COST AND BENEFIT OF FLUORIDE IN THE PREVENTION OF DENTAL CARIES

by

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PREFACE

In 1971 the World Health Organization Regional Office for Europe organized a study on different uses of fluoride in caries prevention. Its aim was to evaluate the preventive effects of the main measures using fluorides and to assess their bearing on the provision of a dental health service.

Professor G. N. Davies, who was then on sabbatical leave in Europe, agreed to undertake the study. In autumn 1971, while working in the London Hospital Medical College Dental School, Professor Davies analysed the worldwide published information on the cost-effectiveness and cost-benefit of the above-mentioned methods. In May 1972, the WHO Regional Office for Europe convened a meeting in London of experts from 6 European countries, who studied extensively the preventive effect of fluorides. The following experts submitted written statements and took part in the meeting:

Professor F. Urban (Czechoslovakia)
Dr O. Pot (Netherlands)
Professor O. Torell (Sweden)
Professor T. Marthaler (Switzerland)
Mr J. Rodgers (United Kingdom)

The Austrian expert (Dr K. Binder) did not participate in the meeting but provided a written summary of the results achieved in that country.

The meeting was assisted by three Temporary Advisers: Professor R. Duckworth and Professor G. L. Slack, London Hospital Dental School, and Miss J. E. Todd, Office of Population Censuses and Surveys, London. Professor R. D. Emslie, London, was present as an observer for the International Dental Federation (FDI). Dr J. Kostlan, WHO European Regional Office, acted as secretary to the meeting.

The group discussed data on the cost-effectiveness and cost-benefit of the prevention of caries by fluoride, which were ascertained in European countries, and made the report of the meeting available to Professor Davies. However, the views expressed here are the author's own.

INTRODUCTION

The most common dental disease is dental caries. It begins at an early age and affects most children. In the European Region of WHO the proportion of preschool children (aged 4 years) with caries experience in the deciduous dentition ranges from 58% in the Federal Republic of Germany (Hessen) to 90% in Norway.[1] The proportion of children aged 14 with caries experience in the permanent dentition ranges from 40% in Malta to 100% in Switzerland.[2]

The treatment of dental caries is time-consuming and expensive. In Norway, for example, in 1969 20% of preschool and 88% of school-age children took advantage of the school dental service. The cost of the service was about 100 000 000 Norwegian kroner per year, 96% of which was paid from public funds. This is 0.15% of the gross national product.

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

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

The most important factors in reducing the intensity of the attacking agents are restricting the frequency with which sugar in a sticky form is consumed, and the establishment of a regular and efficient system of tooth cleansing to reduce the accumulation of bacterial plaque on the surface of teeth.

No one would deny that it is better to prevent disease than to treat it, but sooner or later cost-benefit relationships must be considered.[3] Properly done, this should help public health administrators to decide whether the cost of a certain procedure is justified by the results achieved. In addition, since clinical trials of preventive measures are very expensive in terms of money, personnel, and resources, a cost-benefit analysis should also help financing authorities to decide whether further research on a particular method is worthwhile.

This study was undertaken to assess the various methods of using fluoride in the prevention of caries from a cost-benefit point of view. It soon became obvious that there were some important limitations to a study of this type. The first, and most obvious, limitation was that all clinical trials had been designed to find out whether the specific method of using fluoride did or did not prevent caries, and to what extent. No trial was specifically designed to establish cost-benefit relationships. Secondly, most clinical trials have been cross-sectional rather than longitudinal in character. Thirdly, diagnostic methods and criteria have varied, and there has been no uniformity in the manner of presenting the results.

Fourthly, the cost of fluoridation and other fluoride treatments and of dental treatment vary markedly, not only between countries, but also within countries.

Many compromises and assumptions have had to be made. Wherever possible, the assumptions are defined, but it must be stressed that their final validity will have to be tested by subsequent definitive investigations.

PART I - FLUORIDATION OF DRINKING WATER

1. REDUCTIONS IN THE PREVALENCE AND SEVERITY OF DENTAL CARIES

1.1 Permanent dentition with the tooth as the unit of measurement

Detailed results from Hastings, New Zealand[4,5,6,7,8] Grand Rapids[9,10] and Newburgh[11] (USA); the United Kingdom;[12] Tiel (Netherlands);[15] and Tabor (Czechoslovakia)[16] have been assessed. The results for children with a lifetime's exposure to fluoridated water are summarized in Table 1 and show that absolute reductions in DMFT[a] per child vary from 0.59 to 1.18 at age 6; from 0.30 to 2.01 at age 7; from 0.90 to 2.49 at age 8; from 1.30 to 2.37 at age 9; from 1.30 to 3.02 at age 10; from 0.80 to 3.5 at age 11; and from 4.60 at age 12 to 7.1 at age 15.

The general trend is for percentage reductions to be highest in the youngest children but absolute reductions are highest in the oldest children.

Benefits from fluoridation are also obtained by children who were born <u>before</u> the procedure began. Results from Hastings, New Zealand, which are summarized in Table 2 show that:

(a) Substantial benefits can be expected in children aged 6-15 years who were 5 years old (or younger) when fluoridation began (reductions of 0.19-7.04 DMFT per person).

(b) Substantial benefits can be expected in children aged 10-16 years who were 6 years old when fluoridation began (reductions of 0.57-5.03 DMFT per person).

(c) Substantial benefits can be expected in children aged 11-16 who were 7 years old when fluoridation began (reductions of 0.72-3.28 DMFT per person).

(d) Substantial benefits can be expected in children aged 12-16 who were 8 years old when fluoridation began (reductions of 0.97-3.01 DMFT per person).

(e) Substantial benefits can be expected in children aged 12-16 years who were 9 years old when fluoridation began (reductions of 0.60-2.74 DMFT per person).

(f) Substantial benefits can be expected in children aged 12-16 who were 10 years old when fluoridation began (reductions 0.40-1.57 DMFT per person).

(g) Some benefits can be expected in children aged 12-16 who were 11 years old when fluoridation began (reductions of 0.20-1.61 DMFT per person).

(h) No substantial benefits can be expected in children aged 12-16 who were aged 12-15 years when fluoridation began.

Similar data from Tiel - Culemborg (Netherlands)[15] and Basel (Switzerland)[13] are set out in Table 3. The absolute reductions at Tiel are less than those obtained at Hastings (New Zealand), but the trends are similar. The absolute reductions at Basel are much the same as those at Hastings.

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[a] The following abbreviations are used throughout this report in referring to carious teeth: DMFT = decayed, missing, filled <u>permanent</u> teeth; DMFS = decayed, missing, filled surfaces of <u>permanent</u> teeth; deft = decayed, indicated for extraction, filled <u>primary</u> teeth; defs = decayed, indicated for extraction, filled surfaces of <u>primary</u> teeth.

1.2 Deciduous dentition with the tooth as the unit of measurement

Detailed results from Hastings,[4,5,6,7,8] Grand Rapids (USA),[9,10] the United Kingdom,[12] and Tiel[15] for children with a lifetime of exposure to fluoride are summarized in Table 4.

There appears to be, surprisingly, a much greater uniformity in the benefits to the deciduous dentition than to the permanent dentition. Absolute reductions in deft vary from 1.1 to 2.7 at age 3; from 2.07 to 3.50 at age 4; from 2.50 to 4.34 at age 5; from 3.20 to 4.54 at age 6; from 3.03 to 3.70 at age 7; and from 2.47 at age 8 to 0.49 at age 10.

As in permanent teeth, benefits are also obtained in the deciduous teeth of children who were born before fluoridation began. Results from Grand Rapids, summarized in Table 5, show that:

(a) Substantial benefits can be expected in children aged 4-10 who were aged 1 or 2 years when fluoridation began (reductions of 0.23-1.84 deft per person).

(b) Substantial benefits can be expected in children aged 5-10 who were 3 years old when fluoridation began (reductions of 0.26-1.09 deft per person).

(c) Substantial benefits can be expected in children aged 6-10 who were 4 years old when fluoridation began (reductions of 0.18-0.90 deft per person).

(d) Some benefits can be expected in children aged 7-9 who were 5 years old when fluoridation began (reductions of 0.16-0.71 deft per person).

(e) Some benefits can be expected in children aged 8 and 9 years who were 6 years old when fluoridation began (reductions of 0.43-0.68 deft per person).

1.3 Permanent dentition with tooth surfaces as the units of measurement

Backer Dirks[17] has pointed out that a single tooth can develop more than one cavity and that lesions involving different types of tooth surfaces (pits and fissures, free smooth, and proximal surfaces) are not of equal importance. For this reason, it is necessary to determine the influence of fluoride on the caries experience of specific surfaces. Detailed results from Hastings, New Zealand,[8] and from Tiel, Netherlands,[15] are summarized in Tables 6 and 7.

The outstanding features of these results are:

(a) The remarkable degree of uniformity in the percentage reductions for each surface in each age group at Tiel (Table 7). This point has been noted by Backer Dirks[18] who draws attention to the fact that whereas the protective effect on tooth surfaces appears to increase with age in a cross-sectional study, such as that made at Hastings, "It can be demonstrated in many longitudinally studied groups (as at Tiel) that the percentage caries reduction is remarkably stable".

(b) The close similarity between the results from Hastings and Tiel.

(c) The greater degree of protection obtained by proximal surfaces than pit and fissure surfaces, and the greatest protection obtained by free smooth surfaces (buccal-lingual).

