acid production. All these effects may occur with topical fluoride treatments. However, with oral hygiene procedures like scaling, toothbrushing and flossing, plaque might be removed and the fluoride thus incorporated into the plaque will be removed as well.

The continuous presence of low concentrations of fluoride in the saliva as a result of topical or systemic fluorides may have a more lasting effect than plaque fluorides. They also act as a reservoir for the fluoride ions and enhance the remineralization of an early lesion sufficiently to prevent a clinical lesion from developing.

Although community water fluoridation is the most efficacious and cost-effective measure available to prevent dental caries in the community, much of the world's population does not have fluoridated water supplies. Alternate methods of providing fluoride such as school water fluoridation, fluoride tablets or drops, fluoridated salt, fluoridated milk, fluoride mouthrinses and toothpastes have been advocated.

School water fluoridation can be implemented in areas where there is no central water supply and levels of natural fluoride in drinking water of schools and homes are uniformly low. If some students drink nearly optimal concentration of fluoride in water at home and others only trace levels it is impossible to determine the proper concentration for the school water supply. With the rather minimal equipment necessary to effect school water fluoridation, school personnel can readily be trained to operate the school's fluoridation equipment. School water fluoridation programmes can provide pre-eruptive or systemic sources of fluoride to later erupting teeth. Moreover, the cost-benefit ratio is favorable especially in schools with large populations, such as in Taiwan.

The main advantages of salt as a vehicle for fluorides are that it does not require a community water supply and it permits individuals to accept or reject it. Non-fluoridated salt, like non-iodized salt, can also be made available to the population. The main disadvantages are that salt consumption is lowest when the need for fluoride is greatest-in the early years of life-and the current view is that promotion of salt intake may contribute to hypertension.

Schemes like the unsupervised provision of fluoride tablets and, to a lesser extent, the sale of fluoridated milk requires a high degree of motivation on the part of the parents and children. The effectiveness of fluoride tablets or drops, and fluoridated milk are more difficult to evaluate in terms of percentage caries reduction than is community water fluoridation. Effective home use of fluoride tablets is usually associated with greater awareness of good dental habits in a high socio-economic class groupings. The current literature notes that there has been a decline in the home use of fluoride tablets with introduction, and awareness of, other fluoride vehicles.

However, the problems of compliance associated with home use of fluoride tablets can be largely overcome by using fluoride tablets in a school-based programme. The effectiveness and feasibility of supervised school-based fluoride tablets programmes have been demonstrated in several studies. The per cent reduction in caries have ranged from about 20-36% after two or more years of fluoride ingestion. Wei and Campbell (1978) have reported a reduction of 81% after a three year trial.

One aspect of the evaluation of fluoride tablets or milk fluoridation schemes is the duration of any particular study. Very few fluoride tablets studies have reported results after ten years and only one fluoridated milk study has reported results after five years. In the latter study only 50 children remained in the test group after five years. The binding of added ionic fluoride to milk-calcium or milk-protein occurs after fluoride addition, also makes milk an unsatisfactory carrier of ionic fluoride.

Fluoridated milk could be useful in a school-based programme in which an optimal daily dosage is provided at one time and the problem of compliance can also be overcome. However, the costs of fluoridated milk for distribution in schools are likely to be much greater than corresponding costs for a school-based fluoride tablets programme. There are additional benefits for the nutrition value of a school milk programme.

Some advantages of weekly mouthrinsing with fluorides as a school-based caries preventive programme are:-

- 1) established effectiveness (consistently positive finding)
- 2) little time is required (about five minutes per week for weekly mouthrinsing programme)
- 3) the technique is easy for school-age children to learn
- 4) it is inexpensive - all needed materials cost about \$1.30 US per child per year (1988)
- 5) non-dental personnel with minimal training are able to supervise the procedure
- 6) participants generally accept the programme well
- 7) posttreatment anticaries effects have been reported.

Reduction in the incidence of dental caries by toothbrushing has been clearly demonstrated only when a fluoride-containing toothpaste is used. Studies have shown that brushing without the use of therapeutic toothpaste is not an effective means of preventing caries. The probable reason is the inherent inability of the toothbrush to penetrate fissures and interdental areas. The use of fluoride

toothpaste can overcome these shortcomings and the benefits of fluoride can also be obtained.

