TRENDS OF DENTAL CARIES PREVALENCE

IN AUSTRALIAN AND INDONESIAN SCHOOLCHILDREN

DIBYO PRAMONO

DOKTER GIGI (Gadjah Mada University),

MS (Gadjah Mada University)

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SUMMARY

Dental caries became highly prevalent in the second half of the 19th century in the developed countries. Since then, the demand for restorative treatment has accounted for the largest proportion of dental services and has been the major consumer of dental manpower. This puts dental caries as the most costly dental disease.

Ever since dental caries was recognised as a major problem efforts were attempted for preventive measures. Since dental caries is multifactorial in nature, simultaneous preventive approaches are required. Based on the current concept of caries occurence, prevention is directed to : (1) oral hygiene practices; (2) limitation of ingestion of fermentable carbohydrates; and (3) increase tooth resistance through the use of fluoride.

The WHO data bank revealed that there have been major changes in the prevalence of dental caries in the last 2 - 3 decades. Due to the extensive preventive measures, most developed countries evidenced the declining trends of dental caries prevalence, especially in schoolchildren population. On the other hand, most developing countries are facing increases of dental caries prevalence approaching moderate or higher levels of deterioration due to lack of preventive measures, urbanisation and increase in sugar consumption. The major factors that are commonly cited to be associated with the declining trends are fluoride exposures in different forms, reduction in sugar consumption and successful implementation of school-based dental services in which dental health education programs are emphasized resulting in increased awareness in oral health amongst schoolchildren.

Australia has been considered successful in reducing its caries prevalence especially in schoolchildren. Regarding children at 12 years of age, there has been a 63% reduction of caries experience (DMFT) over a period of 11 years, from 4.79 in 1977 to as low as 1.79 in 1988. The caries prevalence in Australian schoolchildren has been systematically recorded through the annual School Dental Services evaluation. The observed declining trend is obviously a result of various extensive preventive measures such as : successful implementation of School Dental Services, water fluoridation measures, and the use of other forms of fluoride. These are supported by the favourable ratio between dental resources and dental need and high percentage of dental expenditure as against the gross domestic product (GDP).

The provision of dental services to schoolchildren in Australia dates back to 1915. However, on a national-wide basis, the actual provision of dental care was apparently greatly stimulated in 1973 with the establishment of the Australian School Dental Scheme. Currently, with over 1000 school dental clinics and 1134 school dental therapists, the Scheme obviously does not face any significant problem with regard to its fundings and manpower.

Water fluoridation has been a government policy and strongly endorsed by the National Health and Medical Research Council, the Australian Medical Association and the Australian Dental Association. Commenced in 1953, currently over 65% of the total Australian population consume fluoridated water.

Examining the contribution of related factors to the declining trend of dental caries prevalence in Australian schoolchildren, the

available data suggest that the use of fluoride has played a prominent role. Of the various types of fluoride used, water fluoridation has been shown to have the predominant effect, followed by the widespread and regular use of fluoride dentifrices in the second rank, whereas regular fluoride supplement administration has been least effective. The implementation of the School Dental Scheme has also induced a slight lowering of the DMFT figures amongst schoolchildren. The sugar consumption pattern, on the other hand, which has remained at constant and very high level around 50 kg per person per year for more than five decades, does not seem to relate to the declining trend of caries prevalence.

Indonesia had more than 165 millions population in 1988 with about 80% living in rural areas. This provides many pressures to the government to enlarge the coverage of dental services since the geographical conditions, the infrastructure and communications may not be favourable. The outcomes of this situation are the establishment of small clinics known as community health centers in order to reach the remote rural areas. However, while such clinics have been established according to the community need, there is, paradoxically a lack of public demand for dental care.

The share of the GDP spent to health in the last five years remained constant at around 2.7% which is far less than the minimum WHO standard at 5% of GDP. The implication of this lack of funds is that the dental program has to compete with other health programs. Futhermore, the dental program has been put in a very low priority amongst other health programs. Consequently, this does not allow the allocation of sufficient budget and other resources for the dental program.

The dentist : population ratio in Indonesia is extremely low. Consequently, it is hard to provide adequate dental services especially for schoolchildren population. It is obvious that high increase in dental manpower is required. However, given the various current and forseeable economic constraints, increasing the present manpower supply would be a matter of continuing review rather than immediate actions. Therefore, the dentist : population ratio is likely to remain unchanged.

Currently, the only preventive measure against caries is the fluoride mouthrinsing program as an integral part the School Dental Services. School Dental Services are delivered in the basis of the Selective Care System in which comprehensive care is provided to the sixth grade primary schoolchildren of schools situated within a 3 kilometre range of a dentally equipped community health center. However, lack of supervision by dental personnel appears to be the major factor for not improving this program. It is perceived that the school dental program is not functioning, being under-utilised or under-supervised. In most places, the School Dental Service is run without any performance review and rarely offers promotion of dental health care and prevention.

With the scarcity of epidemiological dental data, Indonesian schoolchildren are, similar to those in other developing countries, experiencing increasing trends of caries prevalence varying from low to moderate and from moderate to high or very high. Considering various factors such as low levels of dental demand, lack of dental resources, massive manpower shortage, increase in sugar consumption and absence of sound preventive measures, the level of caries experience in Indonesian schoolchildren will continue to increase in

the forseeable future.

In order to anticipate this possible future increase in caries prevalence in Indonesia, intervention with a preventive program must be carried out before problems become bigger and unmanageable. With some unfavourable backgrounds and constraints, the most seemingly apt answer to the problem of caries in schoolchildren is salt fluoridation. However, water fluoridation is strongly considered, particularly in those eleven provinces which evidenced moderate to very high caries experience. To enlarge the widespread use of fluoride dentifrices, the government should initiate a collaboration with the dentifrice manufacturers to implement mass campaigns and provide affordable fluoride dentifrices to the community especially schoolchildren. Reinforcement and performance review of the fluoride mouthrinsing program set up as an integral part of the School Dental Services is also urged.

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1	ABS	Australian Bureau of Statistics
2	ACT	Australian Capital Territory
3	APF	Acidulated Phosphate Fluoride
4	BPS	Biro Pusat Statistik [Indonesian Bureau of Statistics]
5	CaF	Calcium Fluoride
6	CHC	Community Health Center
7	defs	decayed, extracted and filled deciduous tooth surfaces
8	deft	decayed, extracted and filled deciduous teeth
9	DMFS	Decayed, Missing and Filled Permanent Tooth Surfaces
10	DMFT	Decayed, Missing and Filled Permanent Teeth
11	FDI	Federation Dentaire Internationale
12	IOHC	Integrative Oral Health Care
13	NaF	Sodium Fluoride
14	n	sample size
15	NSW	New South Wales
16	NT	Northern Territory
17	Pelita	Pembangunan Lima Tahun [Five Year Development Plan]
18	ppm	part per million
19	QLD	Queensland
20	SA	South Australia
21	SMFP	Sodium Monofluorophosphate
22	SnF_2	Stannous Fluoride
23	TAS	Tasmania
24	VCHD	Village Community Health Development

25	VIC	Victoria
26	WA	Western Australia

1. INTRODUCTION

1.1 Dental Caries - Its Preventive Approach

Undoubtedly dental caries afflicted ancient man, but the prevalence of the disease in that pre-historic period was very low. In the beginning of the 19th century, the prevalence obviously began to rise. It then became highly prevalent in the second half of that century in industrialised countries (Moore and Corbett 1971, Burt 1978). Epidemiological data from WHO showed that in the period of 1930-1970's dental caries prevalence in those countries was extremely high (Table 1) compared to that in the developing nations which remained low (Table 2).

Sugar was much more available in the developed countries due to the early development of sugar industries in the nineteenth century (Moore and Corbett 1976). In the developing countries, on the other hand, sugar was not widespread until the latter half of the twentieth century. It is plausible, therefore, that the levels of sugar consumption were assumed to be responsible for the difference in the prevalences. This assumption has been supported by strong evidence that caries does not develop in the absence of fermentable carbohydrate (Harris 1963, Scheinin et al 1975, Glass 1981).

Ever since dental caries was recognised as a major problem, efforts were attempted for preventive measures. One of the outcomes was the development of School Dental Services in Britain and Norway before World War I (Burt 1978). In the USA, campaigns for tooth brushing were started in 1884 (Dunning 1980).

Table 1. Caries experience (DMFT) in children aged 12 years in the industrialised countries
(Adapted from Renson 1984)

Country	Highest	Year
Australia	9.3	1956
Canada	7.4	1958-60
Finland	7.5	1975
New Zealand	10.7	1973
Norway	12.0	1940
Sweden	7.8	1937
Switzerland	9.6	1961-63
USA	7.6	1976

Table 2. Caries experience (DMFT) in children aged 12 years in the developing countries
(Adapted from Renson 1984)

Country	Level	Year
Chile	2.8	1960
Ethiopia	0.2	1958
French Polynesia	6.5	1966
Iran	2.4	1966
Israel	2.4	1966
Jordan	0.2	1962
Kenya	1.7	1973-77
Lebanon	1.2	1961
Mexico	2.7	1972
Morocco	2.6	1970
Philippines	1.4	1967-68
Thailand	2.7	1977
Uganda	0.4	1966
Zaire	0.1	1971

Philosophically there are a number of reasons why caries prevention is imperative. Firstly, dental caries is one of the most prevalent diseases. The demand for restorative treatment has accounted for the largest proportion of dental services and has been the major consumer of dental manpower (Renson 1984). Therefore there would be an enormous change in the dental services pattern as well as reduction of personnel needed if dental caries is prevented. Secondly, in the past, curative measures were preferred to preventive efforts but it is a fallacy to believe that any disease, especially caries, can be eradicated merely by treatment procedures. Treatment alone does not protect people from subsequent dental caries attack. Prevention, therefore, is the only means to cope with the problem of caries (Skougaard 1980, Nikiforuk 1985).

Thirdly, treatment of dental caries is very costly. From the economic point of view, it would be advantageous if caries could be prevented because billions of dollars could be saved from providing restorative treatments. In 1980, in the United States, $15.9 billion was spent for dental treatment (Bureau of Economics and Behavioral Research Council on Dental Health and Health Planning 1982). In most countries, finance allocation to the dental sector has a declining priority than other fields such as medical and industry. It becomes clear that prevention of caries will be highly cost-effective especially in industrialised countries where dental caries is considered to be one of the most costly diseases. The fourth and the most scientifically important reason is that dental caries is preventable.

The use of preventive measures is not a new issue because efforts date back to the time of Hippocrates (Dunning 1980). About 100

years ago Miller promoted histo-chemico-parasitic theory of dental caries and its prevention. He recommended four ways for preventing dental caries (Guggenheim 1984) ie: (1) good dietary intake to maintain the optimum formation of the teeth, (2) tooth and oral cleansing to remove those carbohydrate in the oral cavity as well as on the tooth surface that enable the formation of lactic acid, (3) limiting the consumption of carbohydrate to minimise the availability of the main source of such a chemical reaction and (4) the use of antiseptic to eliminate the bacteria in the oral cavity.

The etiology of dental caries is not as simple as Miller's theory. Current concepts are unanimously agreed that caries is a multifactorial disease in which three primary factors (host, environment and agent) and a number of secondary factors are involved (Newbrun 1983). It is plausible, therefore, that caries prevention is now focused on those primary factors (Horowitz 1981, Skougaard 1980) ie: (1) oral and tooth cleansing through plaque control in terms of passive and active measures, (2) dietary modification, especially in terms of sugar consumption, and (3) increasing tooth resistance through the use of fluoride.

The direct causal effect of plaque on caries development was demonstrated by many researchers and they urged plaque removal to prevent caries. This was based on the philosophy that dental plaque can be easily removed by tooth brushing and flossing. Studies regarding the effectiveness of oral and tooth cleansing in caries prevention were conducted. It was shown, however, that plaque removal by these means was not as effective as had been assumed (Horowitz et al 1980, Silverstein et al 1977). The problem appears to be the difficulty in changing community behaviour. It should be

realised that sometimes people put prevention in a low priority in their daily activities (Konig 1982). On the other hand, contacts between community and the dentists are limited. With regard in the dietary modification, dental professionals have had problems in changing the community behaviour in consuming sugar. People are unintentionally consuming sugar that is present in so many commercial foods (Makinen & Scheinin 1975, Horowitz 1981) and it is believed that the desire to eat sweet is instinctive (Leach et al 1983).

Criticism has been directed at preventive efforts through oral cleansing and sugar restriction since they have not achieved practical significance in community prevention of dental caries. Acceptance by the target populations has to be taken into consideration. In terms of practical significance, it seems that fluoridation through water supply is the easiest way to prevent caries (Horowitz 1981). Federation Dentaire International (FDI), in its technical report, has also emphasized the use of fluoride in the prevention of dental caries (FDI 1984). This prevention measure will increase tooth resistance without any demand for active involvement from the community. People remain passive while tooth resistance increases. However, fluoridation does not totally prevent all caries developments and different methods of fluoride use with different reactions also give some level of caries prevention.

It is reported that during the last 20 years there has been a great decrease in caries prevalence in industrialised countries (Barmes 1979, O'Mullane 1982, Kalsbeek 1982, Brown 1982, Von Der Fehr 1982,

Renson 1984, Downer 1984). In contrast, caries prevalence in the developing countries tends to be increasing (Figure 1). It is believed that fluoride is the most important factor causing such a great reduction of dental caries prevalence. In fact, most of those developed countries have been using fluoride in different ways for years.

1.2 Provision of School Dental Services

Other than the widespread exposure of children to fluoride in its different forms, Renson (1984) pointed out that there is another factor which was common in those countries which had achieved the greatest success in reducing caries prevalence. This factor being the preventive oral health services, especially for children. It becomes evident that the provision of dental services to schoolchildren is of great importance because of the large number of its population. There are over 1,500 million children in the world under the age of 15 with an annual increase of 125 million (Barmes 1979). Special attention should also be paid to this age group because 81% of those children live in the developing countries.

The provision of dental services with a preventive approach, in the school environment are advantageous in several ways. Firstly, school settings provide the opportunity to contact a large number of individuals. No other target group can be as easily reached as a large schoolchild population. Dental health services which are set up in school, the place where the children normally congregate, will avoid many problems found if children must be taken for dental services to private practices out of school hours (Dunning 1978).