(d) The large size of the absolute reductions. In 15-year-olds the total savings were 22 surfaces per child at Hastings, made up of 6 pit and fissure surfaces, 12 proximal surfaces, and 4 buccal-lingual surfaces, and 18 per child at Tiel (made up of 5 pit and fissure surfaces, 9 proximal surfaces, and 4 buccal-lingual surfaces).

2. THE MANPOWER REQUIRED AND THE TIME TAKEN TO IMPLEMENT THE PROCEDURE

The great advantage of the fluoridation process is that it does not require the services of dental manpower to administer the programme nor does it require any action by the consumer. However, dentists are required as advocates and advisers. Standard waterworks procedures should be observed with adequate safeguards for waterworks personnel, and regular monitoring and testing is necessary to ensure that the levels of fluoride in the community water supply are maintained at optimal levels within a range of ± 0.1 ppm.

3. THE EFFECT OF THE PROCEDURE ON THE NEED FOR DENTAL TREATMENT

Deft, DMFT, and DMFS are indices of total caries experience. Thus any reduction must be reflected in fewer restorations and extractions. Unfortunately (as explained in Annex 2), there is no consistent relationship between DMFT and deft indices, computed increments, and clinical services which are either required or rendered. DMFS indices based upon the examination of all tooth surfaces and of pit and fissure, proximal, and buccal-lingual surfaces give a better estimate, but are also unreliable. First, because no allowance is made for secondary caries, secondly because most studies (except at Tiel-Culemborg) have been conducted on a cross-sectional instead of a longitudinal basis, and thirdly because the total treatment requirements for young children are governed by the condition of both deciduous and permanent teeth whereas def and DMF data are usually presented separately.

These problems could be overcome if:

(a) Future studies of the effectiveness of fluoridation were designed to permit a longitudinal assessment of the incidence of caries in both deciduous and permanent teeth.

(b) At each examination the status of each tooth (or tooth surface) was recorded together with the type of treatment required as described in Annex 3.

Five attempts have been made to assess the influence of fluoridation on dental treatment: at Hastings, New Zealand;[19] Newburg, USA;[20] Gainesville, Richmond, and Woonsocket, USA;[21,22,23,24,25] Tiel, Netherlands;[15] and Tabor, Czechoslovakia.[16]

In the New Zealand report the number of fillings and extractions required by children aged 2-1/2-13-1/2 years living in a fluoridated community (Hastings) were compared with comparable data for children living in a non-fluoridated community (Gisborne). These results are summarized in Table 8. In order to establish the validity of the data for the non-fluoridated community of Gisborne it would be desirable to compare the number of fillings and extractions required per child in that community with the position in the country as a whole. These data obtained from the Annual Reports of the Dental Division of the New Zealand Department of Health[26] are also summarized in Table 8.

The New Zealand Report[19] also contains data for children aged 13-1/2-15 years who were given regular dental treatment by private practitioners under the Social Security Dental Benefits Scheme. In that case, the effect of fluoridation was assessed in terms of savings in costs and not the number of fillings and extractions.

From the data in Table 8 it will be seen that after 10 years of fluoridation children aged 2-1/2-13-1/2 years had 2.47 (48%) fewer fillings per child and 0.09 (60%) fewer extractions per child than children of the same age in one non-fluoridation community and in the whole of New Zealand.

In 1961/62 Ast et al.[20] took a group of 5-year-old and a group of 6-year-old children who had lived all their lives at Newburgh, where the water supply has been fluoridated since 1945. Complete dental treatment was provided for each child in 1961/62 and for each of the following 5 years. A similar number of children in the non-fluoridation control city of Kingston were provided with the same dental services. The results are summarized in Table 9.

It is interesting to note from these results that in the initial care year the major effect of fluoridation was to reduce the requirements for multiple surface restorations. It is also interesting to note that the overall reduction in the requirements for restorations, 1.79-2.01 (52%) per child, was similar to that for Hastings, New Zealand. The effect of the long-term incremental care programme in New Zealand is reflected in the lower extraction rate. Fluoridation resulted in 0.09 (60%) fewer extractions per child in Hastings compared with 0.19-0.28 (56-46%) per child in Newburgh in the first year. The extraction rate at Newburgh was reduced during the 5 years of incremental care.

A comprehensive study of the effect of fluoridation on dental care for children was made at Gainesville, Florida, USA.[21] Controlled fluoridation had been in operation at Gainesville for 4 years and 2 months when the study began. In the first treatment series, 35% of white children and 54% of Negro children aged 5-16 years had experienced about 5 years of fluoridation. The effect of fluoridation was evident in steadily decreasing DMF rates measured in successive treatment series, whereas at the non-fluoridation towns of Richmond and Woonsocket the DMF rates remained relatively constant. Treatment provided for white children was reduced from an average of 2.9 deciduous and permanent teeth filled per child and 0.2 teeth extracted per child in the first treatment series to 1.7 deciduous and permanent teeth filled per child and 0.1 teeth extracted in the fourth treatment series. For Negro children the treatment provided was reduced from an average of 2.1 filled teeth per child and 0.3 teeth extracted per child in the first treatment series to 1.0 filled teeth per child and no teeth extracted in the fourth treatment series. In the non-fluoridation city of Woonsocket 4.67 deciduous and permanent teeth per child were filled and 0.90 teeth were extracted at the first treatment series. These results are summarized in Table 10.

From these data it can be concluded that:

(a) 4-$^{1}/_{2}$ years' fluoridation at Gainesville resulted in a 38% reduction (1.77) in the number of fillings required per child and 78% reduction (0.7) in the number of extractions required per child at the time of initial care.

(b) After an additional 30 months of fluoridation plus one complete series of treatments the savings at Gainesville compared with the non-fluoridation city of Woonsocket amounted to 3.94 fillings per child (a 66% reduction) and 0.61 extractions per child (a 75% reduction).

The absolute reductions in the number of fillings and extractions in children born at Tiel when fluoridation began in 1954 compared with children at Culemborg[15] are set out in Table 11. In assessing the number of fillings, each proximal cavity was considered to equal 1.5 fillings and each occlusal (pit or fissure) and cervical (buccal or lingual smooth surface) cavity was considered to equal one filling. From these data it can be concluded that:

(a) 16 years of fluoridation at Tiel resulted in a reduction in the number of fillings required ranging from 2.19 per child (58%) at age 7 years to 18.42 per child (60%) at age 15 years.

(b) there was a reduction in the number of extractions required ranging from 0.06 per child at age 7 to 1.35 per child at age 15.

The effects of 13 years' fluoridation on dental treatment for 11-14-year-olds at Tabor, Czechoslovakia[16] are shown in Table 12. The results have been expressed in a slightly different way and show that the average number of fillings saved in 11-14-year-old children during the first 5 years after fluoridation began was 1.30 per child per year (44%) whereas during the following 8 years the number of fillings saved was 1.80 per child per year (61%). From these results, the total savings per child in 13 years can be calculated as 20.9 fillings (1.30 x 5 + 1.80 x 8). This figure is similar to that of 18.42 obtained at Tiel in 14-year-olds.

4. THE EFFECT OF THE PROCEDURE ON THE NUMBER OF PATIENTS A DENTIST OR AUXILIARY CAN KEEP UNDER REGULAR INCREMENTAL CARE

In New Zealand, schoolchildren between the ages of 5 and 13-1/2 years and preschool children aged 2-1/2-5 years are eligible for regular dental care from operating auxiliaries called "School Dental Nurses". According to recent records[26] 96% of schoolchildren aged 5-13-1/2 and 60% of preschool children aged 2-1/2-5 years voluntarily attend twice a year for regular dental care.

According to the report of Denby and Hollis[19] after 10 years of fluoridation at Hastings, 5.5 dental nurses were able to cope with all the treatment requirements of 3 798 children of preschool and school age (dental nurse to patient ratio = 1:690), whereas it required 12 dental nurses to cope with 5 702 children of the same age group in a non-fluoridation community (dental nurse to patient ratio = 1:475). In 1964 it required 984 school dental nurses to provide regular incremental care for 431 941 children in the country as a whole (dental nurse to patient ratio = 1:439). Thus in a long-standing incremental care programme fluoridation enables an increase of 45-57% in the number of children who can be kept under regular 6-monthly care.

Comparable data from three school dental care programmes in the USA are summarized in Table 13.

These data show that:

(a) The completion of initial treatment for children after 4-1/2 years fluoridation took only about a third to a quarter of the time of dentists compared with the time for completion in two non-fluoridated communities.

(b) Regular incremental care in both non-fluoridation and fluoridation communities reduces the time required for completion.

(c) Even after 4 years of incremental care, a dentist in a fluoridation community can complete the treatment required for between 10% and 39% more patients.

In evaluating the data from Tabor, Urban[16] has pointed out that although 13 years of fluoridation has resulted in a 61% saving in the time taken for fillings, the actual total time saved is less than this and amounts to approximately 43%. This difference is due to the fact that the total time necessary for diagnosis and treatment planning does not change to any significant extent.

According to Perret,[27] after 5 years' fluoridation at Basel, Switzerland, the number of dentists required to provide dental treatment for more than 3 000 children was reduced from 20 to 6.

5. THE COST-EFFECTIVENESS OF THE PROCEDURE IN TERMS OF THE NUMBER OF HOURS OF PROFESSIONAL TIME REQUIRED TO ACHIEVE A STATED BENEFIT

This form of analysis cannot be applied to fluoridation of public water supplies since it does not require the time of <u>dental</u> professional personnel for implementation.