In implementing the above mentioned programmes, the risks of the ingestion of excessive fluoride should always be kept in mind. Studies have shown that the total daily fluoride intake should not exceed 0.1mg/kg body weight as there is evidence that fluoride intake above this level could lead to the occurrence of dental fluorosis.

The concentrations of fluoride employed in the various alternatives to water fluoridation are well below the level that could lead to the occurrence of dental fluorosis. Studies conducted for school water fluoridation, fluoride tablets or drops, fluoridated salt, fluoridated milk, fluoride mouthrinses and fluoride toothpastes show no chance of dental fluorosis provided the recommendations of use are followed strictly.

After reviewing the literature on the alternatives to water fluoridation, the writer recommends the following programmes:-

(1) School water fluoridation

Studies have shown that this method requires minimum equipment and the training of personnel for its functioning is simple. This method can provide pre-eruptive or systemic sources of fluoride to later erupting teeth. The cost-benefit ratio of school water fluoridation is favourable especially in schools with a large population. The distribution of the school going population in Taiwan is such that the majority of them are heavily populated, (>2000), making implementation of this programme justified.

The recommended concentration of school water fluoridation is 4.5 times the optimum recommended for community water fluoridation.

(2) Supervised School-based fluoride tablets programme

The supervised school-based fluoride tablets programme can overcome the problem of compliance associated with home use of fluoride tablets. Several studies have shown that dental caries is reduced by an average of 35% when children ingest fluoride tablets daily under supervision in a school-based programme. This programme could be relatively cheap because fluoride tablets purchased in large quantities are inexpensive. Fluoride tablets confer systemic benefits to unerupted developing teeth as well as topical benefits, when chewed, to erupted teeth. The recommended dosage is 2.2mg NaF (1mgF) tablet per day (six per week) since the level of fluoride in drinking water in Taiwan is less than 0.3ppm.

(3) Weekly fluoride mouthrinsing programme in school

The writer recommends this programme as another alternative as it is effective, inexpensive, not time consuming, easy to learn and well accepted by the participants. In addition, posttreatment anticaries effects have also been reported. The recommended dose is 0.2% NaF solution on a weekly basis.

For individuals, the use of fluoride-containing toothpaste is recommended as a routine part of self care. Because toothbrushing is a standard practice in many parts of Taiwan, the use of fluoride toothpaste brings the benefits of fluorides to a great many people.

7 CONCLUSIONS

The review of the literature has shown without doubt that the alternatives to water fluoridation are effective in preventing dental caries.

The main mechanisms by which fluorides act to inhibit dental caries are by its actions on the plaque, saliva and on the tooth itself. The fluoride ions in plaque act mainly by affecting bacterial growth, glycolysis, glycogen synthesis and acid production. Plaque fluorides may also act as a reservoir of fluoride ions available for the remineralization of the early carious lesion. It is believed that the mode of action of fluorides in saliva may be similar to that of dental plaque. Fluorides act directly on the tooth by enhancing remineralization and decreasing the solubility of tooth structure as well as by preventing the colonization of bacteria on the tooth surface.

Due consideration must at all times be given to the risks of the ingestion of excessive fluoride. Studies have shown that the total daily fluoride intake should not exceed 0.1mg/kg body weight as there is evidence that fluoride intake above this level could lead to the occurrence of dental fluorosis.

After reviewing the literature on the use, effectiveness, safety, cost-benefit and cost-effectiveness of the alternatives to water fluoridation, the writer recommends the following programmes which could be applied in Taiwan:-

- (1) School water fluoridation at fluoride concentration of 4.5 times the optimum recommended for community water fluoridation
- (2) Supervised school-based fluoride tablets programme using 2.2mg NaF tablets daily (six days per week)
- (3) Supervised weekly 0.2% NaF mouthrinsing programme in schools.

For individuals, the use of fluoride-containing toothpaste is recommended as a routine daily part of self-care. Because toothbrushing is a standard practice in many parts of Taiwan, the use of fluoride toothpaste brings the benefits of fluorides to a great many people.

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