Secondly, schoolchildren are growing to be the next generation, and

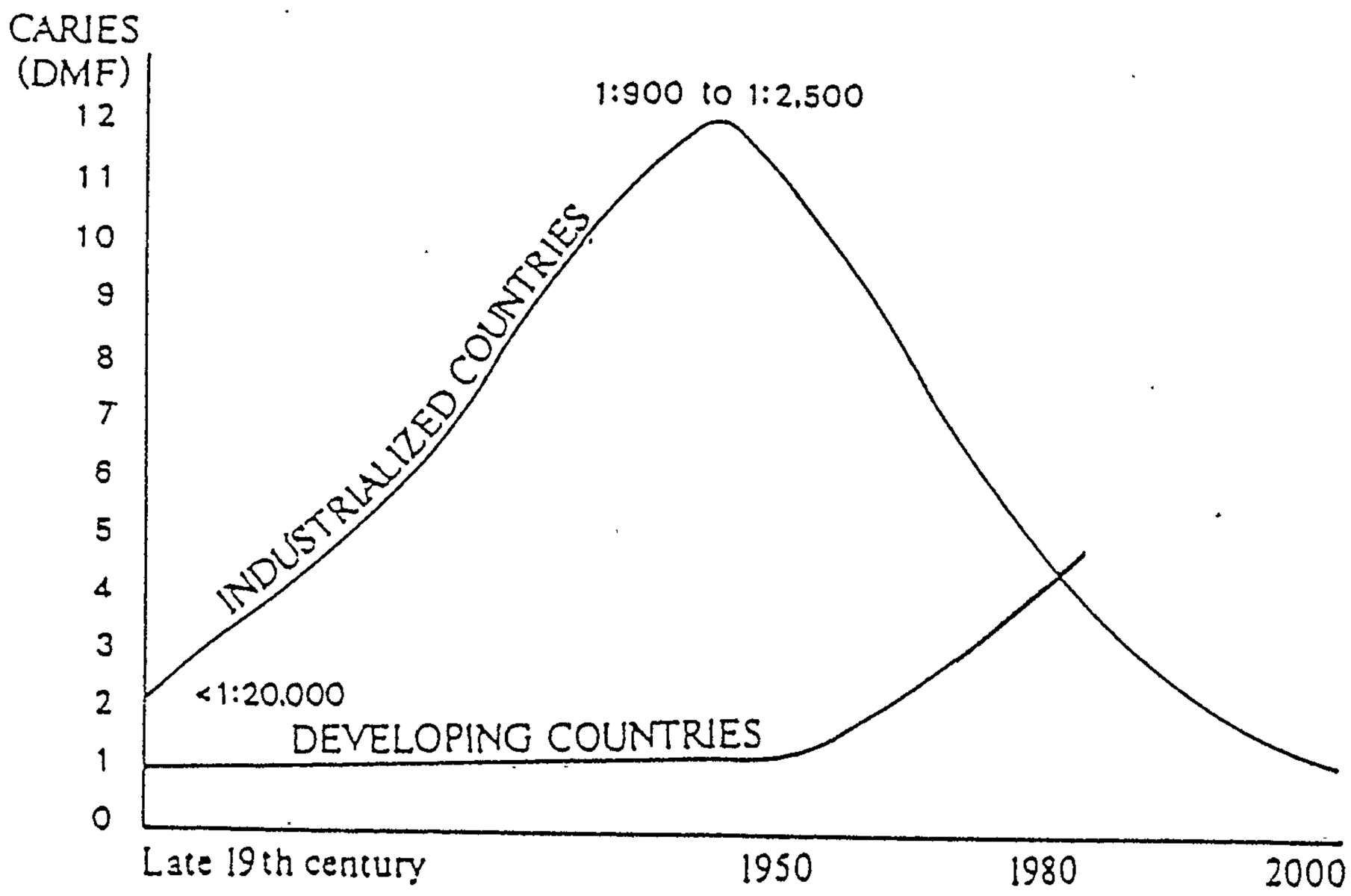

Figure 1. Trends of dental caries prevalence in 12-year-old schoolchildren in developed and developing countries. (Adapted from Renson 1984)

the better the condition of their oral health at the present time the fewer problems will arise in their adulthood life. Barmes (1979) has emphasised the importance of directing dental programs to the young generation and stated:

> "The childhood and adolescent periods are vital because, for caries, the rapidly destructive phase of the disease occurs in childhood to the extent that if the disease is not prevented or treated in childhood or adolescence, the dentition is almost certainly ruined before adulthood."

Thirdly, schoolchildren are young people whose patterns of behaviour are still being formed, therefore it would be easier to develop their beliefs and attitudes towards positive dental health. This would encourage children to practise preventive care and to seek dental check-ups and treatment regularly. Consequently, it would increase the demand for dental services, especially in the developing countries by breaking down public apathy which is the main barrier of the utilisation of dental services mainly due to widespread ignorance, traditions and superstitions.

Realising the importance of school dental services, most industrialised countries have set up such programs at an early stage. Australia established its first Child Dental Health Services of the Commonwealth Department of Health in 1949 although its coverage was limited only in the Australian Capital Territory (Carr 1957). New Zealand set up its similar service even earlier. It was in 1921 when New Zealand developed its School Dental Services, using two-year trained operative auxilliaries. It became the first country in the world using auxilliaries to provide dental services to schoolchildren. Norway and Britain established their School Dental Services in the early 1900's at approximately the same time

as did New Zealand (Burt 1978).

Although the effect of regular treatment provided in school dental programs on the caries experience (including incidence and prevalence) has not been established, slight evidence shows that indirect causal relationships between those variables exist. In Australia prior to fluoride preventive measures, Carr (1957) showed that regular and complete dental treatment had induced a slight lowering of the DMF figure. The phenomenon, probably, is attributable to the increase in oral cleanliness resulting from complete restorative care. Burt (1985) also believes that restorative dental treatment will lessen the caries attack rate. The reason is that curative care will reduce the open lesions that shelter bacteria and consequently lead to some decrease in caries susceptibility.

While in most developed countries school-based dental programs have been reported favourable, in the developing countries such programs are not well run. The latter are facing many problems such as lack of manpower, inadequate funding, limited training facilities and rapid population growth. These problems relate to over 80% of the world child population who reside in the developing countries. Moreover, unlike most developed countries, the programs are not complemented with adequate community preventive measures like fluoridation of water supply, which is highly cost-effective. There has been little political will to implement such measures. Barmes (1979) estimated that if no prevention is undertaken, the needs of dental manpower required to treat caries in schoolchildren population will increase rapidly. Renson (1984) also reminded:

> "It is evident that oral health problems in developing countries are now at a stage when reasonable resources devoted to prevention would obviate the need for huge expenditure in the future on restorative and rehabilitative services."

Regarding Indonesia, the problems tend to be lack of manpower (due to the difficulty in posting and deployment), inappropriate funding (because dental disease is put in the low priority) and the size of its schoolchildren population. It remains a dilemma. However, intervention with a preventive program must be carried out before problems become bigger and unmanageable. The only means to cope with the problems, therefore, is to adopt the relevant and applicable measures that have been used successfully in the developed countries with some adjustments in terms of the scale, the objectives and the financing.

1.3. Purpose of the Study

The phenomena of declining trends of caries prevalence in most industrialised countries has been discussed intensively through a number of international conferences. WHO and FDI have also held a meeting to evaluate and to determine possible explanation of the trends. Australia, one of the industrialised countries, has been considered successful in reducing its caries prevalence, especially in schoolchildren, through various preventive measures. Meanwhile, Indonesia which can be considered as a developing country, might have an increasing trend of caries prevalence due to lack of prevention and changing patterns of lifestyle resulting from the increase in economic growth and urbanisation. It is important, therefore, to gain more detailed information concerning the factors contributing to the declining trend of caries prevalence in

Australia and to analyse its applicability to Indonesia. Therefore, the aims of the present study are: (1) to analyse the trend of caries prevalence in Indonesian schoolchildren and (2) to analyse the preventive measures that have been implemented in Australia resulting in a great decline in caries prevalence, especially in schoolchildren and, (3) to analyse the applicability and the relevance of such measures to Indonesia in order to anticipate the possible future increase in dental caries prevalence.

2. TRENDS OF DENTAL CARIES PREVALENCE IN SCHOOLCHILDREN

2.1 Introduction

To date a number of conferences have been held in which developed countries revealed the declining trends of caries prevalence in the last 20-30 years. The WHO data bank also contains information from many countries but there is no indication in these publications of the manner in which those surveys were conducted. The problem is that some of the reports are subject to criticism that the information was collected in a non-standardised way (Anderson et al 1982, Suomi 1978). In assessing the change in prevalence of any disease, a number of considerations should be taken into account. Since the main aim of such an assessment is to compare two or more prevalences in a given geographical area in a certain time frame, the similarity on various aspects is essential. The similarity should be in: (1) the study sample in terms of its representativeness including sample size and sampling techniques, (2) age grouping, (3) sex proportion, (4) examiners, (5) diagnostic criteria, (6) location or geographical area and, (7) race composition. Since studies are usually conducted retrospectively, these restrictions are sometimes difficult to manage. This problem should not have taken place if research planning had been set up for prospective studies through a regular national survey. As a matter of fact, regular national survey is important in gaining an epidemiological data base on which monitoring, planning and assessing dental health services program can be done. Moreover WHO has urged countries to do so. Yet such a regular survey is not easily conducted due mainly to the financial reasons, especially so

in most developing countries. However, most of the epidemiological studies concerning the prevalence of dental disease are based on local area studies on which it is difficult to draw a valid and clear picture at a national level since they are not logically comparable. Most articles revealing the observed decline of caries prevalence are reported in such a way.

The aim of this section, therefore, is to examine if the reported declining or increasing trends of dental caries prevalence are subject to bias and invalidity of data collection and the drawing of conclusions. This discussion, however, will be based on selected countries which have data available. Information regarding supposedly related factors to these trends has also been compiled in order to choose those factors, that may be influencing the trends, for inclusion in the subsequent section (Section 3).

2.2 Trends of Caries Prevalence - Worldwide

From the United Kingdom, a straightforward report was published by Anderson et al (1982). It was reported that there had been a marked reduction in caries prevalence ranging from 32 - 51% in 12 year old children in England. The work of Anderson et al (1982) was based on five previous papers, ie.: Anderson (1966), James et al (1977), Anderson et al (1981), Anderson (1981a) and Anderson (1981b).

Using schools as sample frames, Anderson et al (1982) noted the declining trends of caries prevalence in four rural areas in England, namely: Somerset, Shropshire, Gloucestershire and Devonshire (Table 3). The baseline data from Somerset and Gloucestershire were taken in 1963 and 1964 respectively and were aimed at measuring the relationship between trace elements and

dental caries prevalence (Anderson 1966). The 1970 baseline figures from Shropshire were taken from a clinical trial regarding the effects of sodium monofluorophosphate that was published by James et al (1977). Anderson (1982) reported on the baseline 1971 and follow up survey in 1981. Examining these original reports, it seems that the similarity of various aspects of the survey have been carefully handled. The conduct of initial and follow up examinations, the same examiners, as well as the same diagnostic criteria were used, thus the intra and inter examiner variability could be minimised. The samples however were not taken at random because the investigators had to use the same schools as they did for the initial surveys. The limitation of this situation is the possibility that the schoolchildren may not represent the same wider geographical area as before even though the school catchment areas remained the same. However, this condition has been taken into account by examining the map showing the scatter diagram of the schoolchildren's addresses and it was found that there was not much difference between the two surveys. Since the standard deviations of the DMFT are available it is possible to carry out significance tests of the difference between two means. The results are shown in table 4. From the statistical analysis point of view, it can be substantiated that there is a significant reduction in caries prevalence over a period of time in Somerset, Gloucestershire, Shropshire and Devonshire. The composition of the samples by sex is not mentioned. Any differences of composition, if it was there, would not have any big influence on the differences in prevalence shown.

Clerehugh et al (1983) and Andlaw et al (1982) also revealed the

Table 3. Reduction of caries prevalence (DMF-T) in schoolchildren in various locations in England

Location and Investigator(s)	Age	Year	Sample Size	Mean (SD)
Somerset Anderson (1981a)	12	1963 1978	180 393	5.36 (0.23) 3.44 (0.12)
Shropshire Anderson et al (1981)	12	1970 1980	966 1,196	4.53 (0.10) 3.08 (0.07)
Northwest Clerehugh et al (1983)	11-12	1970 1980	249 207	5.00 (--) 3.08 (--)
Gloucestershire Anderson (1981b)	12	1964 1979	71 110	4.48 (0.33) 2.19 (0.19)
Devonshire Anderson et al (1982)	12	1971 1981	460 537	5.32 (0.16) 2.70 (0.10)
Bristol Andlaw et al (1982)	11-12	1970 1979	397 520	4.58 (--) 2.89 (--)

Table 4. Comparison between means DMF-T of initial and repeat examinations in various places of England using Student "t" test.

Locations	Mean DMF-T		t value	p
	Initial	Repeat		
Somerset	5.36 (0.23)	3.44 (0.12)	131.50	< 0.001
Shropshire	4.53 (0.10)	3.08 (0.07)	395.62	< 0.001
Gloucester-shire	4.48 (0.33)	2.19 (0.19)	59.23	< 0.001
Devonshire	5.32 (0.16)	2.70 (0.10)	314.45	< 0.001

declining trends of caries prevalence in the Northwest of England and in Bristol respectively. Like the previous articles, the studies were originally not intended to measure the trends. Examining the methodology of the studies, there is no doubt that results are substantiated since they were conducted in a rigorous way with the exception that the composition between male and female and between those who were 11 and 12 year-old are not stated.

The reported decline in caries prevalence in various places in England might be attributed to examiner bias with subtle changes in interpretation of constant criteria. A further study of the number of caries-free children in 3 year-olds showed an increase from 67% in 1973 to 83% in 1981 (Silver 1982) and reinforces that the observed decline is real. It seems to be more significant if it is compared with the trend of the 1950's and 1960's which showed an increasing prevalence of dental caries (DMFT) (Parfitt 1954, James & Parfitt 1957, James et al 1970, Berman & Slack 1972, Jackson 1974).

In accordance with the declining trends in England, various factors are reported as being related to these trends. It was reported that in Somerset there is an increase of dental awareness and an increase in the marketing of fluoride toothpaste from 5% in 1963 to 95% in 1977. There used to be a water fluoridation in Gloucestershire but this ceased in 1972. This may have had an effect on the 12-year-old schoolchildren since they had had five early years exposure to water fluoridation when they were examined in 1979. However, it is surprising that the reduction of caries prevalence in Gloucestershire is similar to the other non-fluoridated areas. The use of fluoride tablets, the change in pattern of sugar consumption

and increase in tooth brushing were reported as being responsible to the reduction of caries prevalence in Nothwest of England and Herdfordshire, while no evidence was found that there was a significant change in the preventive measures in Shropshire (Table 5).

The declining trend of caries attack rates are also reported in various places in the USA as well as at the national level. Three states have claimed to have declines in caries prevalence, ie.: Massachusetts, Indiana and Ohio.

In 1981, DePaola et al (1982) carried out a survey in Massachusetts schoolchildren on a statewide basis. A sample consisting of 8997 schoolchildren was drawn to represent about 900,000 children from 5 to 18 years of age. The results then were compared to a similar survey carried out in 1951 by Wellock (1951).

It was concluded that during a period of 30 years there had been a decline of about one-half in the prevalence of dental caries in the permanent teeth. However, there is no comment nor information about the comparability of the two surveys separated by a period of three decades. Therefore, the possibility that the difference is attributable to bias cannot be ruled out. However, the result is consistent with that reported by Glass (1982). At about the same time period, Glass (1982) conducted a dental examination in two towns in Massachusetts, namely Dedham and Norwood. By comparing the data with an initial survey conducted in 1958, he concluded that there was a substantial reduction in caries prevalence over a period of 20 years. Though the data were derived from clinical trials, therefore they were not intentionally aimed to get epidemiological

Table 5. Factors related to the observed decrease in caries prevalence in various locations in England.

Locations	Factors
Somerset	1. Increase of dental awareness 2. Use of fluoride toothpaste 3. Non-fluoridated area
Gloucestershire	1. Water fluoridation until 1972
Shropshire	1. No change in factors reported
Northwest	1. Use of fluoride tablet 2. Use of fluoride toothpaste 3. Change in pattern of sugar consumption
Herdfordshire	1. Increased use of fluoride tablet (6% in 1973 to 15% in 1981) 2. Increase in brushing habit
Bristol	1. Topical fluoridation 2. Fissure sealant 3. Use of fluoride toothpaste

data, it was not in any way biased comparison because they were conducted by the same examiner, under the same conditions in the same neighbourhood schools using the same diagnostic criteria. The baseline data for Dedham were taken in 1974 whereas for Norwood they were taken twice in 1972 and in 1978 (Table 6 and Table 7). Glass' conclusion, therefore, supports the conclusion made by DePaola.

A reduction in caries attack rate is also reported by Zacherl and Long (1972) in Ohio. They examined schoolchildren aged 6-12 years. The results showed that over the six year period studied, the mean reduction in caries increment was 17%. In these studies, all examinations were conducted by the same examiners whereas the diagnostic criteria and methods were unchanged.