6. THE COST-BENEFIT ANALYSIS OF THE PROCEDURE (cost of implementation divided by savings in the cost of dental treatment)

6.1 Cost of implementation

The actual costs of the fluoridation process are thoroughly documented and are customarily assessed as an annual *per capita* cost for the total population. This includes costs of amortizing the initial capital expenditure and the running costs for chemicals, maintenance, and salaries. Some examples in local currency are:

USA	2-11 cents[28] (average 7.9 cents)[28,29]
New Zealand	10 cents[30]
United Kingdom	1.25 pence (Birmingham) to 2.56 pence (Watford)[31]
Netherlands	50 cents[15]
Czechoslovakia	1 koruna[16]
Switzerland (Basel)	0.41 Swiss franc[14]

It is customary to amortize the initial cost of fluoridation equipment over a period of 10 years at about 10% per annum[27] although at Tiel, Netherlands, the rate applied is 15% per annum.

6.2 Savings in the costs of dental treatment and cost-benefit ratios

It is possible to assess the financial benefits from fluoridation in several ways, e.g.:

(a) Savings in the cost of dental treatment based on the reduction in number of fillings and extractions (calculated on the fee-for-item-of-service basis).

(b) Savings in the dentist's or operating auxiliary's working time due to the reduction in numbers of treatments; or savings in salaries equivalent to this reduced working time.

(c) Data from Hastings (New Zealand), Newburgh and Gainesville (USA), Watford (United Kingdom), Tiel (Netherlands), Tabor (Czechsolovakia), and Basel (Switzerland) are examined from these points of view.

6.2.1 Hastings (New Zealand)

(a) Savings in the costs of dental treatment

In New Zealand children aged 2-1/2-13-1/2 years received regular dental care from the School Dental Service which is staffed by school dental nurses. Children who were enrolled in this service are then able to receive continued regular and free dental care up to and including age 15 from private dental practitioners under the Social Security Dental Benefits Scheme.

Dentists are paid on a fee-for-service basis for the treatment they provide. Denby & Hollis[19] have assessed the effect on dental treatment of 10 years' fluoridation at Hastings. The savings in the costs of dental treatment for children aged 13-1/2-15 years are easily determined from fees paid to private practitioners. The assessment of savings in costs for treatment for children aged 2-1/2-13-1/2 years is very difficult since the School Dental Service is a salaried service financed entirely from governments funds. Unfortunately, total expenses are not readily available since the service is financed from different government votes. However, by dividing the total government grant for the School Dental Service (estimated to be NZ$2 500 000 in 1965) by the total number of children enrolled (456 049 in 1965), the estimated cost of dental care per child NZ$5.48 for the year.

As shown in Table 8, the average number of fillings per child was 5.10 and the average number of extractions per child was 0.16. From these data it can be calculated that since fillings and extractions make up about 70% of the total operations the cost of a single filling or extraction is approximately 70 cents.

On this basis the total savings in children aged 2-1/2-13-1/2 years at Hastings can be calculated as follows:

Number of children enrolled (1965)	=	4 798
Savings in number of fillings and extraction per child (from Table 8)	=	2.56
Savings in cost of fillings and extractions per child (2.56 x $0.70)	=	NZ$1.79
Total savings for 4 798 children		NZ$ 8 598

In the case of children aged 13-1/2-15 years, inclusive, actual savings in costs are stated in the Denby & Hollis report.[19]

Number of children aged 13-1/2-15 enrolled for complete treatment by general dental practitioners under the Dental Benefits Scheme in 1965[26]	=	179 109
Savings in cost of dental treatment per child	=	NZ$5.72
Total savings for 1 360 enrolled children	=	NZ$7 779

Thus the total savings in the cost of dental treatment for 6 158 children aged 3-1/2-15 years who were enrolled for "free" treatment at Hastings in 1965 was (8 598 + 7 779) NZ$16 377.

(b) Savings in working time

According to Denby & Hollis[19] after 10 years' fluoridation at Hastings 5.5 dental nurses were able to cope with all the treatment requirements of 3 798 children of preschool and school age at Hastings, whereas it required 12 dental nurses to cope with 5 702 children of the same age at the non-fluoridation city of Gisborne. There is evidence to show that the 5.5 dental nurses at Hastings and the dental nurses in the rest of the country all carried out essentially the same number of fillings in 1965.[19,26] Adjustment of these figures for the number of children at Hastings shows that 8 dental nurses would be required for 3 798 children in the non-fluoridation city. That is, 2.5 fewer dental nurses were required as a result of fluoridation. This amounts to a saving of 0.65 whole-time dental nurse per 1 000 children.

(c) Cost-benefit analysis

For the purposes of this report, the cost-benefit ratio is defined as the cost of implementation divided by the savings in the costs of treatment. Thus at Hastings the costs of fluoridation may be calculated as follows:

Annual *per capita* costs of fluoridation	10 cents
Population of Hastings in 1965	37 000
Total cost of fluoridation for 1965	NZ$ 3 700
Value of total savings in dental care for 4 798 children aged 2-1/2-13-1/2 years	NZ$ 8 598
Actual savings in costs of dental care for 1 360 children aged 13-1/2-15 years	NZ$ 7 779
Total savings in costs of dental care in 1 year for children aged 2-1/2-13-1/2 years	NZ$16 377

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

$$= \frac{3\ 700}{16\ 377}$$

$$= \underline{\underline{1:4.4}}$$

This, of course, takes no account of the potential savings on the capital cost of accomodation and maintenance expenses for clinics no longer required.

6.2.2 Newburgh (USA)

(a) Savings in the cost of dental treatment

Ast et al.[20] based their estimates of savings in dental care on the 1966 New York Fee Schedule which allowed US$5.00 per surface for restoration and US$6.00 for each extraction.

The Bureau of Economic Research and Statistics of the American Dental Association published the results of the 1970 National Dental Fee Survey in July 1971.[33] According to this report, the average fees charged for restorations and extractions in New York State and the USA as a whole were as follows:

	New York	USA
Simple removal of a tooth (with local anaesthesia and routine postoperative care)	US$10.32	US$ 9.12
Amalgam filling for 1-surface cavity	US$ 7.39	US$ 7.83
Amalgam filling for 2-surface cavity	US$13.24	US$12.51
Amalgam filling for a cavity involving 3 or more surfaces	US$19.02	US$17.31

Calculations of savings based on the results from Newburgh and these fee-schedules are set out in Table 14.

These results show that for 5- and 6-year-old children with a life-long exposure to fluoridated water the savings per child in the initial year of complete dental care range from US$19.89 to US$26.63 and US$23.93 to US$32.00, using USA fee schedules. Savings in the 5 subsequent years of incremental care based on 1966 New York Fee Schedules are set out in Table 15.

These data show clearly, as would be expected, that the savings in the incremental years, after most of the backlog of dental care has been completed, is much less than in the initial year. Nevertheless, on an American fee schedule the savings are substantial and range from US$4.81 to US$8.17 for 5-year-old and US$1.99 to US$9.40 for 6-year-old children.

The results in Tables 14 and 15 also serve to emphasize the economic importance of protecting the proximal surfaces of teeth from caries. In both the initial and incremental care years the savings from 2-surface restorations account for more than half the total savings. It should also be emphasized that financial savings as well as savings in DMF teeth are much less in 5- and 6-year-old children than in older children.

(b) Savings in working time

Data on the chair time per child per year for dental care are set out in Table 16. These results suggest that in 6 years of fluoridation the total savings in chair-time for treating 450 5-year-old and 450 6-year-old children was 90 135 minutes, which amounts to a saving of 1 002 minutes of chair-time per child in the total 6-year period, or of 16.7 minutes per child per year. According to the Indian Health Service,[34] dentists are available for clinical services for 83 000 man-minutes per year.

Thus in 6 years, the saving in chair-side time for all children who were 5 and 6-years-old in 1962 is equivalent to about the clinical time of 1.1 full-time dentists.

(c) Cost-benefit analysis

Data from Newburgh are only available for a small sample of 5- and 6-year-old children. Even if these results are extrapolated to provide an estimate of the potential savings for all 5- and 6-year olds in that city, the cost-benefit ratio will be a gross underestimate of the position in the population as a whole. As was pointed out in paragraph 6.2.2 (a), financial savings as well as savings in DMF teeth are much less for 5- and 6-year-olds than for older children. Nevertheless it can be shown from the data in Tables 14 and 15 that in 6 years the total savings in the cost of dental treatment for children whose initial age was 5 years was US$54.40 per child, made up as follows: US$19.99 in first year, US$7.75 in second year, US$7.41 in third year, US$8.17 in fourth year, US$4.81 in fifth year, and US$6.27 in the sixth year. Likewise, the total savings in the cost of dental treatment for children whose initial age was 6 years was US$55.49.

Annual per capita costs of fluoridation at Newburgh estimated at	8 cents
Population of Newburgh (approximately)	30 000[39]
Cost of fluoridation at Newburgh per year	US$ 2 400
Total cost of fluoridation for 5 years	US$12 000
Value of savings in cost of dental care for 450 children aged 5 years (US$54.40 per child)	US$24 480
Value of savings in cost of dental care for 450 children aged 6 years (US$55.49 per child)	US$24 970
Total savings in cost of dental care for children aged 5 and 6 years at the beginning of a 5-year period	US$49 450

$$\text{Cost-benefit ratio} = \frac{\text{Cost of implementation}}{\text{Savings in cost of treatment}} = \frac{12\ 000}{49\ 450}$$

$$= 1{:}4.1$$

It should be noted that the cost-benefit ratio is equivalent to that obtained for children aged 2-$^1/_2$-15 years in New Zealand. This situation results from the fact that costs of implementation are somewhat lower but the costs of treatment are very much higher in the USA than in New Zealand.

6.2.3 Gainesville (USA)

(a) Savings in the cost of dental treatment

From Table 10 it will be seen that compared with the non-fluoridation city of Woonsocket the savings per child aged 5-13 years at the initial treatment series at Gainesville was 1.77 fillings and 0.7 extractions in the first year and 3.94 fillings and 0.61 extractions in the second. Unfortunately, the type of filling is not stated. If we assume an average fee of US$7.50 for a filling and US$6.00 for an extraction, the average saving per child would be US$17.47 in the first year and US$33.21 in the second.

(b) Savings in working time

From Table 13 it will seen that compared with the non-fluoridation city of Woonsocket there was a saving of 2.5 dentist man-hours per child at Gainesville during the first treatment series 4-1/2 years after fluoridation began and a saving of 2.0 dentist man-hours per child in the second year.

Annual *per capita* costs of fluoridation at Gainesville estimated at	8 cents
Population of Gainesville (approximately)	25 000
Cost of fluoridation at Gainesville per year	US$ 2 000
Total cost of fluoridation for 5-1/2 years	US$11 000
Value of savings in costs of dental care for 2 738 children aged 5-13 years in the first treatment year (US$17.47 per child)	US$47 833
Value of savings in costs of dental care for 2 748 children aged 5-13 years in the second treatment year (US$33.21 per child)	US$91 261
Total savings in cost of dental treatment for children aged 5-13 years in the first and second treatment series	US$139 094
Cost benefit ratio based on savings in costs of treatment	11 000 / 139 063
	= 1:12.7

Since the cost of an average filling was estimated rather on the low side, another cost-benefit ratio, based on the financial estimate of the saved working time, is given below. The value of the saving in dentist-hours per child at Gainesville was US$52.50 per child during the first treatment year 4-1/2 years after fluoridation and US$47.00 per child in the second treatment year.

Thus the value of savings in dentist man-hours in the treatment of 2 738 children during first treatment series is	US$143 745
Likewise, the savings on 2 748 children in second treatment series is	US$129 156
Total savings in dentist man-hours	US$272 901
Cost-benefit ratio based on savings in dentists' salaries	11 000 / 272 901
	= 1:24.8

6.2.4 Watford (United Kingdom)

(a) Savings in the cost of dental treatment

According to Rodgers[31] "the average annual cost of the general dental service of the National Health Service is nearly £2 per head of the population. Conservation (filling) of teeth accounts for about 50 per cent. of this amount and dentures for nearly one-quarter. During the years of compulsory attendance at school (at present 5 to 15) conservation of teeth still accounts for well over 50 per cent. of the fees paid in the general dental services and in the 16 to 20 years age group for over 75 per cent."

The savings in the number of dmf deciduous and DMF permanent teeth per child after 11 years of fluoridation are shown in Table 17. If it is assumed that a saving of 1 dmf or

DMF tooth is equivalent to the saving of 2 two-surface restorations, then the savings in the cost of fillings at Watford (also shown in Table 17) range from £1.62 (US$4.38) at age 3 years to £4.32 (US$11.66) at ages 6 and 7.

(b) Savings in working time

It is not possible to make satisfactory estimates of savings under these headings from available data.

(c) Cost-benefit analysis

Annual *per capita* costs of fluoridation at Watford[31]	$2.562.56
Population of Watford	75 000
Annual cost, including amortization	£ 1 920
Total cost in 11 years	£21 120
Total savings in costs of fillings estimated from data in Table 17 for 1 578 children aged 3-14 years who were examined[36]	£ 4 609.60

(Although the method of selecting children for examination is described in Appendix 5 of the 1962 British report[37] the percentage of total children represented in the sample is not stated. However, it might be expected from Australian data that children aged 3-14 years inclusive might make up 24% of the population. If this is also true of Watford, then the total number of children of this age-group should be about 18 000.)

Thus, estimated total savings for 18 000 children aged 3-14 years $\frac{(4\ 609.60 \times 1\ 800)}{1\ 578}$ = £52 549.44

Cost-benefit ratio $= \frac{21\ 120}{52\ 549}$

$= 1:2.5$

6.2.5 Tiel (Netherlands)

(a) Savings in the cost of dental treatment

Pot[15] has used two methods to estimate costs of dental treatment. In the first, his estimates were based upon absolute reductions in DMF specific surfaces. "Proximal cavities were considered to equal 1.5 fillings and occlusal cavities as 1 filling. Missing specific surface figures have been converted to show the true number of extractions." The savings in the number of fillings and extractions after lifetime exposure to fluoridation at Tiel are set out in Table 11. In the Ziekenfonds, which is the Dutch equivalent of the National Health Service in the United Kingdom, the cost of a 1- or 2- surface filling is 12 guilders and an extraction costs 6 guilders.

In the second method, Pot's estimates are based on absolute savings of DMF teeth. In this case, a saving of 1 DFT is assessed as 2.5 fillings saved, and a saving of 1 MT as extraction saved. The results of calculations based on these two methods of assessment are set out in Table 18.

The calculations show that:

(a) both methods of assessment give similar results;

(b) total savings per child in the cost of treatment after 16 years of fluoridation range from 26 guilders (US$8.12) at age 7 to 229 guilders (US$71.56) at age 15.

(b) Savings in working time

It is not possible to make satisfactory estimates of savings under these headings from available data.

(c) Cost-benefit analysis

In his Table 5, Pot[15] has calculated for Tiel the cost-benefit ratio at age 7 based on surfaces data as 1:6.2, and based on DMT data as 1:8.8. He also claims (reference 15, page 85) that the cost of water fluoridation amounts to 50 cents per capita per year. If this were so, the respective cost-benefit ratios should be 1:7.6 and 1:10.0 calculated as follows:

Per capita cost of fluoridation for 7 years (7 x 0.5)		3.5 guilders
Savings in cost of treatment based on DMF specific surfaces (Table 18)		26.64 guilders
Cost -benefit ratio	=	$\frac{3.5}{26.64}$
	=	1:7.6
Savings in cost of treatment based on DMFT (Table 18)	=	35.10 guilders
Cost-benefit ratio	=	$\frac{3.5}{35.10}$
	=	1:10.0

Pot's data have, therefore, been recalculated and the results based on annual costs of 50 cents and 60 cents per capita are set out in Table 19.

The impressive gains in cost-benefit of lifetime teeth with age are clearly shown. At age 5, the full deciduous dentition would have erupted and these teeth would have been exposed to the full benefits of fluoridation. The cost-benefit ratio varies from 1:34 to 1:41, depending upon the method of assessment. At age 15 the full permanent dentition (except for the third molars) would have erupted and would have been exposed to the full benefits of fluoridation. The cost-benefit ratio varies from 1:34 to 1:41.

It must be stressed, however, that whereas the method of assessing cost-benefit for the other locations mentioned in this report underestimates the true position, this method of presenting data exaggerates the benefits because it understates the costs of implementation for the community as a whole.

In a separate analysis, Backer Dirks[18] concluded that the cost-benefit ratio of fluoridation is 1:4 if fluoridation equipment is amortized over 10 years; 1:4.7 if the equipment is amortized over 15 years, and 1:5.7 if it is amortized over 20 years.

6.2.6 Tabor (Czechoslovakia)

(a) Savings in the cost of dental treatment

Urban[16] has estimated the cost per filling for children aged 11-14 years enrolled in the School Dental Service as 16.68 korunas. During the first 5 years after fluoridation began the average savings in the number of fillings per child was 1.30 (Table 12), which at 16.68 korunas per filling amounts to an average saving of 21.68 korunas per child per year, and a total saving in the first 5 years of 108.40 korunas. During the following 8 years the average saving in the number of fillings per child was 1.80 (Table 12), which amounts to an average saving of 30.02 korunas per child per year, and a total saving in the following 8 years of 240.16 korunas. Thus the total average savings for each child after 13 years' exposure to fluoridation was (108.40 + 240.16) = 348.56 korunas.

(b) Savings in working time

Urban[16] has analysed the results from Tabor and made extrapolations which might apply to the situation as it exists in Prague:

Number of working hours per dentist enrolled in the School Dental Service	=	2 023
Percentage of working hours devoted to fillings	=	70
Thus number of working hours devoted to fillings	=	1 416
Percentage saving in fillings 6-13 years after water fluoridation at Tabor	=	61
Saving in working hours devoted to fillings after fluoridation $\left(\frac{1\,416 \times 61}{100}\right)$	=	864
Thus, number of working hours per dentist after water fluoridation (2 023 - 864)	=	1 159
Thus, percentage saving in number of working hours per dentist (864/2 023 x 100)	=	43%
Number of dentists in School Dental Service, Prague	=	63.19
Number of children enrolled in School Dental Service, Prague	=	103 400
Thus, number of children per dentist	=	1 636
Predicted number of children per dentist after water fluoridation $\left(1\,636 \times \frac{100}{100-43}\right)$	=	2 870
Predicted number of dentists in School Dental Service in Prague 6-13 years after the beginning of water fluoridation $\left(63.19 \times \frac{100-43}{100}\right)$	=	36.02
Thus, predicted savings in the number of dentists in the School Dental Service in Prague 6-13 years after the beginning of water fluoridation $\left(63.19 \times \frac{43}{100}\right)$	=	27.17

Since no information is available on the salaries of dentists in the School Dental Service in Czechoslovakia it is not possible to specify the saving in costs under this heading. However, Urban[16] claims that the prediction "underestimates the value of water fluoridation. This underestimation can be explained by the fact that water fluoridation does not only influence the caries incidence but also its quality. Caries lesions are of smaller size and the treatment with fillings is less time-consuming".