Stookey et al (1985) claimed that caries prevalence in Indiana has decreased dramatically during the previous 23 years (Table 8). On the national level, Brunelle and Carlòs (1982) reported that the declining trend was taking place in the USA. Unlike other countries, the data in the USA were collected from four national surveys for which direct comparison can be made. Three of the surveys were conducted by the National Centre for Health Statistics (NCHS) in 1963, 1966 and 1971 as part of the general health survey using household as sample frames. The other one was conducted by the National Institute of Dental Research (NIDR) in 1979 utilising classroom as sample frames since the survey was targetted to the schoolchildren population (Table 9 & Table 10). The differences in the aspects of sampling frame and the institution conducting the surveys do not seem to lessen the comparibility of the data since they were using the same sampling method and diagnostic criteria so

Table 6. Mean DMF-T in Dedham, Massachusetts in 1958 and 1974
(Adapted from Glass 1982)

Age	1958	1974
7	3.70 (1.25)	1.55 (1.82)
8	4.92 (1.46)	2.22 (1.99)
9	6.73 (3.47)	2.71 (1.90)
10	7.96 (3.11)	3.38 (1.64)
11	11.02 (5.54)	4.71 (2.52)
12	13.06 (4.29)	6.69 (4.80)

Table 7. Mean DMF-T in Norwood, Massachusetts in 1958, 1972 and 1978.
(Adapted from Glass 1982)

Age	1958	1972	1978
7	-	1.19 (1.49)	1.32 (1.42)
8	4.49 (1.81)	1.75 (1.55)	-

Table 8. Comparison of dental caries prevalence in Ohio in 1982 with that observed in two prior surveys. (Adapted from Stookey et al 1985)

	1958-1959		1971-1972		1981-1982	
Age	n	DMFT	n	DMFT	n	DMFT
7	1709	0.99	833	0.65	299	0.18
8	1779	1.77	952	1.11	492	0.46
9	1550	2.50	944	1.55	534	0.67
10	1494	3.17	1002	1.98	582	0.93
11	1438	3.95	1002	2.51	584	1.19
12	1406	4.05	965	3.16	583	1.48

Table 9. Mean caries prevalence (DMF-T) in four national surveys in the USA
(Adapted from Brunelle & Carlos 1982)

Age group	NCHS 1963	NCHS 1966	NCHS 1971	NIDR 1979
6-11	1.4	-	1.7	1.1
12-17	-	6.2	6.2	4.6

Table 10. Percentage of caries-free children in four national surveys in the USA
(Adapted from Brunelle & Carlos 1982)

Age group	NCHS 1963	NCHS 1966	NCHS 1971	NIDR 1979
6-11	51.1	-	53.6	56.7
12-17	-	10.4	9.7	17.2

that the rigorous application of the survey methodoloy was maintained. However, the reported declining trend was not strongly demonstrated since for 6-11 age group there was only a 0.3 DMFT reduction over 16 years period of time 1963-1979.

It is interesting to discuss that while the state level data showed that there was a great decline, at the national level the reduction was slight. One possible explanation is that in calculating the mean DMFT for 6-11 age group, the adjustment or weighting for each individual age with regard to the number of children in each group was not done. As a matter of fact such an adjustment would have given a different result because this weighting would avoid the dominance of the children in a particular age. This possibility is supported by the fact that there is a significant increase in the percentage of caries-free children in the 6-11 and 12-17 age groups (Table 10).

In relation to the declining trends in caries prevalence in the USA, several factors are noted down to be responsible. DePaola et al (1982) pointed out that there are seven factors attributable to the trends i.e.: (1) use of systemic fluoride supplements, (2) use of professionally applied topical fluorides, (3) use of fluoride dentifrice, (4) use of antibiotics, (5) declining population of children, (6) improved levels of restorative care and, (7) change in pattern of sugar consumption and snacking. By considering that less interproximal caries is found Brunelle and Carlos (1982) postulated that the declining trend were attributable to water fluoridation. As a matter of fact, interproximal caries prevention is well known to be one of the important benefits of water fluoridation. They

noted the increase of population benefiting from fluoridation of water supply throughout the USA. In the 1960s there were 40 million people exposed to water fluoridation whereas in 1980's the number was doubled. The role of water fluoridation does not seem to be of less importance although the declining trend is also occurring in non-fluoridated areas as reported by DePaola et al (1982), Zaherl and Long (1979) and Glass (1982). One possible explanation to this phenomenon is that children in non-fluoridated areas were drinking, in some extent, fluoridated water as they were consuming so much commercial drink which were produced with fluoridated water.

Burt (1985) pointed out three factors involved in this decline in dental caries ie: (1) change in cariogenic bacteria, (2) change pattern of sugar consumption, and (3) fluoride exposures. Regarding the role of fluoride, most researchers claim the increase of fluoride dentifrices to be a significant factor. Fluoride dentifrice sales increased to 80% of the annual market of $435 million in 1981 (Glass 1982). The other uses of fluoride reported are self-applied fluoride mouthrinses and fluoride tablet distribution under supervision in school. Brunelle and Carlos (1982) reported that in the early 1970s there were only one million schoolchildren involved in such activities and by 1981 over 12 million children were estimated to be involved in school-based fluoride rinse and tablet programs. Increased dental manpower and increased dental insurance are also believed to be factors accounting for the declining trend of caries prevalance in the USA (Stookey et al 1985) but no data was found to support that postulate.

Brown (1982) has also reported that the declining trend of caries

prevalence was taking place in New Zealand. He claimed that there had been an enormous reduction of caries prevalence as well as an increase in the percentage of caries-free children (Table 11 and Table 12). However the study groups are not entirely comparable. In the 8-9 age group, five different studies undertaken in different places were presented to demonstrate the trend. The first data were derived from a survey conducted by Fulton (1951) in 1950 in two main areas, namely Auckland and Canterbury which was taken to represent the country's whole population. The second data were derived from the International Collaborative Study (ICS) conducted in 1973 (Hunter and Drinnan 1977, Hunter et al 1980) which was repeated in 1978. The 1978 survey however was conducted only in an urban area. Therefore it is not comparable with the 1973 study. On the other hand, the 1973 study is not comparable with Fulton's study since the 1973 study was conducted only in Canterbury. From table 12, therefore, only the 1950 survey and the 1980 national survey are considerably comparable to each other as representing the whole population in the national level. In taking samples of studies, purposive sampling techniques are used by both surveys. Comparing those 1950 and 1980 surveys, there was a 62% reduction of caries prevalence and an increase of 8-9 year old caries-free children from 7% in 1950 to 46% in 1980. The figures, however, are subject to bias since the two surveys are independently separated from each other in terms of the similarity of examiners and diagnostic criteria.

In 1978, Hunter et al (1980) repeated the 1973 ICS in the same urban area. Then the data were compared with the urban part of the 1973 ICS data (Table 13). The comparison is perfect because the two

Table 11. Caries prevalence in the permanent teeth of 8 and 9 year old New Zealand children 1950-1982
(Adapted from Brown 1982)

Location	Year	Mean DMFT	Percent caries-free
Auckland and Canterbury	1950	3.5	7
Canterbury	1973	3.3	11
Canterbury (urban)	1978	2.0	31
National	1980	1.3	46
Timaru	1981	0.9	59
Dunedin	1982	1.0	54

Table 12. Caries prevalence in the permanent teeth of 12 and 13 year old New Zealand children 1950-1982
(Adapted from Brown 1982)

Location	Year	DMFT
Auckland and Canterbury	1950	7.9
National	1977	7.0
National	1980	5.1
Dunedin	1982	4.1

surveys utilised the same examiners, the same diagnostic criteria and the reliability was checked regularly. The proportion of the subjects between boys and girls were also the same. Therefore there is no reason to reject the conclusion that there had been a declining trend of caries prevalence in Canberbury. The figures show that there was 1.3 less DMFT in 1978 for 8-9 year old children which is clinically and statistically significant ($p < 0.001$). This fact supports the conclusion made by Brown (1982).

In New Zealand there has been strictly defined criteria for the diagnosis of caries. In 1973, following the evaluation of school dental services, as a result of the findings of ICS, the philosophy in the diagnosis of caries was changed from "if in doubt - restore", to "if in doubt - monitor" (Brown 1982). With regard to this change, there should be a query to what extent the modification would influence the measure of caries prevalence in epidemiological study. If the criteria were not strict, logically the D component would rise. By examining the data in Table 13 however, it could be found that it was not the case, because it was recorded that in 1973 (before modification) the D component is 0.4 whereas in 1978 the figure is 0.04. Evidently the change in philosophy of care in no way became a nuisance factor in counting DMF index.

Further support to the conclusion that there was a declining trend of dental caries in New Zealand was put forward by Hunter and Henderson (1982). They conducted two surveys separated by a period of eight years. The initial examination was part of the 1973 Canterbury study. The repeat examination was undertaken in 1981 by exactly the same examiners using the same diagnostic criteria. The

Table 13. Caries prevalence of 8 and 9 year old children from Canterbury urban area in 1973 and 1978 (Adapted from Hunter et al 1980)

Statistics	1973	1978
Sample size	557	529
D	0.4	0.04
M	0.0	0.0
F	2.9	2.0
DMF	3.3	2.0
Standard deviation	1.8	1.7
% with caries-free permanent teeth	11	31

Table 14. Mean DMFT and percentage of caries-free of 8 and 9 year old children in Timaru in 1973 and 1981 (Adapted from Hunter & Henderson 1982)

Statistics	1973	1981
Sample size	165	158
DMFT	3.16	0.89
Standard deviation	1.71	1.29
% Caries-free	9	59

subjects were randomly chosen and the proportion of boys and girls remained the same as at the initial examination. The data presented in table 14 shows a great decline in caries prevalence from 3.16 in 1973 to 0.89 in 1981 ($p < 0.001$) as well as an increase in the percentage of caries-free children from 9% in 1973 to 59% in 1981. From the facts discussed above, it can be concluded that the declining trend of caries prevalence in New Zealand is indeed real.

In relation to the decline, some factors are reportedly responsible for the trend. Brown (1982) claimed that water fluoridation and widespread use of fluoride toothpaste have been the major factors accounting for the decline. The decline is also taking place in non-fluoridated areas. Hunter and Henderson (1982) reported that some children in non-fluoridated areas are consuming fluoride tablets. They also believed that the role of active preventive programs of the School Dental Services is of paramount importance.

As well as those three countries, UK, USA and New Zealand, some European countries have contributed evidence documenting the decline in caries prevalence. Those countries being Denmark (Thylstrup et al 1982) Ireland (O'Mullane 1982), Netherlands (Kalsbeek 1982), Norway (Heloe et al 1980), Scotland (Downer 1982) and Sweden (Koch 1982). The reports mostly showed data as representing each country but they came from local not national studies. Moreover, some reports are based on unpublished articles. It is difficult, therefore, to examine the validity of the conclusion since no other sources are available that can be used to cross-check these reported declines. With regard to the Netherlands, adjustment had to be undertaken to limit the difference in the average of age in

different studies. This manner gives too rough a picture of the prevalence to fulfill the precision requirement of the comparison. However, an attempt has been made to summarise the findings of these articles (Table 15). It can be noted that although the declining trends are reportedly taking place, the prevalence in some countries is still high. Barmes (1979) reported that in two countries, namely Japan and Italy, the prevalence was even increasing (Table 16).

While the phenomenon of the declining trends of dental caries is echoing in most developed countries, most developing countries are experiencing increases in the prevalence of this disease (Table 17 and Table 18). General trends in those developing countries appear to be in three categories (Stamm 1984, Barmes 1979) ie: (1) some nations are experiencing an increase from low or very low to moderate levels, (2) the others are moving from moderate to high and; (3) the prevalence appears to be significantly higher in the urban rather than in rural areas.

Stamm (1984) pointed out that dietary change in relation to sugar consumption is associated with the increase of the prevalence. The study of Walker et al (1981) can be used to prove this proposition. They examined 16-18 year old South African students from both rural and urban parts of the country. They found out that urban students experienced significantly higher caries prevalence than rural students and it was strongly associated with the higher sugar intake of the urban group. The rapid increase of sugar consumption in some developing countries might be attributable to the urbanisation and change of lifestyle and in some other countries might be due to the economic growth.

Table 15. Reported declining trends in caries prevalence in various European countries

Country & investigator	Age Group	Year	DMFT
Denmark (Thylstrup et al 1982)	15	1973	15.9 *
		1980	10.8 *
Netherland (Kalsbeek 1982)	12	1965	8.4
		1981	3.9
Sweden (Koch 1982)	15	1973	27.3 **
		1978	13.7 **
Ireland (O'Mullane 1982)	8-9	1961	2.8
		1980	1.3
	13-14	1961	8.0
		1980	4.4
Norway (Heloe et al 1982)	15	1955	16.5
		1979	10.8
Scotland (Downer 1982)	12	1970	8.1
		1980	5.8

* DMFS ** DFS

Table 16. Trends of dental caries in 12 year old in Japan and Italy (Adapted from Barmes 1979)

Country	Year	DMFT	Level
Japan	1957	2.8	moderate
	1975	5.9	high
Italy	1966	3.0	moderate
	1977	6.9	very high

Table 17. Trends of dental caries in children aged 12 years in developing countries
(Adapted from Barmes 1979)

Country	Year	DMFT	Level
Ethiopia	1958	0.2	very low
	1975	1.5	low
Kenya	1952	0.1	very low
	1973	1.7	low
Nigeria	1963	1.1	very low
	1973	2.5	low

Table 18. Increase in prevalence of dental caries in 10-14 year old children from selected countries
(Adapted fom Moller 1978)

Country	Increase in DMFT from	to	Within number of years
Irak	0.7	3.5	9
Thailand	0.7	4.5	15
Vietnam	2.0	6.3	11
Greenland	1.5	10.4	20

2.3 Trends of Caries Prevalence - Australia

The figures of caries prevalence of schoolchildren since 1977 are well documented at the national as well as at the state level and are recorded from annual measurements. Different from other countries, the measurement of caries prevalence in Australia was planned in a prospective way (Carr 1982, Carr 1983, Carr 1985, Commonwealth Department of Health 1987). The study virtually is a part of the evaluation of aspects of the School Dental Scheme which had operated since 1973 following agreement between the Federal and State Governments concerning a proposal to provide free dental care for schoolchildren until their completion of primary education (Commonwealth Department of Health 1980). The prime aim of the scheme was the reduction of dental disease through prevention and treatment in schoolchildren throughout Australia. Therefore it was necessary to set up a valid and reliable means to measure the change in the caries prevalence in order to appraise the existing program. Regarding dental caries, the diagnostic criteria which is used was based on the Oral Survey Basic Method WHO document 1971 (Carr 1982, Carr 1982, Carr 1985, Commonwealth Department of Health 1987). Different from other countries, the study of the trends is based on measurement of considerably large size samples which were drawn from each state and territory (Table 19).

The DMFT figures of 12 year old schoolchildren for national and each state and territory from 1977 to 1986 are presented in table 20. Although data for other age groups are also available, the 12 year old age group is chosen because this age is now regularly used as an indicator for school aged population both in developed and

Table 19. Total children examined in 1977 - 1986
(Adapted from Commonwealth Department of Health 1987)

Year	Total children examined
1977	245,144
1978	415,803
1979	547,907
1980	649,585
1981	812,605
1982	827,361
1983	928,797
1984	870,021
1985	931,749
1986	302,340

Table 20. Mean DMFT in 12 year old children in Australia and each State and Territory 1977 - 1986
(Adapted from Commonwealth Department of Health 1987)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUST
1977	3.99	6.12	4.96	4.54	3.89	5.91	-	2.97	4.79
1978	3.63	6.06	4.69	3.93	3.61	5.33	4.24	2.95	4.51
1979	2.93	5.51	4.12	3.50	3.20	4.76	3.47	2.52	3.94
1980	2.55	4.96	3.85	3.34	3.02	4.13	3.14	2.52	3.56
1981	2.37	4.30	3.51	3.12	2.97	3.47	2.76	2.35	3.22
1982	2.12	3.93	3.15	2.78	2.98	2.92	2.59	2.12	3.01
1983	1.88	3.45	2.81	2.67	2.80	2.48	2.20	2.01	2.62
1984	1.71	3.03	2.53	2.49	2.61	2.05	1.88	1.83	2.35
1985	1.53	2.72	2.29	2.31	2.43	1.83	1.91	1.71	2.13
1986	1.53	2.42	2.10	2.26	2.38	1.68	1.69	1.74	2.01
1987	1.29								1.76

developing countries (Infirri & Barmes 1979, Barmes 1979, Burton et al 1984).