(c) Cost-benefit analysis

From the data on Tabor presented by Urban[16] it is possible to make an analysis similar to that made by Pot[15] for Tiel.

Annual *per capita* cost of fluoridation at Tabor		1 koruna
Total cost in 13 years per child		13 koruna
Total average savings for each child after 13 years' exposure to fluoridation		348.56 koruna
Thus, cost-benefit ratio excluding salary savings	=	$\frac{13}{348.56}$
	=	1:26.8

It is noteworthy that this ratio lies within the range of the estimates for 13-year-olds at Tiel.

6.2.7 Basel (Switzerland)

(a) Savings in the cost of dental treatment

According to Marthaler[13] the average number of DMFS saved in children aged 6-14 years after 5 years' fluoridation at Basel was 1.21 DMFS per child per year. The average cost of fillings is 15 Swiss francs per surface, according to the official tariff for school dental services. Thus the average saving in the cost of fillings per child per year is 18.15 Swiss francs or 90.75 Swiss francs in 5 years. It must be remembered, as Marthaler[13] points out, that after 5 years' water fluoridation the effect on children aged 8 years and over is not at its maximum.

According to Marthaler[14] there are about 3 000 children per cohort of one year, and children aged 6-14 years represent about one-tenth of the population, so that there are about 25 000 children in the age-group 6-14 years. Thus, the estimated total savings in 5 years in the cost of fillings at 90.75 Swiss francs per child amounts to 2 268 750 Swiss francs.

(b) Savings in working time

According to Perret[27] after 5 years' fluoridation 6 dentists were able to carry out the number of fillings required by enrolled children whereas in 1960 20 dentists were required to do the same work. The report also reveals that in 1960 each of the 20 dentists carried out an average of 1 956 fillings in the year while in 1967 6 dentists completed an average of 2 009 fillings in the year. It is not possible to assess the financial implications of these savings, but assuming that the dentists in 1967 worked for the same number of hours as the dentists in 1960 there was an overall saving of (14/20) 70% in dentist man-hours.

(c) Cost-benefit analysis

The data for Basel provided by Marthaler[13,14] make it possible to make the following calculations.

Per capita cost of total population including running costs and amortization of capital outlay		Sw.F. 0.41
Population of Basel		250 000
Annual costs		Sw.F. 102 500
Total costs for 5 years		Sw.F. 512 500
Estimated annual average savings in cost of treatment per person aged 6-14 years		Sw.F. 18.15
Estimated total savings in 5 years per child		Sw.F. 90.75
Total savings from 25 000 children aged 6-14 years		Sw.F. 2 268 750
Thus, cost-benefit ratio excluding salary savings	=	$\frac{512\ 500}{2\ 268\ 750}$
	=	1:4.4

The results of all these calculations are summarized in Table 20.

The cost-benefit ratios obviously vary greatly according to the method of calculation, the costs of dental treatment, and whether or not salary savings are included in the benefits side of the equation.

It is worth noting, however, that in all cases the value of the benefits exceed the costs of implementation by a substantial margin, and this is true even when the benefits obtained by children in only two age groups are concerned, as at Newburgh.

7. PUBLIC ACCEPTANCE

Public opposition to fluoridation has been persistent and worldwide, and has created considerable social and political difficulties in relation to the implementation of programmes.[38] Nevertheless, substantial progress has been made, and the number of communities with fluoridation plants has shown a steady increase in more than 30 countries since the first installation was made in 1944.

8. SIDE-EFFECTS

No side-effects to properly controlled fluoridation of public water supplies have been substantiated.[28,38,39,40,41]

9. CONCLUSIONS CONCERNING FLUORIDATION

This review of the literature on the fluoridation of public water supplies has revealed that no single published report provides sufficient data for making a satisfactory cost-benefit or cost-effectiveness analysis.

The major deficiency arises from the fact that all the studies, except the one at Tiel-Culemborg, have been conducted on a cross-sectional instead of a longitudinal basis. In some cases (Hastings, New Zealand, for example) the effectiveness of fluoridation in terms of caries reduction has been assessed over a 10-year period by a single investigator, but the assessment of cost-benefits has been made for a single year by different people and based on work done by auxiliaries or dentists who were neither involved with, nor had access to, the results of the clinical examination carried out by the first investigator.

This review also reveals the deficiencies of DMFT and deft indices, since there is no consistent relationship between computed increments and clinical services either required or rendered. DMFS indices based on the examination of all tooth surfaces and of occlusal (pit and fissure), proximal, and buccal-lingual smooth surfaces are also unreliable as indicators of treatment requirements. This does not mean that these indices are of no value, but it does mean that when used by themselves they are unreliable as a basis for estimating costs, and savings in costs, of treatment.

Maximum benefits are only obtained by lifetime residents in a fluoridation area, children born before fluoridation begins will derive some benefits from a topical action and the benefits in lifetime residents will be carried into adult life. However, an important consideration is that the total amount of dental treatment received by adult lifetime residents in a fluoridation community can be expected to exceed that received by adult lifetime residents of a non-fluoridation community because they will retain their natural teeth to a much greater age.

The cost benefits of fluoridation can be assessed in several different ways, as follows:

(a) Savings in the cost of dental restorations and extractions

This will depend on whether the service is provided by operating auxiliaries working in public health clinics, "dental teams", which include operating auxiliaries, or private dental practitioners. Since caries increments cannot be assessed from deft or defs because of the exfoliation of deciduous teeth, and since there is no consistent relationship between computed DMFT and DMFS increments and treatment requirements, there is a need to promote longitudinal studies of representative samples of children and young adults in fluoridation and non-fluoridation towns. At each examination not only should the def and DMF status of each tooth or tooth surface be recorded, but also the actual treatment required.

The minimum requirements is to record the number of 1-surface, 2-surface, 3-surface, and other restorations needed, as well as the number of teeth that need to be extracted because of caries. The cost of treatment provided by private practitioners can be estimated from fee-schedules. Costs of treatment provided by public health services may be estimated from data concerning the operating expenses of the service.

(b) Savings in the time required to provide dental treatment

There is evidence to show that operating auxiliaries (school dental nurses)[19] and dentists[21] can maintain a larger number of patients under regular incremental care in a fluoridation community than in a non-fluoridation community. These data can be expressed in monetary terms as salary savings, and/or as savings in dentist and operating auxiliary man-hours.

There are, of course, other tangible benefits to be derived from the prevention of dental caries, but it is not possible to assess them in financial terms. Such benefits from fluoridation include:

1. Less pain and discomfort from decayed teeth.

2. A reduction in the annual per capita loss of time from school and industry for keeping dental appointments.

3. A possible reduction in the prevalence of malocclusion due to a lower rate of extraction of teeth.[42]

4. An opportunity for dentists to provide more attention to the problem of periodental disease which affects many children and virtually every adult.

5. An opportunity for children who practise reasonable dietary control and maintain a good standard of oral hygiene to be completely free of dental caries.

PART II - SCHOOL FLUORIDATION

10. INTRODUCTION

Recognizing the fact that about 46 million persons or 23% of the population of the USA reside in areas without a central water supply and that in other countries there is an even greater proportion of the population for whom fluoridation of community water supplies is not feasible, the Epidemiology Branch of the Division of Dental Health of the United States Public Health Service designed three studies to determine the practicability and effectiveness of fluoridating school water supplies.[43,44]

There are several reasons for suggesting this particular procedure:

(a) In the USA nearly all children aged 6 years and older spend between 20% and 25% of their total waking hours in school each year.[44]

(b) A considerable uptake of fluoride occurs between the completion of the calcification of permanent teeth and their eruption.[45]

(c) A considerable portion of the permanent dentition calcifies after age 6 years.

(d) Erupted teeth derive some benefit from the topical effect of fluoridated water.[44]

(e) Part-time exposure to fluoridated water helps to increase the resistance of enamel to caries.[46,47]

11. THE EFFECT ON THE PREVALENCE AND SEVERITY OF DENTAL CARIES

A pilot study to test the efficacy of fluoridating an elementary school water supply to a level of 2.3 ppm of fluoride (approximately 3 times the optimal level) was begun at Charlotte Amalie in the Virgin Islands in 1954. After 6 years the results were so encouraging (a 22% reduction in the incidence of caries) that two further studies were set up in the USA.[48] At Pike County in Kentucky fluoride was added to two school water supplies to a level of 3 ppm and at Elk Lake, Pennsylvania, the water supply of a rural school was fluoridated to a level of 5 ppm.[43] The results after 8 years for continuously resident children are summarized in Table 21. Reductions in 6-year-olds ranged from 0.57 DMFT at Pike County to 0.58 DMFT in Elk Lake. The greatest reductions were obtained in 13-year-olds at Elk Lake (4.82 DMFT) and 15-year-olds at Pike County (3.99 DMFT). When the data from the last year of the study were adjusted to the distribution of children at the beginning of the study the overall reduction in children aged 6-17 years was 2.35 DMFT at Pike County and 2.62 DMFT at Elk Lake.