As a consequence of the large size of the sample, it was impossible to have only a single examiner to undertake the examination. It was reported that approximately 1300 dental therapists were occupied (Commonwealth Department of Health 1987). Therefore variation between examiners could have been present. Moreover, no clinical standardisation is made the examinations were conducted as part of their daily activities in the Scheme. However, it was argued (Commonwealth Department of Health 1987):

> " earlier trials in Canberra had shown that one of the most reliable ways of producing standardised results was to have a large number of examiners participate in the program and pool their results. This procedure produced an accuracy and consistency which was at least as good as that obtained if one specially selected examiner had undertaken the examination."

Yet, some doubt about the reliability of the data is still perceived. The DMFT figure, in one aspect, could be perceived as the outcome of dental therapists work in the School Dental Scheme. The measurement of DMFT figure, therefore, could be perceived as the evaluation of their quality of work, and consequently there is the possibility that they tend to record an under-estimated DMFT count.

One deficiency of the studies is that the samples were not taken at random from the community. All those children who were examined throughout the year were included in the sample. Random sampling procedures of completed examinations was used from 1986 for final estimates. Consequently, there may be over-estimated data because those children who seek dental examination may have had more perceived reason to be seen by the therapists. In other words, the

children who came to dental examinations may possibly have had higher DMFT counts than the total child community. Combination of these factors could be a potential variable, especially when the DMFT being measured or the increment expected is very slight. However, the consistent reported decline in DMFT is matched with the increase in the percentage of caries-free children. As a matter of fact, the number of caries-free children is one of the most important parameters in measuring the improvement in caries prevalence. It was reported that the percentage of caries-free children aged 12 years was increasing from 10.4% in 1977 to 36.5% in 1986 (Table 21). The facts were in accordance with earlier studies undertaken by Barnard (1980). He reported that there has been a marked reduction in caries prevalence in Tamworth schoolchildren over a period of 15 years (Table 22). Another report written by Burton and her colleagues (1984) also gave a similar pattern of trends. Although different examiners were used in the studies, the diagnostic criteria remained the same. A reduction of 84% was reported with the DMFT in 1963 and 1982 being 8.49 and 1.37 respectively (Table 23).

A great decline of dental caries prevalence among schoolchildren was also recorded in Yass, a country-side of New South Wales (Martin 1979). Three dental examinations carried out in 1962, 1967 and 1978 revealed that there was a constant decline in caries experience of schoolchildren aged 6 to 12 years (Table 24). With regard to those who were 12 years old, the decline was as high as 70 % over a period of 16 years.

The declining trend of caries prevalence in Australian

Table 21. Percentage of caries-free children in Australia from 1977 to 1986
(Adapted from Commonwealth Department of Health 1987)

Year	6-13 years	12 years
1977	30.1	10.4
1978	32.4	12.0
1979	37.5	16.0
1980	40.8	17.6
1981	44.7	20.0
1982	47.4	22.3
1983	51.3	26.4
1984	54.2	30.5
1985	57.2	34.6
1986	58.6	36.5

Table 22. Mean DMFT of children in Tamworth 1963, 1973 and 1979
(Adapted from Barnard 1980)

Age	1963	1973	1979
6	1.3	0.4	0.1
7	2.5	0.7	0.4
8	3.2	1.2	0.7
9	3.8	1.9	1.1
10	5.1	2.2	1.5
11	5.9	3.1	1.8
12	8.3	3.9	2.2

Table 23. Dental caries experience of 12-year-old Sydney schoolchildren in 1963 and 1982.
(Adapted from Burton et al 1984)

Caries index	1963 (n=426)	1982 (n=736)	Percent reduction
DT	2.7	0.1	95
MT	0.5	0.03	94
FT	5.3	1.2	78
DMFT	8.5	1.4	84

Table 24. Caries experience of schoolchildren aged 6 to 12 years in Yass, New South Wales, 1962 - 1978.
(Adapted from Martin 1979)

Age	1962		1967		1978	
	n	DMFT	n	DMFT	n	DMFT
6	109	0.7	91	0.6	94	0.2
7	118	1.6	96	1.7	88	0.3
8	102	2.3	113	2.2	102	0.7
9	76	3.0	99	2.6	89	1.1
10	95	4.1	96	3.6	76	1.3
11	73	5.8	104	4.2	87	1.4
12	77	8.0	77	5.8	90	2.4

schoolchildren was also strongly supported by epidemiological studies conducted in Canberra by Carr (1976). Being carried out to measure the effect of water fluoridation, the studies exhibited a marked decline of caries experience in children aged 6 to 12 years (Table 25). In 12 year old, a 48% reduction was achieved over a period of 10 years.

Videroni et al (1976) also recorded a declining trend of dental caries prevalence among schoolchildren in Townsville. Two surveys were carried out in 1969 and 1975 to examine 6, 8, 10 and 12 year-old schoolchildren. The results of the studies suggested that there was a reduction of dental caries prevalence ranging from 25 to 48 % in these ages in Townsville (Table 26).

The data performed from those surveys apparently could be used to cross-check and to support the reported declining trend of caries prevalence in Australian schoolchildren. It can be convincingly concluded that the phenomenon of the declining trend of caries prevalence really exists in Australia.

Table 25. Caries experience (DMFT) in schoolchildren aged 6 to 12 years in Canberra, 1964 - 1974.
(Adapted from Carr 1976)

Age	1964	1970	1971	1972	1973	1974
6	0.6	0.2	0.2	0.2	0.1	0.1
7	1.7	0.9	0.9	0.7	0.5	0.4
8	2.7	1.8	1.6	1.0	1.1	0.9
9	3.6	2.6	2.4	2.0	1.6	1.5
10	4.4	3.3	3.1	2.7	2.4	2.2
11	5.7	4.3	4.1	3.7	3.3	3.0
12	7.0	5.3	5.2	4.6	4.2	3.6

Table 26. Caries experience (DMFT) of Townsville schoolchildren aged 6, 8, 10 and 12 years in 1969 and 1975.
(Adapted from Videroni et al 1976)

Age	1969		1975	
	n	DMFT	n	DMFT
6	115	0.4	93	0.3
8	140	2.3	80	1.2
10	139	4.0	81	2.2
12	79	5.7	81	4.0

2.4 Trends of Caries Prevalence - Indonesia

Similar to other developing countries, the available dental data in this country are sparse and suffer from the defficiencies of all cross-sectional studies. To date, there has been only 3 national level epidemiological studies regarding the prevalence of dental caries. The first survey was carried out in 1972 by Moller and Effendi (1972) but it was limited to urban schoolchildren in seven cities. The second, the most extensive survey, was that conducted by Wibowo (1984) in the period of 1979 - 1984. Twenty-one out of 27 provinces were included in the sample with both urban and rural population were represented. The third survey was carried out by the Directorate of Dental Health (1989) during the fourth Five Year Development Plan (Pelita IV) between 1984 - 1989.

As previously mentioned, in assessing the change in dental caries prevalence over a period of time, the comparibility of the surveys is essential. Examining the the three surveys, it appears that the manner of data collections does not fit to the criteria. It is not surprising, however, because the survey were not planned in a prospective way. Similarities in various aspects of the surveys such as examiners, diagnostic criteria and geographical area covered have failed to meet the criteria. Nothwithstanding, the second survey (1979-1984) was the most well planned study with the widest area covered. About 78 % of total provinces were represented in both urban and rural areas. The study sample was taken randomly using a multistage sampling method. However, the sample size as small as 8195 schoolchildren aged 8 and 14 years is considered to be insufficient to represent a total of 7.2 million children in those ages, as it is only about 0.1 % of the population being sampled.

Moreover, no sound calibration of the examiners was performed. On the other hand, the Pelita IV data were virtually not a result of an epidemiological survey since the "samples" were apparently taken from the Community Health Centers and only 11 provinces were represented.

With lack of validity and reliability, an attempt is made to compare these survey results to draw a possible trend of dental caries prevalence in Indonesian schoolchildren. The first survey, however, has to be taken out from the comparison since it covered extremely limited urban areas. The comparison, therefore, will include the last two surveys. For getting a better comparison, only 11 provinces are taken from the Pelita III data, to compare to those in the Pelita IV survey.

The caries experience in both urban and rural areas during the period of Pelita III and Pelita IV for children aged 8 and 14 years are presented in tables 27, 28, 29 and 30 and summarised in table 31. Table 31 shows that in those 8 year old the DMFT figures appear to be slightly decreasing both in urban and rural areas. However, 14-year-old schoolchildren are apparently experiencing an increasing caries prevalence. Urban children consistently show a higher caries experience than rural dwellers, and it can be assumed that different life style resulting in different sugar consumption is responsible for the change in the prevalence. It is difficult to speculate on the slight decrease in prevalence of children aged 8 years in both urban and rural areas. One possible explanation is that 8 year old children are not exposed to commercial food as extensively and intensively as those who are 14 year old. Due to lack of epidemiological data, it is difficult to judge whether the change is

Table 27. Dental caries experience (DMFT) of children aged 8 years in urban and rural areas of 11 provinces in Indonesia during Pelita III (1979 - 1984).
(Adapted from Wibowo 1984)

Province	Urban		Rural	
	n	DMFT	n	DMFT
West Java	100	1.7	100	0.9
Central Java	99	1.2	100	1.9
Yogyakarta	100	0.5	100	0.5
Bali	100	0.5	100	0.4
East Java	100	1.1	100	0.5
West Kalimantan	100	1.9	100	2.9
East Kalimantan	100	0.9	99	0.9
South Sumatra	100	1.7	100	1.0
North Sulawesi	100	1.3	100	1.0
South East Sulawesi	100	0.7	100	0.3
East Nusa Tenggara	100	1.4	100	0.1
Total	1199	1.2	1099	0.9

Table 28. Dental caries experience (DMFT) of schoolchildren aged 14 years in urban and rural areas of 11 provinces in Indonesia during Pelita III (1979 - 1984).
(Adapted from Wibowo 1984)

Province	Urban		Rural	
	n	DMFT	n	DMFT
West Java	100	3.0	100	1.4
Central Java	100	1.7	100	2.8
Yogyakarta	100	1.7	100	1.7
Bali	100	0.9	100	0.9
East Java	100	2.3	100	1.7
West Kalimantan	100	6.1	100	3.9
East Kalimantan	100	1.9	100	1.5
South Sumatra	100	2.7	100	2.2
North Sulawesi	100	2.8	100	2.5
South East Sulawesi	100	2.6	99	0.6
East Nusa Tenggara	100	1.7	100	0.9
Total	1100	2.5	1199	1.9

Table 29. Dental caries experience (DMFT) of schollchildren aged 8 years in urban and rural areas of 11 provinces in Indonesia during Pelita IV (1984 - 1989)
(Adapted from the Directorate of Dental Health 1989)

Province	Urban	Rural
West Java	0.9	0.7
Central Java	0.2	0.3
Yogyakarta	0.3	0.5
Bali	0.7	0.6
East Java	1.1	0.5
West Kalimantan	1.9	2.0
East Kalimantan	0.9	0.9
South Sumatra	1.9	1.3
North Sulawesi	1.0	0.8
South East Sulawesi	0.6	0.5
East Nusa Tenggara	0.8	0.6
Total	0.9	0.8

Table 30. Dental caries experience (DMFT) of schoolchildren aged 14 years in urban and rural areas of 11 provinces in Indonesia during Pelita IV (1984 - 1989)
(Adapted from the Directorate of Dental Health 1989)

Province	Urban	Rural
West Java	2.9	2.9
Central Java	1.1	1.3
Yogyakarta	1.9	1.6
Bali	2.2	2.9
East Java	2.3	1.7
West Kalimantan	7.2	5.3
East Kalimantan	1.9	1.5
South Sumatra	4.0	2.6
North Sulawesi	1.9	3.8
South East Sulawesi	1.9	1.4
East Nusa Tenggara	1.9	2.5
Total	2.6	2.5

Table 31. Dental caries experience (DMFT) of schoolchildren aged 8 and 14 years during Pelita III (1979 - 1984) and Pelita IV (1984 - 1989) by urban and rural areas.

Age	Area	Pelita III	Pelita IV
8	Urban	1.18	0.94
	Rural	0.94	0.76
14	Urban	2.50	2.64
	Rural	1.85	2.50

a cyclic variation or a real increase. However, if it were true that sugar is responsible for the change of DMFT in children aged 14, it can be expected that the prevalence will continue to increase in the near future (discussed in section 5.6).

2.5 Concluding Remarks

An attempt has been made to summarise and to reassess articles concerning the declining trends of dental caries prevalence in developed countries. The reassessment is aimed to evaluate whether or not the reported declining trends are subject to bias or other factors. It was realised that the proof is often limited, mainly due to lack of information regarding research methodology used in revealing the decline. However, some general conclusions may be drawn as follows:

1. Some countries have contributed data documenting the decline by performing several studies which are not entirely comparable. In some cases, data from local studies are cited to represent the whole country. Therefore, whether the reported decline really exists appears to be doubtful and inconclusive. However, in some other countries the reported declines are convincingly substantiated by available data.

2. Although a continuous and great reduction of caries attack rate is reportedly taking place, the levels of caries still remains high in some countries because the magnitude of the trends varies in different places.

3. The factors that have been commonly cited to be associated with the declining trends are: fluoride exposures in its different

forms, reduction in sugar consumption, and successful implementation of school-based dental services in which dental health education programs are emphasized resulting in increased awareness in oral health amongst schoolchildren.

4. Due to lack of preventive measures, urbanisation and increase in sugar consumption, some developing countries are facing increases of dental caries prevalence approaching moderate or higher levels of deterioration.

5. Australia has systematically recorded its national figure of caries level through School Dental Services evaluation revealing a continuous reduction in caries level.

6. Similar to that in other developing countries, Indonesian schoolchildren are apparently experiencing an increase in dental caries prevalence.

3. FACTORS AFFECTING THE CHANGE IN CARIES PREVALENCE - A THEORETICAL BASIS

3.1 Introduction

It was suggested in the previous section that several factors have been reportedly attributed to the declining trend of dental caries prevalence in the last 2-3 decades. Three major factors that have been commonly cited to be associated with the trends being: (1) various fluoride exposures, (2) reduction in sugar consumption and (3) increase in dental awareness. In its report, the joint FDI/WHO Working Group 5 (1985) has put two additional factors which were: (1) widespread use of antibiotics and (2) herd immunity. The aim of this section is to establish a theoretical basis concerning the relation between the factors and the trends.

The role of the widespread use of antibiotics as a potential factor in reducing caries prevalence has been hypothesised. This was mainly based on the findings that there was an inverse relationship between caries experience and antibiotic usage among children (Loesche et al 1982). It has been assumed that antibiotic use for infected throats in children has a positive additional effect in suppressing the growth of Streptococcus mutans in oral environment. With the estimate that the present generation of children has been exposed to antibiotics more intensively than it used to be, it has been assumed that antibiotics may play an important role in changing the pattern of dental diseases on a community basis. The hypothesis, however, remains speculative since there has not been any study investigating the spread of antibiotic use both quantitatively and qualitatively. If it were true, not only dental

caries is affected but also periodontal disease. However, the prevalence of periodontal disease in the developed countries remains stable (Renson 1984). Furthermore, it would not also be relevant when attempting to identify the factors related to the trends to be implemented in the developing countries where the use of antibiotics is not a common curative treatment. In the third world nations, antibiotics seems to be an exclusive medication and is considerably expensive in cost compared to the income of the vast majority of its populations.

The role of herd immunity in explaining the declining trends has been put forth by Burt (1978) and Bowen (1981). Herd immunity or the immunity of a group or community is defined as "the resistance of a group to invasion and spread of an infectious agent, based on the resistance to infection of a high proportion of individual members of the group" (Last 1983).