It is useful to compare these results with those obtained at Grand Rapids. In 1966 the oldest children at both study sites who had been exposed to fluoridated water from the time they entered the first grade at school in 1958 were the 14-year-olds. At Pike County in 1966 they had 3.77 (33.8%) fewer DMFT and at Elk Lake 3.94 (33.2%) fewer DMFT. At Grand Rapids after 8 years' fluoridation,[49] 14-year-olds had 3.72 (33.9%) fewer DMFT. Thus children who were exposed to fluoride for 8 years from the time they entered school received virtually the same benefit as children of the same age exposed for the same number of years to fluoride from a community water supply.

12. THE MANPOWER REQUIRED AND THE TIME TAKEN TO IMPLEMENT FLUORIDATION PROCEDURES

Professional dental personnel are not involved in the implementation of school fluoridation procedures. However, the maintenance of the equipment, the control of the fluoridation process, and the surveillance of fluoride levels must be under the direct control of a responsible engineer, teacher, or health official. The principles are the same as for community fluoridation, but since the procedure is not a standard practice at schools and is operated independently of community waterworks, per capita costs are bound to be higher and the control less reliable.

However, at the installations cited, the cost of equipment ranged from US$250 to about US$3 000, and the cost of chemicals averaged approximately US$20 per 1000 pupils per school year.[44]

13. THE EFFECT OF THE PROCEDURE ON THE NEED FOR DENTAL TREATMENT

It is not possible to make a reliable estimate of increments of dental caries and the requirements for dental treatment from a consideration of DMFT or DMFS data alone. The data from the school fluoridation studies are also deficient in that results for the deciduous dentition have not been published. However, if the results of the Woonsocket investigation[24] are accepted as a guide, a DMFT incremental saving of 2.35-2.62 in children aged 6-17 years would be equivalent to a saving of approximately 4.6-5.2 restorations per child in 8 years.

14. COST-BENEFIT ANALYSIS

One obvious cost advantage of school fluoridation is that the treated water is used solely by those who can be expected to receive immediate benefits, even though these may be less than would be obtained from the life-long consumption of fluoridated water from a community supply.

14.1 Cost of implementation

The annual cost of chemicals	=	US$20 per 1 000 children
	=	20 cents per child per year
Thus in 8 years the total cost of chemicals per child	=	US$1.60
To which must be added the cost of amortizing the capital expenditure plus additional salaries (say US$1 per child for 8 years)		
Making the total cost per child	=	US$2.60

14.2 Savings in the cost of dental treatment and cost-benefit ratios

If the average US Scale of Fees is used as a basis, the average cost of a restoration per tooth would not be less than US$8.[50] Since it is possible that the saving of 2.35-2.62 DMFT per child in 8 years might be equivalent to a saving of 5 restorations, the possible savings in the cost of restorations per child in 8 years would be US$40.

$$\text{The cost-benefit ratio} = \frac{\text{Cost of implementation}}{\text{Savings in cost of treatment}} = \frac{2.60}{40.00} = 1{:}15.4$$

15. PUBLIC ACCEPTABILITY

This procedure does not eliminate the problem of freedom of choice, which is commonly raised as an issue in opposition to the fluoridation of community water supplies. It does, however, meet the objection that community fluoridation requires non-beneficiaries, such as the edentulous, to consume fluoridated water.

16. SIDE-EFFECTS

The results of these investigations demonstrated unequivocally that the levels of fluoride added to the water supplies of schools did not produce any form of objectionable fluorosis. Only 0.13% of canines, premolars, and second molars that were still calcifying when first exposed to fluoride at school showed any sign of fluorosis. The effects were classified as very mild and of neither pathological nor aesthetic significance. It should be emphasized that the permanent central incisors of most children are completely calcified by the age of 6 years, so that the fluorosis of such teeth could not be caused by fluoridated water at school

PART III - FLUORIDE TABLETS

17. INTRODUCTION

The status of fluoride tablets in the prevention of caries was ably reviewed by Paulsen & Møller in 1969.[51] On the basis of some 30 clinical trials which had been completed at that time they concluded that fluoride tablets have a certain value in reducing dental caries by 20-40%. Subsequent studies have confirmed this general conclusion and suggest that the extent of the benefit was underestimated. Indeed, the latest data suggest that the consumption of fluoride tablets has a positive effect, even when taken after tooth formation is complete but a much greater effect when consumed both during and after tooth development.

18. EFFECT ON THE PREVALENCE AND SEVERITY OF DENTAL CARIES

From the results of a selected sample of studies,[52,53,54,55,56,57] summarized in Table 22 it is possible to draw the following conclusions:

(a) Fluoride tablets taken prenatally and continued postnatally until 6 years of age result in substantial reductions in dental caries in the deciduous dentition from 3.84 to 4.80 deft and to the extent of 9-10 defs per child in areas where the prevalence of dental caries is fairly high.

(b) The postnatal consumption of fluoride tablets also produces a substantial reduction in deft (2.52-3.28), but one study showed no effect in the deciduous dentition when intake began at the age of 3 years.

(c) Substantial reductions in the prevalence of caries in the permanent dentition can be obtained when fluoride tablets are consumed during the pre- and post-eruptive period of the permanent dentition.

(d) Substantial reductions in the prevalence of dental caries in the permanent dentition are obtainable even when tablet administration does not begin until the age of 6 years. In a high prevalence area, Switzerland, reductions as great as 5 DMFT and 15 DMFS were obtained in 15-year-olds after 8 years of intermittent administration of fluoride tablets.

(e) These results, together with those from the studies of school fluoridation,[43,44] support the suggestion of De Paola & Lux[57] that fluoride supplements need not be ingested daily for substantial benefits to be obtained.

(f) The data from De Paola & Lux[57] demonstrate that there is a marked increase in benefit for teeth that erupt after regular fluoride supplementation begins.

Additional results have been made available by Binder.[112] These data came from a long-term study of the administration of fluoride tablets in Vienna. The distribution of fluoride tablets was introduced in 1956 in five districts. At that time tablets were administered only to children in the age range 6-10 years. The distribution proceeded incrementally starting with 6-year-olds in 1956, 6- and 7-year olds in 1957, 6-, 7- and 8-year olds in 1958, and so on. Since 1960-62, however, the tablets have also been recommended for preschool children (through mother and child welfare centres), and for schoolchildren the distribution was continued up to 14 years. Since 1965 tablets have been distributed throughout Vienna.

The following conclusions may be drawn from the results reported by Binder which are set out in Table 23:

(a) At age 6 a lifetime's exposure to fluoride tablets produced a substantial reduction in DMFT per child of 0.70 (70%).

(b) At age 10 a lifetime's exposure to fluoride tablets produced a reduction of 2.40 DMFT per child (55%) whereas in 10-year-olds who only received fluoride tablets at school between the ages of 6 and 10 years the reduction was 1.65 DMFT per child (38%).

(c) At age 14 a lifetime's exposure to fluoride tablets produced a reduction of 3.85 DMFT per child (43%), whereas in 14-year-olds who only received fluoride tablets at school between the ages of 6 and 10 years the reduction was 1.54 DMFT per child (17%).

(d) The caries experience of the control group is relatively small; 8.97 DMFT at age 14 compares favourably with a pre-fluoridation baseline at age 14 of 14.35 DMFT at Hastings, New Zealand, and 10.95 at Grand Rapids, USA.

19. THE MANPOWER REQUIRED AND THE TIME TAKEN TO IMPLEMENT THE PROCEDURE

Responsibility for the administration of fluoride tablets can be assumed by parents but there is evidence to show that, even when tablets are provided free, many participants drop out of the programme. In their study Hennon, Stookey & Muhler[52] found only about 20% of the original number of subjects were present at the 5-$^1/2$ year examination. In Western Australia, Prichard[54] found that although 15 local authorities distributed tablets free of cost the tablets were taken regularly by only 16% of children aged 6-14 years. About 50% of the age-group 6-8 years had some experience of the tablets but only 25% took them regularly.

A survey made in Switzerland in 1963/64 showed that roughly 13% of families have made some use of fluoride tablets. In most cases, however, the administration lasted for only 1-3 years.[58]

Nevertheless, the benefits to be derived are so striking that when fluoridation of water is impracticable dentists, doctors, and child health centres should be encouraged to prescribe tablets. Countries with a national health service should consider including fluoride tablets as a pharmaceutical benefit.

The alternative procedure is to arrange for the distribution of fluoride tablets through kindergartens and schools. The studies of Marthaler,[56] De Paola & Lux,[57] and Binder[112] provide substantial evidence of the benefit and practicability of this procedure. In this case, responsibility for the daily issuing of tablets may be placed in the hands of school-teachers or dental assistants seconded to schools for that purpose.

No time would be required from the dental personnel.

20. EFFECT ON THE NEED FOR DENTAL TREATMENT

From the data so far available and summarized in Tables 22 and 23 absolute reductions in dental caries may be as high as 4.80 deft in 6-year-olds after 6 years of tablet therapy and as high as 5.12 DMFT in 14-year-olds after 8 years' tablet therapy.

If the procedure suggested by Pot[15] and described in paragraph 6.2.5 is adopted (i.e., assuming that 1 DFT saved = 2.5 fillings saved and 1 MT saved = 1 extraction saved) the savings in the number of fillings required in the various studies reported in Table 22 would be as shown in Table 24.

The possible annual savings in the number of fillings required in deciduous teeth per year range from 1.05 to 2.4 in children after the administration of tablets for 4-$^1/2$ -6 years starting between the time of birth and 2 years of age.

The possible annual savings in the number of fillings required in permanent teeth range from 0.3 to 0.6 per year for children who received tablets from birth or during the first

2 years up to the age of 6-7-$^{1}/2$. In 14-year-olds the possible savings in fillings range from 0.7 to 1.6 per year.

21. COST-EFFECTIVENESS

Since dental personnel are not involved the calculation of savings per hour of professional time cannot be made.

22. COST-BENEFIT ANALYSIS

22.1 Cost of implementation

There is a considerable variation in the cost of fluoride tablets not only from country to country but also between retail, wholesale, and bulk order supplies in each country, so that the calculations in this section should be regarded as tentative until firm quotations are available. Costs will, of course, also vary according to the recommended dosage, which should be related to the natural fluoride content of the domestic water supply and the age of the child. A commonly accepted dosage for children in a fluoride-free area is 0.5 mg of the fluorine daily for children under 3 years of age and 1.0 mg of fluorine daily for children over 3 years of age.

In Australia the most common retail price of fluoride tablets is 75 cents for 200. According to Dunning,[59] the group purchase price of a year's supply of fluoride tablets is US$3.65 per child. Marthaler[13] says that the cost of tablets per year per child, including instruction sheets and other supplements, is approximately 1 Swiss franc. In Czechoslovakia, at the dosages recommended, the cost of tablets per child per year ranges from 6.75 korunas for children aged 0-2 years, 13.50 korunas for children aged 2-3 years, 20.25 korunas for children aged 3-4 years, and 27.00 korunas for children aged 4-12 years.

22.2 Savings in the cost of dental treatment

Assuming the average cost of a restoration to be A$5.00 in Australia, US$8.00 in the USA, and 15 Swiss francs in Switzerland, the total savings in the cost of treatment based on the data in Table 24 would be as follows:

USA[52,53]

Total savings per child in fillings in deciduous and permanent in 5-$^{1}/2$ years (10.38 + 3.5)	=	13.88
Total savings in cost per child at US$8.00 per restoration	=	US$111.04
Average savings in cost per child per year	=	US$ 20.19

USA[57]

Total savings per child in fillings in permanent teeth in 2 years	=	1.00
Total savings in cost per child at US$8.00 per restoration	=	US$ 8.00
Average savings in cost per child per year	=	US$ 4.00

Australia[54,55]

Total savings per child in fillings in deciduous teeth in 6 years	=	6.3 - 12.0
Total savings in cost per child at A$5 per restoration	=	A$31.50 - A$60.00
Average savings in cost per child per year	=	A$5.25 - A$10.00

Switzerland[56]

Total savings per 14-year-old child in number of fillings in permanent teeth in 8 years	=	12.8
Total savings in cost per child at Sw.F 15 per 1 restored tooth surface	=	Sw.F 192.00
Average savings in cost per child per year	=	Sw.F 24.00
Total savings per 15-year-old child in number of fillings in permanent teeth in 8 years[a]	=	10.95
Total savings in cost per child at Sw.F 15 per 1 restored tooth surface	=	Sw.F 164.25
Average savings in cost per child per year[a]	=	Sw.F 20.53

22.3 Cost-benefit ratios

$$\text{Cost-benefit ratio} = \frac{\text{Estimated cost of tablets per child per year}}{\text{Average savings in cost of fillings per child per year}}$$

USA

(a) 5-1/2 years' use of fluoride tablets from birth $= \frac{3.65}{20.19} = 1:5.5$

(b) 2 years' use of chewable fluoride tablets at school $= \frac{3.65}{4.0} = 1:1.1$

Australia

(a) 6 years' use of fluoride tablets from birth to 2 years $= \frac{1.02}{5.25} = 1:5.1$

(b) 4-1/2-6 years' use of fluoride tablets from birth $= \frac{1.02}{10.00} = 1:9.8$

Switzerland

(a) 8 years' use of fluoride tablets at school by 14-year-olds $= \frac{1.00}{24.00} = 1:24.0$

(b) 8 years' use of fluoride tablets at school by 15-year-olds $= \frac{1.00}{20.53} = 1:20.5$

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[a] Assuming that 1 filled tooth-surface equals 1 filling.

The marked variation between countries in these cost-benefit ratios is noteworthy. Results from the USA and Australia for children who have taken fluoride tablets from birth vary from 5.1 to 9.8. The favourable cost-benefit ratio in Switzerland is a reflection of the low cost of fluoride tablets in that country.

The success of the administration of fluoride tablets in schools is apparent.

23. PUBLIC ACCEPTABILITY

Even those most strongly opposed to fluoridation usually support, and indeed often advocate, the prescription of fluoride tablets.

In considering the merits of various alternatives to fluoridation the Royal Commissioner for Tasmania[38] said:

> ". . . tablets are certainly effective as a measure of individual prophylaxis. Indeed, I believe the effect of the evidence to be that if taken regularly and consistently from birth and if supplemented (by topical applications). . they are capable of conferring a measure of caries resistance which will surpass the average statistical expectation of a child of the same age drinking fluoridated water . . . However, both as a continuing means of individual protection and as an effective measure of public prophylaxis, they are subject to severe limitations, so severe that they do not in my opinion rank as a feasible alternative to water fluoridation. . . The successful administration of tablets as a caries prophylaxis measure . . . calls for a degree of parental responsibility and persistence that is so high as in the mass to be regarded as unattainable and this has been confirmed by experience."

24. ADVANTAGES, DISADVANTAGES, AND SIDE-EFFECTS

Supported by an active education campaign by individuals and public health authorities, the use of fluoride tablets is an important preventive measure in areas where water fluoridation is not in operation. Difficulties of persistence in individual children can be overcome if education and health authorities are willing to issue the tablets daily in schools. The contentious issue of individual liberty does not arise. There are dangers, and these should be neither avoided nor overemphasized. Cases have been reported of children consuming a whole bottle of 200 tablets at once. This is the equivalent of consuming 200 litres of fluoridated water at one sitting - a feat which is, of course, a physical impossibility. If a child does consume 200 tablets it is necessary to induce immediate vomiting, and this should be followed by gastric lavage with lime water or large amounts of milk.

Dental fluorosis resulting from the consumption of fluoride tablets is possible, but at the recommended dosage level any cases that do arise will be mild and of no greater intensity than idiopathic enamel opacities.[53]

Marthaler[56] and the Tasmanian Royal Commissioner[38] have pointed out that it is not known to what extent the protective effective is maintained after the administration of tablets is discontinued, although it would appear that first molars and incisors experiencing the longest period of posteruptive fluoride administration may retain part of the benefit.

PART IV - PROFESSIONALLY ADMINISTERED APPLICATIONS OF FLUORIDE SOLUTIONS

25. INTRODUCTION

In the last 20 years a large number of different fluoride solutions and techniques of application have been subjected to clinical trials. Research has been concentrated on several agents and at least 6 techniques of application.

(a) The Knutson technique[60]

After a prophylaxis each surface of each tooth is thoroughly wetted with the solution which is allowed to dry for 3-4 minutes. Three further applications are made at intervals of about a week, but a prophylaxis is not carried out. Recommended ages for treatment are 3, 7, 10, and 13 years.

(b) The Muhler single application technique[61]

The teeth are given a thorough prophylaxis including the stripping of every interproximal surface. Teeth are isolated, dried with air, and kept moist with the solution for 4 minutes. Repeat applications are made every 6 months, or more frequently if the patient is susceptible to caries.

(c) The Mercer & Muhler technique[62]

This is essentially the same as the Muhler method except that the teeth are kept moist for 30 seconds instead of for 4 minutes.

(d) The Dudding & Muhler technique[63]

This is a combination of a 4-minute topical application of a standard fluoride solution preceded by a prophylaxis with a stannous fluoride paste, each surface of each tooth being treated for 10 seconds. Unwaxed floss silk is used interproximally. Szwejda modified this technique by applying the solution for 30 seconds instead of for 4 minutes.

(e) The Englander technique[64,65]

In this method the solution or gel is applied in special maxillary and mandibular mouthpieces made from sheets of thermoplastic vinyl resin. Applications are made for 3 minutes 3 times a week in schools.

(f) The Szwejda-Knutsen multiple-chair technique[66]

This method is essentially the same as the Knutsen method but the time taken per child is greatly reduced by using several chairs.

26. THE EFFECT ON THE PREVALENCE AND SEVERITY OF DENTAL CARIES

26.1 Clinical trials of professionally administered topical applications of sodium fluoride, stannous fluoride, and acidulated phosphate fluoride

These results are summarized in Table 25.[15,61,62,64,65,66,67,68,69,70,71,72,74,75,76,77,78]

The following conclusions can be drawn from these results:

(a) The results obtained with sodium fluoride are more consistent that those obtained with stannous fluoride and acidulated phosphate fluoride, and range from annual absolute reductions of 0.14 (11%) to 1.11 DMFS (69%). Results with stannous fluoride vary from an annual reduction of 2.23 (69%) DMFS to an annual <u>increase</u> of 0.16 (8%) DMFS. Results with acidulated phosphate fluoride vary from an annual reduction of 1.62 (75%) DMFS to an annual <u>increase</u> of 0.02 (2%) DMFS.