Since oral environment is contaminated by microorganism in the early stage of life, no single individual is free from oral microflora. The existence of microorganisms in the oral cavity is considered to be inherent in human life, and it is physiologically required, to a lesser extent, for the metabolism of carbohydrate. Based on this phenomenon, the concept of herd immunity is not applicable to a group of individuals. The concept would be meaningful if it is applied to a group of teeth. Moreover, if it were true, it would be exhibited by a slow decline of dental caries. Again, however, there is no way of measuring such a change in herd immunity retrospectively. Therefore, the theory remains speculative.

3.2 Use of Fluoride

It is believed that the use of fluoride in various forms is the most important factor causing a great decline of dental caries prevalence. The use of fluoride has been common in those countries which have achieved a great improvement of caries experience in schoolchildren. In this section, the basic mechanism by which fluoride could increase the tooth resistance against caries attack will be discussed. Firstly, it proceeds to the mode of action of fluoride and is followed by presenting epidemiological studies and clinical trials regarding the efficacy of various fluoride exposures.

3.2.1 Mode of actions of fluoride

Although the benefits of fluoride are recognised around the world, the mechanism by which fluoride protects the teeth against caries is not completely understood except that it appears to be more than one mode of action is involved. Jenkins (1963) suggested that there are three ways by which fluorides inhibit caries, i.e.: (1) in ionic forms, fluoride undergoes exchange with the hydroxyl group of hydroxyapatite to form fluorapatite, (2) fluoride enhances remineralisation of demineralised lesion of enamel and (3) fluoride has some inhibitory effects to some enzymes producing acids.

Fluoride incorporation in the lattice by replacing hydroxyl ion is made possible because they have similar properties in which both ions have a primary hydration number of 5 and physically F^- and OH^- have a similar dimension (ionic radii): 1.29 A and 1.33 A respectively (Myers 1972). If all of the hydroxyl groups are replaced by fluoride ions, it will take the tooth to the

concentration of 38,000 ppm of fluoride whereas the detection of the first 10 um of the surface enamel of persons from fluoridated areas yields 3,000-4,000 ppm of fluoride (Nikiforuk 1985).

Based on the concept that the caries process is a result of demineralisation in which acids produced by oral bacteria dissolve the mineral phase of the enamel, it has been postulated that fluoride incorporation into the apatite lattice reduces the solubility of the enamel (Jenkins 1963). The solubility-reduction theory was initially proposed by Volker about 50 years ago, but for a long period the theory remained unclear (Shannon 1971, Johansen and Olsen 1979). Finn & De Marco (1956), Isaac et al (1958), Jenkins (1963) and Healy & Ludwig (1966) have given evidence in vitro and in vivo that fluoride incorporation into the enamel is associated with a decrease of its solubility and that teeth from fluoridated areas are less soluble than teeth from non-fluoridated areas. The difference in solubility, however, is not as high as it has been expected. Gray et al (1962) estimated that initially fluorapatite does not differ in solubility from hydroxyapatite. A study conducted by Manly and Harrington (1959) showed that 0.1 ppm fluoride treatment did not appear to reduce calcium solubility rate during the first 5 minutes. Gray et al (1962) interpreted this fact as the fluorapatite dissolves in the first 5 minutes of acid exposures, calcium and fluoride ions form calcium fluoride that acts as a layer protecting the enamel surface from the subsequent dissolution. Thus, according to Gray (1962) the dissolution rates of hydroxyapatite and fluorapatite are similar. However, in his review, Brown et al (1977) suggested that hydroxyapatite is basically more soluble than fluorapatite but the difference in solubility varies

under different circumstances. In strong acid the solubility rates are about the same, whereas in weak acid fluorapatite is significantly less soluble than hydroxyapatite.

In explaining how fluoride could reduce the solubility of apatite, various theories emerged. Nikiforuk (1985) suggested that fluoride has the ability to stabilise crystal structure by filling the void position left by hydroxyl. As a matter of fact some hydroxyl of hydroxyapatite is invariably missing. This defect (and in other conditions impurities of hydroxyapatite) reduces the stability of the crystal and therefore increases its solubility (Brown et al 1977). Fluoride, because of its property of strong affinity to mineral tissue (Murray and Rugg-Gunn 1982), will fill the voids and become more bonded to the lattice than hydroxyl ion. In addition, Driessen (1973) suggested that the presence of fluoride ion will diminish natrium and carbonate incorporation into the lattice. It has been known that natrium and carbonate incorporation results in impurities of the crystal and increase the solubility as well as the reactivity of the enamel (Nikiforuk 1975). As a result, fluoride incorporation, especially during enamel development, reduces the solubility of enamel by stabilising the crystal structure of enamel apatite.

Another theory regarding the effect of fluoride in reducing the solubility of hydroxyapatite was released by Brown (1977). The theory is based on the fact that if hydroxyapatite and fluorapatite are dissolved in solution, the difference between those two saturated solutions would be in the $Ca(OH)_2$ activity and increase the H_3PO_4 activity. As a result, this will alter the rate of diffusion in such a way that diminishes the rate of caries formation

or increases the rate of remineralisation.

The second mode of action by which fluoride reduces caries prevalence is its ability to accelerate the remineralisation of demineralised lesions of enamel. The term remineralisation is defined as "all attempts to precipitate calcium phosphate and other ions either into or onto sound or partially demineralised enamel" (Silverstone 1977). The sources of the ions can be from the previous dissolution of the tooth enamel, be available in saliva secreted from salivary glands or orally administered, or be a combination of these sources.

The remineralisation of early carious lesions was reported occurring in vivo (Anderson 1966, Backer-Dirks 1966) and in vitro (Koulourides et al 1961, Von der Fehr et al 1970, Feagin et al 1971, Ten Cate and Arends 1977). Epidemiologically, Backer-Dirks (1966) reported that 50% of early lesions (white spots) examined in buccal surfaces of maxillary first molar disappeared during the following year due to this phenomenon. Therefore, studies confirmed that remineralisation exists as a natural process in the human oral cavity as a defence mechanism against the formation of carious lesions. It was reported that such a precipitation of minerals from saliva into or onto enamel is influenced by several factors such as: calcium, phosphate and hydroxyl ions concentration in the saliva (Feagin et al 1971), pH, ionic strength (Silverstone 1977), the presence of magnesium and carbonate (Brudevold et al 1961) and copper and berryllium (Briner et al 1974) and the availability of fluoride.

Regarding the role of fluoride, initially it was postulated by Knappwost in 1951 (Jenkins 1963) that fluoride favours the

deposition of mineral from saturated solutions such as saliva. The proposition was based on his study using hamsters which were administered with 0.04 mg fluoride daily for 24 days. It was then followed by injection of P^{32}. It was found that more P^{32} was deposited on the teeth of those receiving fluoride than in the control group. Based on that postulate, several studies regarding the role of fluoride in the remineralisation were conducted in vivo and vitro. Koulourides et al (1961) suggested that fluoride as much as 0.05 mM (1 ppm) accelerated the rate of demineralisation by 4 to 8 fold in a synthetic solution in vitro. In vivo, since the remineralising ability of saliva was less than that of a synthetic solution, higher concentration of fluoride (about 20 ppm) was required to enhance remineralisation (Koulourides et al 1965 cit Silverstone 1977). However, von der Fehr and his colleagues (1970) have demonstrated in vivo that remineralisation was enhanced with relatively small concentrations of fluoride. With an experiment in vitro, Feagin et al (1971) reported that there was a significant increase in the rate of remineralisation if 0.05 mM (1 ppm) fluoride was added in the solution. Other workers (Ten Cate and Arends 1977) showed that the presence of 1 ppm fluoride in solution could improve the deposition of OH^-, Ca^{2+} and PO_4^{3-} by two fold.

In vivo, Featherstone et al (1982) suggested that mouth rinsing with a solution containing 6×10^{-4} mol/l (approximately 12 ppm) for 1 minute on each 14 consecutive days could reharden the inner 40-50 um and give a twofold rehardening of the remaining body lesions.

Other workers suggested that remineralisation process can only be achieved when considerably high concentration of fluoride is present

in saliva (Briner et al 1974, Silverstone et al 1981). However Panthumvanit et al (1977) provided evidence that optimum remineralisation would be achieved if the concentration of fluoride in the saliva was ranging between 0.26 - 0.5 mM (5-10 ppm). They suggested that the increase of fluoride concentration above 0.5 mM did not necessarily increase the remineralisation since that range was sufficient to facilitate the remineralisation mechanism.

The mechanism by which fluoride could enhance the rate of remineralisation has not been conclusive. One of the factors influencing remineralisation being the concentration of calcium, phosphate and hydroxyl ions in the saliva. When saliva becomes saturated with those ions then the precipitation takes place. Feagin et al (1977) reported that fluoride lowered the saturation point of saliva. Less concentration of calcium, phosphate and hydroxyl is required to be precipitated or remineralised in the presence of fluoride. Hence, fluoride accelerates remineralisation. Other workers (Brudevold et al 1961, Gron et al 1963, Gron and Messer 1964) suggested that the presence of magnesium and carbonate had a negative effect in the rate of remineralisation. On the other hand, fluoride suppressed the effect of these two ions. As a result fluoride enhances the rate of remineralisation. Different from those two previous theory, Johansen and Olsen (1979) explained that when enamel surfaces are exposed to acid solution (pH < 4.5), the hydroxyapatite is dissolved to dicalcium phosphate; and it was found that fluoride promoted the conversion of dicalcium phosphate to fluoride containing apatite.

Remineralised enamel, especially that containing fluorapatite, was reported to be more resistant than initial hydroxyapatite in

naturally mineralised enamel (Feagin et al 1971). Therefore, to become arrested, a lesion does not have to be entirely remineralised. Remineralisation in the surface zone only is enough to protect teeth against subsequent acid attack (Nikiforuk 1985).

The third mode of action of fluoride is in inhibiting bacterial activities in carbohydrate metabolism and bacterial growth. It is an important effect since glycolysis by plaque bacteria is believed to be an essential step in caries etiology (Murray and Rugg-Gunn 1982). Unlike the first two modes of actions this effect deals with the tooth environment. Therefore it is likely to occur when fluoride is applied topically and fluoride remaining in plaque is responsible for this effect. As reported by Jenkins and Edgar (1977) and Agus et al (1980), plaque from individuals consuming fluoridated water contains higher fluoride levels than does plaque from individuals living in non-fluoridated areas. When incubated with sucrose, plaque from subjects living in fluoridated areas shows a smaller pH drop than does plaque from those who live in non-fluoridated areas. This indicates that plaque fluoride exerts an inhibitory effect on bacteria producing acid.

Bibby and Van Kesteren (1940) showed that fluoride as low as 0.024 mM (0.5 ppm) inhibited acid production by pure cultures of oral streptococci and lactobacilli. This study was then confirmed by Wright and Jenkins (1954). Using incubated saliva instead of synthetic media, Wright and Jenkins (1954) reported that 0.024 mM (0.5 ppm) NaF had a significant effect in the reduction of acid production. Other workers, Sandham and Kleinberg (1969), Jenkins et al (1969), Kleinberg et al (1977), Bibby and Fu (1986), Iida et al

(1986), Harper and Loesche (1986) and Zameck and Tinanoff (1987) and many others also provided evidence that fluoride suppresses acid production by oral bacteria.

The mechanism by which fluoride could inhibit acid production by oral bacteria has not been conclusive. Several theories regarding this mechanism have been put forth. These theories being : (1) fluoride has a significant effect on enolase, an enzyme which converts 2-phosphoglycerate (2-PGA) to P-enolpyruvate (Hamilton 1977, Bunick and Kaskhet 1981 cit Iida et al 1986), (2) fluoride inhibits glucose uptake (Sandham and Kleinberg 1969), (3) fluoride affects the bacterial membrane permeability (Murray and Rugg-Gunn 1982) and (4) fluoride inhibits glycogen synthesis (Hamilton 1977).

Enolase is one of the enzymes involved in the glycolytic pathway in oral bacteria. It was reported that enolase is sensitive to fluoride. To be active, enolase needs the presence of magnesium as a catalyst. In the presence of fluoride, magnesium ions would be inactive because it forms Mg-fluorophosphate complex (Hamilton 1977).

Sandham and Kleinberg (1969) suggested that fluoride could change the structure of bacterial membrane resulting in the inhibition of glucose transport through the cell membrane. They indicated that fluoride inhibits ATP-ase, an enzyme involved in membrane transport, by affecting the activity of Na and K ions. As reported by Marsh et al (1982), the rate of sugar uptake is influenced by the concentration ratio between these two ions. The sugar uptake is much higher in a K^+-rich than in a Na^+-rich. With regard to bacterial cell membrane, Murray and Rugg-Gunn (1982) suggested that at lower

pH level the cell membrane permeability is increased. As a result, more fluoride could penetrate into bacterial cells resulting in more inhibition to the glycolitic process.

It has been shown that plaque bacteria has an ability to form large quantities of glycogen in its intracellular anaerobic glucose metabolism. In the absence of extracellular glucose uptake, intracellular glycogen is broken down into glucose that enables the continuous glycolytic process to produce acid. Hamilton (1977) suggested that fluoride inhibits phosphoglucomutase, an enzyme which converts Glucose-6-P to Glucose-1-P in the glycogen synthesis pathway.

Although the prime site of fluoride inhibition is still not conclusive, it seems that intracellular glucose metabolism is more affected than the extracellular metabolism which produces fructan and glucan (Jenkins 1969, Carlsson et al 1969, Iida et al 1986). Carlsson et al (1969) in their study revealed that 4.0 mM (100 ppm) fluoride did not have any effect on the synthesis of extracellular glucan and fructan from sucrose. Iida et al (1986) also reported that there was no effect of fluoride in the concentration ranging from 0 to 10,000 ppm on the synthesis of glucan.

With regard to bacterial growth, it was reported by Bibby and Van Kesteren (1940) that a concentration of fluoride more that 250 ppm is needed to affect the growth. However, Bowen and Hewitt (1974) suggested that 70 ppm was enough to inhibit bacterial growth. Other workers, Iida et al (1986) reported that 90 ppm of fluoride inhibited the growth of S mutans whereas the concentration of 180 - 360 ppm completely arrested bacterial growth.

3.2.2 Epidemiological studies and clinical trials

3.2.2.1 Water Fluoridation

It was McKay who made extensive observations of several thousand of mottled enamel cases and observed that mottled enamel showed less susceptibility to caries (McKay 1928). Based on the proof that fluoride is a causative agent for mottled enamel, it was postulated that the increase of fluoride in drinking water could reduce the susceptibility of teeth to caries. In other words, fluoride, beside causing mottled enamel also reduces the prevalence of dental caries. Based on that postulate, Dean and his colleagues (Dean 1938, Dean et al 1939, Dean et al 1942) conducted several studies to establish the relationship between fluoride and caries. By examining a total of 7257 children aged 12 to 14 years from 21 cities which had different fluoride levels in their water supplies, Dean et al (1942) established the inverse relationship between fluoride content of the public water supply and dental caries experience (Figures 2 and 3).

To confirm the result of previous surveys, Dean and his colleagues conducted an experimental study in which public water supply was artificially fluoridated to bring the level of fluoride up to 1 ppm. It was the first field experiment on the efficacy of artificially fluoridated water as a community-wide measure to prevent caries. The study was carried out in two cities, Grand Rapids and Muskegon which served as the experimental and control towns respectively. In the beginning of 1945, water supply in Grand Rapids was fluoridated. In 1951, six and a half years after the initiation of fluoridation, the first assessment was conducted. The result is presented in Table 32 (Arnold et al 1953). It was reported that the fluoridation

NUMBER OF CITIES STUDIED	NUMBER OF CHILDREN EXAMINED	NUMBER OF PERMANENT TEETH SHOWING DENTAL CARIES EXPERIENCE* PER 100 CHILDREN EXAMINED (0 100 200 300 400 500 600 700)	FLUORIDE (F) CONCENTRATION OF PUBLIC WATER SUPPLY IN P.P.M.
11	3867		< 0.5
3	1140		0.5 TO 0.9
4	1403		1.0 TO 1.4
3	847		> 1.4

* DENTAL CARIES EXPERIENCE IS COMPUTED BY TOTALING THE NUMBER OF FILLED TEETH (PAST DENTAL CARIES), THE NUMBER OF TEETH WITH UNTREATED DENTAL CARIES, THE NUMBER OF TEETH INDICATED FOR EXTRACTION, AND THE NUMBER OF TEETH MISSING (PRESUMABLY BECAUSE OF DENTAL CARIES).

Figure 2. Amount of dental caries (permanent teeth) observed in 7257 selected 12-14 year old white schoolchildren of 21 cities classified according to fluoride concentration of the public water supply.
(Adapted from Dean et al 1942)

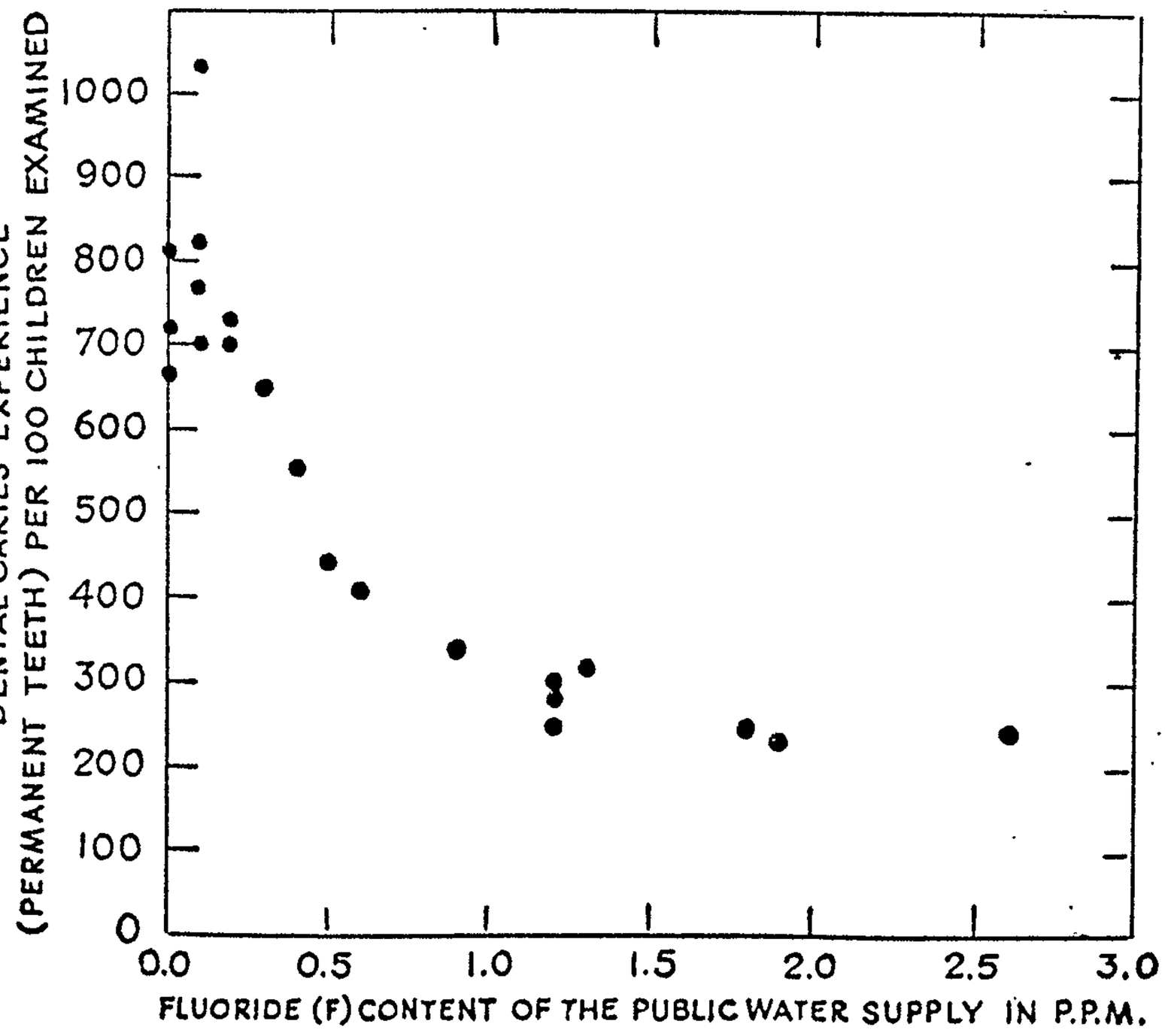

Figure 3. The relation between the amount of dental caries (permanent teeth) observed in 7257 selected 12-14 year old white school children of 21 cities and the fluoride content of public water supply.
(Adapted from Dean et al 1942)

Table 32. Mean deft* in Grand Rapids (1 ppm) and Muskegon, 1951. (Adapted from Arnold et al 1953)

Age	Grand Rapids	Muskegon	% difference
4	2.1	4.5	53
5	2.3	5.3	57
6	2.9	5.7	49

* Decayed, extraction indicated or filled, deciduous teeth. A decayed and filled tooth is counted as filled tooth.

measure could reduce about 50% of the caries prevalence.

The city of Newburgh was fluoridated in 1945. In 1955, Ast et al (1956) carried out an examination on children aged 6 to 16 years. The study was actually a 10 year evaluation of the water fluoridation. The city of Kingston served as the control town. The results presented in table 33 showed that the prevalence of caries in Newburgh was around 50% lower than that in Kingston.

The successful result of the study reported by Arnold et al (1953) and Ast et al (1956) then encouraged other cities and countries to initiate fluoridation of their public water supplies.

In the Netherlands, it was reported that the water supply in the city of Tiel was fluoridated in 1953. In 1959-1960, six and a half years after the initiation of water fluoridation, Backer Dirks et al (1961) evaluated its effect on the prevalence of dental caries. Different from the two previous studies, the subjects in this study were born before the initiation of fluoridation. The study was specific because it was designed to investigate the fluoride effect on the individual surface of the tooth with emphasises on the approximal surface. It was reported that the reduction was greatest for caries of approximal surfaces and other smooth surfaces and least for caries of pits and fissures on the occlusal surfaces of teeth. In addition, although the majority of the teeth examined had erupted prior to the institution of fluoridation, the effect on caries inhibition was still obvious (Table 34). It indicates that post calcification and/or post eruptive exposure to fluoridation has also a significant effect on caries occurrence.

The effect of post eruptive exposure to a fluoride water supply on

Table 33. Mean DMFT of children aged 6-16 years in Newburgh (1 ppm) and Kingston (0.12 ppm), 1955 (Adapted from Ast et al 1956)

Age Group	Sample size		DMFT		Percent reduction
	Newburgh	Kingston	Newburgh	Kingston	
6-9	708	913	1.0	2.3	57
10-12	521	640	3.3	7.0	53
13-14	263	441	6.1	11.7	48
16	109	119	9.8	16.5	41

Table 34. Mean DMF carious approximal surfaces per child in children aged 10 to 15 years in Culemborg and Tiel, 1959. (Adapted from Backer Dirks et al 1961)

Age	Culemborg (0.1 ppm)	Tiel (1.1 ppm)	Percent difference
10 (3)*	1.5	0.5	67
11 (4)	2.3	1.1	50
12 (5)	4.0	1.6	60
13 (6)	4.5	2.8	38
14 (7)	6.0	4.3	28
15 (8)	7.4	5.8	22**

* in bracket, age at the start of fluoridation (1953).
** the difference is not significant at the p=0.01 level.

caries occurrence has also been confirmed by the study of Tank and Storvick (1964) who investigated the caries inhibition effect on deciduous teeth of children aged 1 to 6 years of age. It was reported that there was a reduction of caries occurrence ranging from 43 to 66% in the experimental town (Corvallis) which was fluoridated in 1953. With regard to the effect of post calcification or post eruptive exposure to fluoridated water, it was suggested that those children who had been 1 to 17 months old when the water supply was fluoridated showed significant caries reduction when compared with caries rates in the control town (Albany - 0.01 ppm) but the reduction was less than of those who were born after the initiation of the fluoridation (Tables 35 and 36).

The water supply in Evanston, Illinois, was fluoridated in 1946. In 1960, fourteen years after fluoridation, its effect was measured by Blayney and Hill (1967). Oak Park, a nearby town, served as a control population. Children aged 6 to 8 and 12 to 14 years were examined. It was reported that in Evanston there was a 50 percent reduction of caries prevalence in 14 years while in Oak Park no change was found during the 9 years (1947 to 1956) (Table 37).

In New Zealand, Ludwig (1971) conducted a study to evaluate the effect of water fluoridation in Hastings which was commenced in 1954. The study was carried out in 1970, ie: sixteen years after the initiation. No control group was used. It was suggested that during the 16 years period of time there was about 50 percent reduction of caries prevalence (DMFT).

Water fluoridation was instituted in Leeds in 1968, with an average level of 0,9 ppm of fluoride. In 1979, Jackson et al (1980) carried

Table 35. Mean dmft* of children in Albany (non-fluoridated) and Corvalis (fluoridated).
(Adapted from Tank and Storvick 1964)

Location	Age on last birthday						All ages
	1	2	3	4	5	6	
Albany	0.14	1.26	4.25	5.51	6.00	7.77	4.16
Corvallis	0.08	0.59	1.44	2.31	3.29	3.19	1.82
Percent difference	43	53	66	58	45	59	56

* decayed, missing and filled deciduous teeth.

Table 36. Mean dmft* of children one to six year old with no exposure, with postnatal exposure and pre and postnatal exposure to a fluoridated water supply.
(Adapted from Tank and Storvick 1964)

Caries index	Consumption of fluoridated water		
	None	1-11 months post-natally	Pre & post natally
dmft	4.16	2.65	1.82
d	3.43	1.58	1.28
e	0.10	0.19	0.00
f	0.78	0.88	0.59

* decayed, missing and filled deciduous teeth.

Table 37. Mean DMFT of children aged 6 - 8 and 12 - 14 years in Evanston (1946-1960) and Oak Park (1947-1956). (Adapted from Blayney and Hill 1967).

	Evanston		Oak Park	
Age	1946	1960	1947	1956
6	0.47	0.12	0.27	0.24
7	1.53	0.44	1.03	1.28
8	2.50	0.99	2.22	2.41
12	7.63	3.28	7.74	7.13
13	10.09	4.71	9.70	10.04
14	11.66	5.95	11.94	11.35

Table 38. Mean dmft* in 5-year old children from fluoridated and low fluoride neighbouring districts of Leeds, 1979. (Adapted from Jackson et al 1980)

Districts	n	dmf	d	m	f
Fluoridated	190	1.23	0.71	0.11	0.41
Low-fluoride	198	3.28	2.30	0.43	0.54

* decayed, missing or filled deciduous teeth.

out an examination in 5 year old children. No baseline data were reported but a similar study was conducted in the neighbouring population which served as a control group. It was reported that after experiencing 11 years of fluoridation, the dmtf (decayed, missing and filled deciduous teeth) figure was 1.23 compared with 3.28 in the non-fluoridated neighbouring area (0.1 ppm).

That caries experience varies inversely with water fluoride level has been confirmed by Rugg-Gunn et al (1981). Children aged 5 years in four areas with different water fluoride level (0.1, 0.2, 0.5 and 1.0) have been examined. No baseline study was conducted. It was reported that in the 4 areas, the deft were 6.1, 4.9, 3.8 and 2.5 respectively, and the defs figures were 11.6, 8.9, 6.2 and 4.1 respectively (Table 39).

The domestic water supply in Birmingham was fluoridated in 1964. Rock et al (1981) conducted a study to investigate the caries experience in children aged 6-13 years compared to children in Wolverhampton which was fluoride free. The result showed that the DMF figure of children in Birmingham was 38 to 66 per cent lower than that of Wolverhampton (Table 40) whereas the caries reduction in deciduous teeth ranged from 42 to 52 per cent (Table 41).

Although there is a "hallo effect" in the non-fluoridated areas provided by the use of fluoride dentifrices (Newbrun 1989), recent studies consistently showed lower DMFT figures in the fluoridated areas compared to that of the non-fluoridated localities.

The city of South Birmingham has had its water supply fluoridated at 1 ppm since 1964, whereas a neighboring city of Bolton has a water supply with less than 0.1 ppm fluoride. Mitropoulos et al (1988)

Table 39. Mean deft* and defs** of 5-year-old children in each of the 4 areas with 0.1, 0.2, 0.5 and 1.0 ppm water F concentration.
(Adapted from Rugg-Gunn et al 1981)

Caries indices	Water F concentration in ppm 0.1	0.2	0.5	1.0
deft	6.1	4.9	3.8	2.5
defs	11.6	8.9	6.2	4.1

* decayed, extracted or indicated for extraction and filled teeth.
** decayed surfaces, extracted or indicated for extraction teeth, and filled surfaces.

Table 40. Mean DMFT of children aged 6 - 13 years in Birmingham (1 ppm) and Wolverhampton (0.1 ppm).
(Adapted from Rock et al 1981)

Age	DMFT Wolverhampton	Birmingham	Percent difference
6	0.42	0.14	66
7	0.77	0.26	66
8	1.59	0.94	40
9	2.24	1.06	52
10	3.24	1.34	58
11	3.45	1.91	44
12	5.68	2.63	53
13	5.42	3.36	38

Table 41. Mean deft of children aged 6 - 9 years in Birmingham (1 ppm) and Wolverhampton (0.1 ppm). (Adapted from Rock et al 1981)

Age	deft		Percent difference
	Wolverhampton	Birmingham	
6	5.08	2.42	52
7	5.43	3.11	42
8	5.52	3.14	43
9	5.47	3.12	42

carried out caries examinations in schoolchildren aged 14 years in those areas which have similar social class profiles. A total of 234 and 275 children from South Birmingham and Bolton respectively were involved in the study and were drawn from the populations using a two stage stratified random sampling. The results suggested that a 40% lower caries prevalence (DMFT) was experienced in South Birmingham compared the non-fluoridated area of Bolton. The recorded DMFT were 2.26 and 3.79 in South Birmingham and Bolton respectively.

Fluoridation of water supply began in Newcastle upon Tyne in 1969 when the fluoride content of the public water supply was raised to 1 ppm. As part of a regular evaluation on the effect of this measure, Rugg-Gunn et al (1988) conducted an examination in 5 year old children to compare the caries level in this area with that of the non-fluoridated city of Northumberland. The results showed that the dmft figure for Newcastle was 1.8 compared with 3.9 in Northumberland, a difference of 2.1 carious teeth per child (54%).

The lower DMFT figures in fluoridated areas compared to that of non-fluoridated localities ranging from 30 to 50% were also reported in Canada by Clovis et al (1988), in Ireland (O'Mullane et al 1988) and in the USA by Fitzgerald et al (1989), Brunelle and Carlos (1989) and Kumar et al (1989).

The effectiveness of water fluoridation is further supported by the fact that the caries level tends to increase when the fluoridation is ceased. The water supply in the town of Wick, Scotland was defluoridated in 1979. Stephen et al (1987) carried out a study to compare the caries experience of 5 to 6 year old children who had been born and raised in the fluoridation period with those similar

subjects five years after Wick's water supply was defluoridated. The results showed that the mean dmft index rose by 27% and there was a 10.1% reduction in the number of caries-free children. Futhermore, this caries increase had occured when there was a reported overall reduction in caries nationally and when fluoridated dentifrices had been universally available (Stephen et al 1987).

In summary, fluoridation of public water supply is the cornerstone of caries prevention. In an extensive review of the results of studies conducted between 1945 and 1978, Murray and Rugg-Gunn (1982) reported that the average percentage caries reduction achieved by this measure was 50 - 60% for permanent teeth. The results of several recent studies, however, indicated that the magnitude in the caries reduction was not as same as the previous study. This is probably caused by the use of fluoride dentifrice and the spread effect of fluoridated water in the non-fluoridated areas through manufactured drinks and foods which are produced in the fluoridated areas.

3.2.2.2 Fluoride dentifrice

Efforts in adding fluoride to toothpastes were undertaken after success with the use of fluoride topical application which showed its topical inhibitory effect on caries occurrence. Studies regarding the effectiveness of these methods have been conducted for more than four decades with more interest in this field than any other fluoride studies (Murray and Rugg-Gunn 1982). It is probable that such investigations were encouraged by toothpaste manufacturers since they have potential commercial value. There are five major compounds of fluoride which have been incorporated into toothpastes, ie: (1) sodium fluoride, (2) stannous fluoride, (3) sodium monofluorophosphate, (4) acidulated phosphate fluoride, and (5) amine fluoride. The discussion, however, will be limited to the first three compounds since they are commonly used in fluoride dentifrice and have been extensively tested (Forward 1980).

Sodium Fluoride

The early experiments of the efficacy of sodium fluoride dentifrice were conducted in the 1940's and it was definitely the first fluoride compound to be added into toothpastes. It was expected that daily use of a sodium fluoride dentifrice could reduce the incidence of caries to the same extent as other forms of topical applications. However, the result of the trials with this fluoride compound were initially not promising.

In 1961 Ericson (1961) investigated the reaction between fluoride and the common components of toothpaste. Using radioactive fluoride (F^{18}), he revealed that sodium fluoride reacted with the abrasive component of toothpaste which was calcium carbonate or calcium

phosphate. It turned out that the calcium ions inactivated the fluoride ions by forming insoluble calcium fluoride. As a result, maximum effectiveness of the fluoride compound was not achieved. Realising that fact, workers considered the use of other abrasive components such as sodium bicarbonate and sodium metaphosphate (Torrel and Ericsson 1965, Brudevold and Chilton 1966).

Instead of using these abrasives, Koch (1967) utilised acrylic particles in his 3 year sodium fluoride dentifrice study. This had less reaction with fluoride ions since the uptake of sodium fluoride by acrylic particles was only one tenth of that by calcium phosphate (Table 42). The subjects of this daily supervised tooth-brushing study were children aged 8-10 years (Group A) and 11-12 (Group B). A great reduction of caries increment in the experimental groups was recorded. These being 40% and 48% for group A and group B respectively (Table 43).

The first positive result of a sodium fluoride dentifrice study encouraged other workers to find other abrasive systems which were compatible to sodium fluoride. Two abrasives that were subsequently extensively tested were high-beta-phase calcium pyrophosphate and silica.

The use of high-beta-phase calcium pyrophosphate was considered to be effective in studies carried out by Weisenstein and Zacherl (1972) and Zacherl (1972), with recorded caries reduction of about 25%. Reed (1973) utilised this abrasive in a clinical study of three concentrations of sodium fluoride dentifrices. In a two-year study, a very rigorous methodology was carried out in which the confounding variables were carefully handled by stratifying the

Table 42. Mean uptake of sodium fluoride from a 20 mM solution by 3 abrasives.
(Adapted from Koch 1967)

Abrasives	Uptake of sodium fluoride (in mg NaF/gr abrasives) Mean	SE
Calcium carbonate	0.97	0.042
Tricalcium phosphate	1.19	0.058
Acrylic particles	0.12	0.021

Table 43. Caries increment during 3 years in children aged 8 - 10 and 11 - 12 years after completing a three year daily supervised toothbrushing study with sodium fluoride and acrylic particles as an abrasive.
(Adapted from Koch 1967)

Caries increment	Study	Control	Percent reduction	p level
8 - 10 year old				
Sample size	64	60	-	-
New carious teeth	6.1	9.3	35	<0.001
New carious surfaces	11.4	19.2	40	<0.001
11 - 12 year old				
Sample size	60	60	-	-
New carious teeth	5.1	7.2	30	<0.001
New carious surfaces	11.9	23.0	48	<0.001

subjects according to age, sex and initial DMF scores. Random permutation method was used to assign subjects to each treatment. The three concentrations of sodium fluoride which were tested were: 0.055% (250 ppm F), 0.11 (500 ppm F) and 0.22% (1000 ppm F). The result showed that the mean DMFT and DMFS in group C (0.22% NaF) were respectively 24 and 20% lower than that of the control group or a saving of 0.4 surfaces from caries per year (Table 44).

Stookey and Beiswanger (1975) confirmed the previous studies, that sodium fluoride was compatible with calcium pyrophosphate leading to the maximum availability of fluoride ions. A concentration of 0.2% sodium fluoride (1000 ppm F) was compared to a placebo. A total of 441 children aged 8 to 15 years were involved in the study which was divided into an experimental group (n = 223) and a control group (n = 218). The result showed that the unsupervised daily toothbrushing with 0.2% NaF could save 2 surfaces per child from caries during the 27 month test period. It was a 24% reduction of caries increment compared with those using a non-fluoride toothpaste.

As an abrasive system, silica has also been proven to be definitely compatible with sodium fluoride. A marked reduction of 17% of caries increment was reported even with a very low concentration of sodium fluoride (0.05% NaF yielding 225 ppm F) (Forsman 1974). It was then confirmed by Zacherl (1981) in a study originally designed to determine if an 0.243% sodium fluoride-silica abrasive dentifrice provided greater anticaries efficacy than 0.4% stannous fluoride. Compared with the placebo, the use of 0.243% sodium fluoride silica abrasive dentifrice could reduce, by 40%, the caries increment during a three-year test period (Table 45).

Table 44. Mean DMFT and DMFS of children aged 5 to 14 years after receiving a 24 month treatment with 250 ppm, 500 ppm, and 1000 ppm fluoride dentifrices.
(Adapted from Reed 1973)

Dentifrice	n	Mean DMFT	Percent reduction	Mean DMFS	Percent reduction
Control	440	2.5	-	4.0	-
250 ppm fluoride	441	2.1	16	3.7	7
500 ppm fluoride	444	2.2	15	3.6	8
1000 ppm fluoride	411	1.9	24	3.2	20

Table 45. Mean caries increment of children and adolesents aged 6 to 24 years after receiving a 3 year treatment with a sodium fluoride dentifrice containing 1000 ppm fluoride.
(Adapted from Zacherl 1981)

Caries increment	Dentifrice NaF (n=740)	Dentifrice Control (n=254)	Percent reduction
DMFT	1.9	3.3	40
DMFS	3.6	6.0	40

Stannous Fluoride

Stannous fluoride dentifrice was first introduced in the USA and had been claimed to have significant anticaries properties. It has received considerable attention since it was introduced at the time when initial results of sodium fluoride dentifrice trials were not promising. The incorporation of stannous fluoride into toothpaste was based on the intensive work on its efficacy resulting in its great success as a topical agent (Murray and Rugg-Gunn 1982). In 1955, stannous fluoride containing toothpastes were marketed in the USA (Von der Fehr and Moller 1978) and clinical trials were conducted. The first trial was carried out by Muhler and others (1955a) who utilised a stannous fluoride dentifrice containing 4000 ppm F and calcium pyrophosphate was used as an abrasive. With unsupervised home use, it was reported that the dentifrice could save 1.4 surfaces during a one year test period, or a reduction of about 50% of caries increments compared with the control group (Table 46). However, in another study, in which a lower concentration was used (1000 ppm) the reduction was 34% (Muhler et al 1955b) (Table 47).

The third trial was one of the few studies which involved adults. Muhler and Radike (1957) tested a 4000 ppm F of stannous fluoride dentifrice in freshmen students aged 17 to 36 years. A total of 247 subjects were involved in the study. After being stratified according to their previous caries experience, the subjects were randomly assigned into two groups of 131 (experimental) and 116 (control). The result of the study indicated that the compound could save 1.7 surfaces from caries during a one year test period (Table 48).

Table 46. Caries increments in children aged 5 to 15 years after a one year treatment with a 4000 ppm stannous fluoride dentifrice.
(Adapted from Muhler et al 1955a)

Caries Increment	SnF_2 (n=214)	Control (n=209)	Percent reduction
DMFS	1.6	3.0	49
DMFT	0.6	1.3	50

Table 47. Mean caries increment after 12 month test period of a 1000 ppm stannous fluoride dentifrice.
(Adapted from Muhler et al 1955b)

Caries Increment	SnF_2	Control	Percent reduction
DMFS	1.5	2.4	36
DMFT	0.8	1.3	34

Table 48. Mean caries increment in adults aged 17 to 37 years after being treated with a 4000 ppm F stannous fluoride dentifrice in a one year period of time.
(Adapted from Muhler and Radike 1957)

Caries increment	SnF_2 (n=131)	Control (n=116)	Percent reduction
DMFS	3.3	5.0	34
DMFT	1.1	1.5	30

Different from the previous studies which tended to test higher concentrations (4000 ppm) and were conducted in a relatively short period of time (one year), Muhler (1962) tested a concentration of 1000 ppm of this compound over 3 years. The study, carried out in subjects aged 6-18 years, was to determine the efficacy of a stannous fluoride dentifrice as marketed under the name "Crest". Some variables such as: frequency of toothbrushing, examination procedures and composition of subjects in the test and control groups were carefully controlled. Stratification according to caries susceptibility and previous caries experience was made. The results showed that the fluoride dentifrice could reduce the caries increment by 11% (table 49).

An interesting finding was put forward by Zacherl and McPhail (1970) who assessed the efficacy of "Crest" toothpaste in two groups of children. Group 1 consisted of children aged 6 to 7 years, whereas group 2 comprised 12 year old children. In a 30 month study, the recorded reductions of caries increment were 40% and 43% (DMFS) for group 1 and group 2 respectively (Table 50). It was suggested that the percentage of reduction was proportional to the magnitude of the caries rate.

The compatibility of stannous fluoride to silica abrasive system has been established by Slack and others (1967). However most clinical trials used calcium pyrophosphate as an abrasive component. The comparison of these two abrasives was studied by Fogels and his colleagues (1979) in 890 children aged 5 to 13 years who were divided into two groups of 451 (silica) and of 43 (calcium pyrophosphate). The result of the three year study indicated that there was no difference in efficacy between a stannous fluoride-

Table 49. Mean caries increment in children aged 6 to 18 years after being treated with a stannous fluoride dentifrice in three year period of time.
(Adapted from Muhler 1962)

Caries increment	SnF_2	Control	Percent reduction
DMFS	8.0	10.3	22
DMFT	3.9	5.1	24

Table 50. Mean caries increment in children aged 6-7 years (Group 1) and 12 years (Group 2) after receiving a 30 month treatment with a stannous fluoride dentifrice.
(Adapted from Zacherl and McPhail 1970)

Group	Dentifrice	N	Caries increment DMFT	DMFS
1	SnF_2	251	1.7	3.8
	Control	261	2.6	6.4
	Percent reduction		34	40
2	SnF_2	260	3.1	8.5
	Control	268	5.1	15.0
	Percent reduction		39	43

silica abrasive dentifrice and a stannous fluoride calcium pyrophosphate abrasive dentifrice.

That stannous fluoride dentifrice is also efficacious in adults was confirmed by Lu and others (1980). A total of 1105 adults aged 18 to 78 years participated in a one year study. Stratification according to sex, age interval and previous caries experience (DMFS) was carried out. Within each stratum, the subjects were randomly assigned into study groups, ie: an experimental (n=558) and a control (n=547) groups. A 33% reduction of caries increment in those subjects using stannous fluoride was reported to be comparable to the results yielded in children and young adults.

Studies concerning the efficacy of stannous fluoride dentifrices indicated that the compound had a great effect in preventing caries. In spite of its variability, studies suggested that, roughly, the caries inhibitory effect was around 30%. However, in regular use of this dentifrice, a slight pigmentation or discolourisation was reported to occur.

Sodium Monofluorophosphate

Sodium monofluorophosphate (SMFP) was first incorporated into toothpaste after the successful use of this compound in topically applied solutions which established its caries inhibitory effect (Zipkin and McClure 1951, Hawes et al 1954, Goaz et al 1966). To date, dentifrices containing SMFP have been the most commonly used fluoride toothpaste. Therefore, it is not surprising that SMFP dentifrices have been more extensively tested than any other toothpaste. From reported clinical studies, it can be concluded that the caries inhibitory effect of this compound appears to be in

the magnitude of 25% within the range of 15 to 40% (DePaola 1983).

The compound is usually added in a concentration of 0.76% (equal to 0.1% F yielding 1000 ppmF). However, some studies have employed a higher concentration up to 2% (2400 ppm) such as the study conducted by Hargreaves and Chester (1973). The result of this three-year home use unsupervised study (n=884 which was equally divided into 2 groups) was a 23% reduction of caries increment (DMFS) which was similar to the reported reduction from studies using the lower concentration. The magnitude of the caries inhibition of this study did not differ from a study conducted by James et al (1977) who used the same concentration.

Other reports involved the use of different concentrations of SMFP in the same study. Mitropoulos et al (1982) employed concentrations of 0.19% and 0.76% SMFP. It was reported that 19% fewer DFS was recorded in those utilising 0.76%. In a 48-month clinical study, Triol et al (1987a) investigated the caries reducing benefit of three concentrations of SMFP dentifrices namely 1000, 1450 and 2000 ppm F which were given to three groups, ie: Group 1 (n=448), Group 2 (n=470) and Group 3 (n=452) respectively. All of the dentifrices were formulated in a dicalcium phosphate dihydrate abrasive system. The result of the study indicated that dentifrices containing 1450 and 2000 ppm F in SMFP had a greater caries inhibitory effect than the concentration of 1000 ppm. However, no difference was found between dentifrices containing 1450 ppm and 2000 ppm F. The recorded DMFS increments were 3.21, 2.95 and 2.79 for 1000, 1450 and 2000 ppm F respectively.

A recent study reported by Conti et al (1988) compared the efficacy

of a dentifrice containing 1.14% SMFP (1500 ppm F) to a dentifrice containing 0.75% SMFP (1000 ppm F). No placebo control was used in this three year daily supervised toothbrushing study. The result (Table 51) suggested that there was a 21% less caries increment (DMFS) in the subjects using the concentration of 1500 ppm F (1.14% SMFP) than those who utilised the concentration of 0.76%. These studies suggest that the higher the concentrations above 1000 ppm F the higher the magnitude of caries reduction. However, further evidence is still required to support this proposition since previous studies have given equivocal results. So far studies suggest that the concentration of 0.76% appears to have an optimum caries inhibitory effect.

In contrast with dentifrices containing sodium fluoride or stannous fluoride, the abrasive property of a dentifrice is not a major consideration in a SMFP toothpaste.

It was noted that the SMFP compound has greater compatibility with calcium-containing abrasive agents (De Paola 1983). It is evident that the calcium salt of this compound is relatively soluble. Moreover, as reported by Mellberg and Chomicki (1982), some levels of soluble calcium enhance fluoride uptake by artificial caries lesions. Therefore this characteristic enables the SMFP compound to be used in a variety of calcium or calcium-free abrasives. By comparing studies which used calcium formulation as its abrasive and those which were calcium-free, De Paolla (1983) concluded that on average there was no difference between the two formulae. It confirmed the compatibility of the SMFP compound. As a result, various abrasives have been successfully incorporated into SMFP

Table 51. Mean dental caries increments in children aged 7 to 14 years examined after 3 years using a 1000 and 1500 ppm sodium monofluorophosphate dentrifice.
(Adapted from Conti 1988)

Caries Increments	F concentration 1000 ppm (n=1228)	1500 ppm (n=1500)	Percent reduction	p level
DMFT	1.3	1.0	23	0.01
DMFS	2.4	1.9	21	0.01

toothpastes such as: insoluble metaphosphate (IMP), chalk ($CaCO_3$, Silica (SiO_2) and alumina (Al_2O_3) with various levels of efficacy (Table 52).

Comparison of different compounds

Having established caries inhibitory effects, workers were interested to compare different fluoride dentifrices with the same F concentration within one study.

Zacherl (1972) studied the relative effectiveness of four fluoride dentifrices namely sodium fluoride, stannous fluoride, sodium monofluorophosphate and acidulated phosphate fluoride against a placebo. All of the dentifrices contained 1000 ppm fluoride. A total of 894 children aged 7 to 14 years were randomly assigned into five groups, ie: SnF_2 (174), NaF (175), SMFP (151), AFP (184) and Placebo (210). The study was carried out over 20 months with unsupervised toothbrushing use at home. The DMFS increments for each experiment group were then compared to a placebo (Table 53). However, no statistical analysis was made to compare the efficacy between each fluoride dentifrice. Notwithstanding, the figures indicated that the smallest increment was recorded for the NaF group (4.7) followed by SnF_2 (4.8), SMFP (5.4) and APF (5.7).

The superiority of NaF to other compounds was exhibited by two studies (Cilley and Haberman 1981, Mobley and Tepe 1981). In these studies, an 0.243% NaF dentifrice was compared to an 0.4% SnF_2 dentifrice. Both studies showed that 0.243% NaF (1100 ppm F) was significantly more efficacious than 0.4% SnF_2 (1000 ppm). However, the difference could be attributable to the difference in concentration since the NaF dentifrice yielded 100 ppm F higher than

Table 52. Clinical trials of sodium monofluorophosphate dentifrices using various abrasive components

Investigator(s)	SMFP concentration	Percent reduction	p level
SILICA			
Howat et al (1978)	0.76	26	<0.01
Conti et al (1988)	1.14	22*	<0.01
ALUMINA			
Hargreaves and Chester (1973)	2.0	23	<0.01
Lind et al (1974)	2.0	38	<0.01
Andlaw & Tucker (1975)	0.76	19	<0.01
James et al (1977)	2.0	23	<0.01
Murray & Shaw (1980)	0.76	34	<0.01
Hanachowicz (1984)	1.2	27	<0.01
CHALK			
Torell & Ericsson (1965)	0.76	25	<0.01
Naylor & Emslie (1967)	0.76	18	<0.01
Peterson et al (1975)	0.76	23	<0.05
Glass & Shiere (1978)	0.76	28	<0.01
Naylor & Glass (1979)	0.76	25	<0.01
Glass (1981)	0.76	40	<0.05
Cahen et al (1982)	1.14	5**	<0.05
		25***	<0.01
Glass et al (1983)	0.76	22	<0.01
IMP			
Finn & Jamison (1963)	0.76	26	<0.01
Fanning et al (1968)	0.70	20	<0.01
Moller et al (1968)	0.76	19	<0.01
Thomas & Jamison (1970)	0.76	34	<0.05
Downer et al (1976)	0.76	31	<0.01
Mainwaring Naylor (1978)	0.76	17	<0.01

* compared to 0.76%
** permanent teeth
*** deciduous teeth

Table 53. Mean caries increments of children aged 7 to 14 years after being 20 months treated with various fluoride dentifrices.
(Adapted from Zacherl 1972).

Fluoride dentifrice	Sample size	DMFS increments	Percent reduction
NaF	175	4.7	29
SnF_2	174	4.8	27
SMFP	151	5.1	23
APF	184	5.7	14 *
Placebo	210	6.6	-

* The reduction is not significant at p = 0.05

the stannous fluoride dentifrice.

Recently, Lu and others (1987) compared the effect of a sodium fluoride and sodium monofluorophosphate dentifrices. In a 3-year study, Lu and his colleagues used three groups, ie: group A (n=703), B (n=679) and C (n=673) which were treated with 1100 ppm NaF, 2800 ppm NaF and 2800 ppm SMFP dentifrices respectively. The result indicated that 2800 ppm NaF was better than both the 1100 ppm NaF and 2800 ppm SMFP, and that there was no different effect between 1100 ppm NaF and 2800 ppm SMFP.

Recent studies on the efficacy of fluoride dentifrices tend to investigate the effect of a combination between sodium fluoride and sodium monofluorophosphate. Since the mechanism of action of the compounds are different (Jongebloed et al 1975, Benton et al 1980) it was hypothesised that such a combination would increase its caries inhibitory effect. Hodge et al (1980) studied three groups, ie: group A (n=194) which was given 0.76% SMFP (1000 ppm F), group B (n=203) which was treated with a combination of 0.76% SMFP plus 0.1% NaF yielding 1450 ppm F, and group C (n=202) served as a control group (no fluoride added). It was reported that group B was better than group A. However, it is most likely that the difference was attributable to the difference in concentration since Group B used 450 ppm F higher than did group A.

Mainwaring and Naylor (1983) overcame the design deficiency of the study by Hodge et al (1980) by using both formulae with the same F concentration. No difference was recorded between the efficacy of 0.76% SMFP (1000 ppm) and a combination of 0.38% SMFP plus 0.11% NaF (1000 ppm).

An imbalanced comparison as had been done by Hodge et al (1980) was also reported by Diodati et al (1986). A combination of SMFP plus NaF in the concentration of 1450 ppm and 2000 ppm was compared to 1000 ppm SMFP. Therefore, no conclusion could be drawn if the combination could improve the effect synergistically.

Three other studies by Triol et al (1987), Ripa et al (1988) and Blinkhorn & Kay (1988) investigated the combined formula of SMFP and NaF and consistently concluded that no added benefit was achieved by combining the two compounds (Table 54).

In conclusion, it is evident that fluoride dentifrices have been proven to be an effective anti-caries agent in hundreds of clinical trials. The most commonly evaluated and used fluoride dentifrices are: sodium fluoride, stannous fluoride and sodium monofluoro-phosphate. Their caries inhibitory effects have been reported to be in the magnitude of 20 to 40%. Recorded evidence showed that sodium fluoride appears to be slightly superior than the two other compounds. However, sodium monofluorophosphate has become the most preferred formula and has been more extensively marketed. Probably it is because this compound has several advantages over stannous and sodium fluoride, these being: no staining problem; the compound is stable; and the pH is close to neutral. The most important reason, probably, is its higher compatibility with most abrasive systems (Table 55). With regard to the effect of combined formulae of SMFP and NaF, studies suggested that no added benefit was achieved by such a combination.

Table 54. Clinical trials examining the effect of combined formula between SMFP plus NaF

Investigators	Comparisons	ppm F	Result
Hodge et al (1980)	A. 0.76% SMFP	1000	A < B
	B. 0.76% SMFP plus 0.1% NaF	1450	
	C. Placebo	0	
Mainwaring & Naylor (1983)	A. 0.76% SMFP	1000	A = B
	B. 0.38% SMFP plus 0.11% NaF	1000	
Diodati et al (1986)	A. SMFP	1000	A < B
	B. SMFP plus NaF	1450	B = C
	C. SMFP plus NaF	1000	
Triol et al (1987)	A. 0.76% SMFP	1000	A = B
	B. 0.30% SMFP plus 0.113% NaF	1000	
Ripa et al (1988)	A. 0.76% SMFP	1000	A=B=C
	B. 0.38% SMFP plus 0.11% NaF	1000	
	C. 0.95% SMFP plus 0.28% NaF	2500	
Blinkhorn & Kay (1988)	A. 0.32% NaF	1450	A=B=C
	B. 1.1% SMFP	1450	
	C. 0.76% SMFP plus 0.1% NaF	1450	

Table 55. Compatible fluoride and abrasive systems in dentifrices. (Adapted from Forward 1980)

Fluoride	Abrasive system
Sodium fluoride	Calcium pyrophosphate Insoluble sodium metaphosphate Organic polymers Silica
Stannous fluoride	Calcium pyrophosphate Insoluble sodium metaphosphate Silica
Sodium monofluro-phosphate	Calcium Carbonate Dicalcium phosphate Calcium pyrophosphate Alumina tryhidrate Insoluble sodium metaphosphate Silica

3.2.2.3 **Salt fluoridation**

Domestic salt has been used as a vehicle for fluoride for more than three decades. The initiation of this effort was inspired by the success of iodised salt in the prevention of goitre in Switzerland (Marthaler et al 1978). Although studies regarding the efficacy of this measure were the least in quantity when compared to other fluoride studies, the results were in favour of a cariostatic effect of fluoride-supplemented salt. It was reported that salt fluoridation could reduce caries occurrence by more than 30% but less than that observed from water fluoridation (Murray and Rugg-Gunn 1982).

Marthaler and Schenardi (1962) reported the effectiveness of 90 mg F/kg salt in Switzerland after five and a half years use. It was a retrospective study in which a total of 1241 children aged 7 to 14 years were involved. The results suggested that there was a 30% caries reduction in children aged 7 to 9 years who were consuming fluoridated salt regularly (Table 56). However, this study cannot be considered as fully adequate in terms of its validity since some limitations were involved. The subjects were assigned into study groups in a non-random way and no pre-test was carried out. Therefore, less decay in children using fluoridated salt might be due to other influences than fluoride alone. On the other hand, as children in the control group consumed fluoride to some extent (those who consumed fluoridated salt irregularly were counted as not consuming it), the results might have provided an underestimate of fluoride effect. Moreover, the use of 90mg F per kg salt has been considered to have an inadequate fluoride level compared with that in 1 ppm fluoridated water. This possibility was supported by

Table 56. Mean DMFS of children who consumed and did not consume fluoridated salt since 1956 to 1961.
(Adapted from Marthaler and Schenardi 1962).

Consumption pattern	Age groups 7-9 (n=436)	12-14 (n=395)
No fluoridated salt or sometimes	4.7	22.2
Fluoridated salt (90ppm/kg salt) regularly since 1956	3.2	22.7

evidence that in children aged 12-14 years the DMF counts were similar whether or not they consumed fluoridated salt.

Encouraging results were reported by Mejia and his colleagues who intiated a study in four Colombian communities in 1964 (Murray and Rugg-Gunn 1982). Three of the four communities served as experimental groups in receiving either sodium fluoride salt, calcium fluoride salt or water fluoridation, while the other community was used as a control group. After 8 years, a 78% caries reduction was reported in the group receiving water fluoridation compared with a 72% and a 61% reduction in the calcium fluoride group and natrium fluoride group respectively. In the control town a 13% reduction was recorded (Table 57).

A well-planned study was conducted in 2 villages of Hungary by Toth (1976) in a period of 8 years from 1966 to 1974. Noting the experience of the Switzerland study, Toth (1976) used a concentration of 250 mg F/kg salt which was considered to be a comparable level to that in 1 ppm fluoridated water. The determination of whether or not subjects consumed an adequate fluoride level was detected from the urinary fluoride level. Only those subjects considered to consume adequate fluoride were included in the measurements. The children aged 2 to 14 years involved in the study were grouped in three age groups: 2-6, 7-11 and 12-14 years. In the 2-6 age group, the recorded dmft figures indicated that there was a 54% caries reduction in the experimental group and a 6% increase in the control group (Table 58). A marked caries reduction was also exhibited in the other two age groups, namely 59% and 42% for 7-11 and 11-12 age groups respectively.

Table 57. Mean DMFT in children aged 8 years in three test towns and one control community in Colombia, after 8 years. (Adapted from Murray and Rugg-Gunn 1982).

Year	NaF salt	CaF salt	Water F	Control
1964	3.7	3.8	3.8	4.3
1972	1.4	1.1	0.8	3.8
Percent Reduction	61	72	78	13

Table 58. Mean dmft and DMFT of children aged 2 to 6, 7 to 11 and 12 to 14 years in experimental and control groups of salt fluoridation in Hungary, 1966 - 1974. (Adapted from Toth 1976).

Age Group	Study groups	1966	1967	1974	Percent difference (Compared to 1967)
2-6	**Experimental**				
	dmft	4.2	5.2	2.4	-54
	n	82	-	127	
	Control				
	dmft	-	5.2	5.5	+6
	n	-	92	537	
7-11	**Experimental**				
	DMFT	3.6	3.7	1.5	-59
	n	190	-	164	
	Control				
	DMFT	-	3.4	3.0	-11
	n	-	236	1028	
12-14	**Experimental**				
	DMFT	6.6	7.3	4.2	-42
	n	140	-	101	
	Control				
	DMFT	-	7.3	7.5	+3
	n	-	212	640	

In another study, Toth (1979) confirmed the previous reported efficacy of fluoridated salt. Over a 10 year span, Toth (1979) reported a marked increase of percentage of caries-free children as well as a tremendous caries reduction in the three age groups examined. In the 4-6, 7-12 and 12-14 age groups the percentage of caries-free children increased from 8.1, 4.7, and 1.4 to 46.8, 43.9 and 7.9 respectively (Table 59). For dmft and DMFT counts, it was reported that the dmft in the 4-6 age group dropped from 5.4 to 2.8. In those 7-11 and 12-14 years there was a 58% and a 45% caries reduction respectively (Table 60).

Although no further salt fluoridation studies are reported, the efficacy of fluoridated salt has been supported by the studies that have been commented on. Although its effect is slightly lower than that of fluoridated water, salt fluoridation has some advantages compared with water fluoridation. These are: (1) salt fluoridation is an appropriate measure when technically and financially water fluoridation is not feasible such as in an area in which the water supply is not centralised, (2) it has simple and cheap production and control because there is no limitation by water-work equipment, and (3) it gives free choice for individual households to use or not to use it (Ericsson and Anderson 1983).

However, the use of fluoridated salt has its own problem. The problem occur in the determination of fluoride level in the domestic salt. Some criticisms were addressed to the use of 90 mg F/kg salt reported by Marthaler and Schenardi (1962) as this level was considered to be definitely under-dosed. Logically, the determination of maximum permissible fluoride level in the salt much depends on the average individual ingestion of domestic salt.

Table 59. Percentage of caries-free children in 4-6, 7-11 and 12-14 age groups after ten years of salt fluoridation measure. (Adapted from Toth 1979).

Age group	Pre measurement	Post measurement
4 - 6	8.1	46.8
7 - 11	4.7	43.9
12 - 14	1.4	7.9

Table 60. Mean dmft and DMFT of children in 4-6, 7-11 and 12-14 age groups after ten years of salt fluoridation. (Adapted from Toth 1979).

Age group	Pre measurement	Post measurement	Percent reduction
4 - 6 *	5.4	2.8	48
7 - 12 **	3.6	1.5	58
12 - 14 **	6.6	3.6	45

* dmft
** DMFT

However, studies of salt intake are very difficult to conduct since the salt may reach the consumers by varying ways in the form of visible salt, partially hidden salt and hidden salt (Marthaler et al 1978). Visible salt is salt purchased as such for the household. Included in partially hidden salt is salt added in local production and preparation such as in small bakeries, butchers, canteens, restaurants and hospitals. Hidden salt is that salt added in industrial food production. In some salt consumption studies, it was suggested that a considerable amount of salt purchased for an individual household is not ingested.

Instead of measuring the total salt consumption, urinary fluoride excretion has been used as a convenient and satisfactory parameter of the total fluoride ingestion (McClure and Kinser 1944, Zipkin et al 1956, Ericsson 1971, Ericsson and Anderson 1983, Wespi and Burgi 1971, Wespi and Burgi 1981) since it is known that approximately 50% of all ingested fluoride is excreted (Martaler et al 1978). by comparing the urinary excreted fluoride from individuals who ingest a certain concentration of fluoridated salt to that excreted from those who consume 1 ppm fluoridated water, one could adjust, by means of trial and error, the optimum concentration of fluoride in fluoridated salt.

Wespi and Burgi (1971) in their study revealed that the mean 24-hour fluoride excretion from individuals with water fluoridation at the 1ppm level was 0.89 mg. Measurements in two women who used a salt with 250 mg F per kg salt had a mean fluoride excretion of 1.04 mg. This result suggested that 250 mg F per kg salt may give the same or even slightly higher fluoride intake, as well as caries preventive effect, as 1 ppm water fluoridation.