(b) The best results are obtained using the daily application of solutions with the aid of fabricated mouthpieces, but the reduction is not proportional to the number of applications.

(c) The results from short-term studies are generally better than those from long-term studies.

26.2 Clinical trials of topical applications of fluoride solutions in communities with optimal levels of fluoride in the water supply

These results are summarized in Table 26.[69,79,80,81] These results suggest that additional substantial reductions in the increment of dental caries in a fluoridated area are only obtained from the use of a self-applied zirconium silicate paste 4 times at school during the study period of 1-1/2 years together with the use of a stannous fluoride dentifrice at home. This finding, however, is not consistent with the insignificant results obtained from the topical application of stannous fluoride solution in a fluoridated community.

26.3 Clinical trials of professionally administered prophylactic treatments with a fluoride paste and of topical applications of stannous fluoride in combination with a fluoride prophylactic agent

These results are summarized in Table 27.[66,75,82,83,84,85] The following conclusions may be drawn from these results:

(a) A prophylactic treatment with either a stannous fluoride or an acidulated phosphate fluoride paste does not provide a significant reduction in the incidence of caries.

(b) The combination of a stannous fluoride prophylactic treatment with the home use of a stannous fluoride dentifrice produces a reduction in the incidence of caries in both children and adults to the extent of between 1.18 and 1.36 DMFS per year.

(c) The combination of a stannous fluoride prophylactic treatment with a topical application of a stannous fluoride solution results in a reduction in the annual increment of caries, but the results are variable and range from 0.01 DMFS to 1.73 DMFS.

(d) The best results were obtained from a combination of a stannous fluoride, prophylactic treatment, a topical application of a stannous fluoride solution, and the home use of a stannous fluoride dentifrice.

27. THE MANPOWER REQUIRED AND THE TIME TAKEN TO IMPLEMENT THE PROCEDURE

Prophylactic treatments and topical applications of fluoride solutions can be carried out by dentists or auxiliary personnel. The construction of plastic mouthpieces involves the time of dentists and dental technicians.

The time taken is not always reported, and when it is usually estimated and not based on actual measurements. However, the time was measured by Szwejda.[66] Horowitz[86] stated: "Our records indicate that a thorough prophylaxis and topical application using the half-mouth technique requires approximately 30 minutes". Hoskova et al.,[87] cited by Konig, gives 1.5 hours as the time required for the Knutsen 4-application technique and 1-1/2 hours in 3 years for the Muhler annual application technique (i.e., 30 minutes for each prophylactic treatment and application).

28. EFFECT OF THE PROCEDURE ON THE NEED FOR DENTAL TREATMENT

Some of the results from the studies summarized in Table 28 were expressed as reductions in the increments of caries affecting pit and fissure, proximal, and buccal-lingual tooth surfaces. It should be possible to obtain a reasonable approximation to the number of fillings saved by allowing 1 filling for each pit and fissure surface, 1 filling for each buccal/lingual surface, and 1.5 fillings for each proximal surface as recommended by Backer Dirks.[18] However, since all the studies are not reported in this way, estimates in this report are based on 1 filling saved for each DMF surface. This procedure will, of course, result in an underestimate of the benefits.

29. COST-EFFECTIVENESS

The cost-effectiveness is a measure of the number of tooth surfaces protected from caries for each hour of time taken by dental personnel. These calculations are summarized in Table 28.[15,61,62,64,66,67,68,69,70,71,72,74,75,76,77,79,80,82,83,84,85]

Hedegard[88] has established that an average of 1.7 fillings per hour is the customary working rate of the School Dental Service at Gothenburg, Sweden. Urban[16] gives a similar estimate of 2 fillings per hour. If this is accepted as a reasonable target, and if it is assumed that a saving of 1 DMF surface is equivalent to a saving of 1 filling, it follows that to be effective from a practical point of view a preventive measure should result in the saving of at least 1.7 DMF surfaces per hour of professional time.

The results of 46 clinical trials are listed in Table 28. Only 19 (or 41%) achieved a cost-effectiveness value of 1.7 or more. Those that qualified were as follows:

(a) 2 trials made by Szwejda of sodium fluoride applications using the multiple-chair technique and the Muhler 30-second technique.

(b) 5 out of 10 trials of stannous fluoride using the Muhler technique, the Knutsen technique, and the Mercer & Muhler technique.

(c) 3 trials of acidulated phosphate fluoride (APF) made by Wellock et al., Bryan & Williams, and Szwejda using the Muhler method, APF gel in a rubber tray, and the Knutson multiple chair technique, respectively.

(d) 9 out of 14 trials of stannous fluoride prophylatic paste and combinations of stannous fluoride prophylactic paste and/or a stannous fluoride topical application and a stannous fluoride dentifrice qualified. In order of rank these were:

   (1) 3-agent technique, i.e., stannous fluoride prophylactic paste, stannous fluoride topical, and stannous fluoride dentifrice (Bixler & Muhler);

   (2) stannous fluoride prophylactic paste and stannous fluoride topical by the Knutson multiple chair technique (Szwejda);

   (3) stannous fluoride prophylactic paste and stannous fluoride topical (Bixler & Muhler);

   (4) stannous fluoride prophylactic paste and stannous fluoride topical (Scola & Ostrom);

   (5) stannous fluoride prophylactic paste and stannous fluoride dentifrice (Bixler & Muhler);

   (6) APF gel in a rubber tray (Bryan & Williams);

(7) stannous fluoride prophylactic paste and stannous fluoride topical (Scola & Ostrom);

(8) stannous fluoride prophylactic paste and stannous fluoride dentifrice (Scola & Ostrom);

(9) stannous fluoride prophylactic paste and stannous fluoride topical (Scola).

(e) None of the trials of topical fluoride in a fluoridation water area qualified.

The cost-effectiveness value of 1.7 must be regarded as a very conservative basis for estimating the practical value of a preventive measure since Hedegard[88] has also shown that a 1-surface restoration takes 15-24 minutes and a 2-surface restoration takes 18-31 minutes. Hoskova et al.[87] allow 15 minutes for a filling. Thus a more realistic cost-effectiveness value would be between 2 and 4, say 3.0. If this value is accepted as appropriate then only 9 of the 46 studies would qualify (investigators' names shown in parentheses).

		cost-effectiveness
1.	Stannous fluoride topical by the method of Muhler (Mercer & Muhler)	8.94
2.	Stannous fluoride topical by the method of Muhler (Howell et al.)	5.92
3.	Sodium fluoride topical by the Szwejda-Knutson multiple-chair method (Szwejda)	5.52
4.	3-agent method - stannous fluoride prophylactic paste, topical and dentifrice (Bixler & Muhler)	4.26
5.	APF topical by the method of Muhler (Wellock et al.)	4.22
6.	APF topical by the Szwejda-Knutson multiple-chair method (Szwejda)	3.64
7.	Stannous fluoride prophylactic paste and stannous fluoride topical by the Szwejda-Knutson multiple-chair method (Szwejda)	3.60
8.	Stannous fluoride prophylactic and stannous fluoride topical (Bixler & Muhler)	3.47
9.	Stannous fluoride prophylactic paste and stannous fluoride topical (Scola & Ostrom)	3.45

In their 3-year study, Hoskova et al.[87] measured the total time needed to make the applications, the total number of fillings avoided, and the time needed "for making of these fillings". From these data, the cost-effectiveness of topical applications of 2% sodium fluoride by the Knutson method = $\frac{0.6}{1.5} = \underline{0.4}$ and the cost-effectiveness of annual topical applications of 8% stannous fluoride by the Muhler method = $\frac{0.9}{1.5} = \underline{0.6}$.

The data can also be used in another way. The ratio of the time needed for the fillings saved to the time taken for the applications = $\frac{9 \text{ minutes}}{90 \text{ minutes}} = \underline{0.1}$.

Urban[16] evaluated the cost-effectiveness of the following techniques under comparable conditions; (i) Knutson method of applying 2% sodium fluoride 4 times a year at intervals of 3 years; (ii) Muhler's method of applying 8% stannous fluoride once a year; (iii) the Brudevold method of applying acidulated sodium fluoride once a year; (iv) the twice yearly application of an organic fluoride proprietary product (Elmex); (v) and the twice yearly application of a proprietary sodium fluoride lacquer (Duraphat). He determined the time required for the method used, the number of fillings that could be carried out in the same time, and the expected reduction in the number of fillings needed as a result of the preventive effect of the method. Calculations of the time saved to time taken for the applications for 3 000 children in 3 years gave the following results:

		Ratio of number of hours saved to hours spent on applications	cost-effectiveness
(a)	2% sodium fluoride (Knutson method)	300/1 000	0.30
(b)	8% stannous fluoride (Muhler method)	520/1 000	0.52
(c)	APF (Brudevold method)	250/2 000	0.12
(d)	Elmex	530/2 000	0.26
(e)	Duraphat	590/1 670	0.35

As in the study by Hoskova et al.[87] it was necessary in each case for a stomatologist to spend more time on making the applications than he would have spent on the fillings that would have occurreed without prevention. However, in many countries the applications can be legally made by dental hygienists or by personnel specially trained for the purpose.

It should also be pointed out that in making this cost-effectiveness analysis the prophylactic treatment is included in the time required to implement the procedure. This is a valid consideration when the measure is to be used by itself in a preventive programme, but if a prophylactic treatment is carried out routinely at the end of each "treatment series" then the only additional time required would be for the application of a fluoride solution. Under these conditions, the cost-effectiveness is much improved.

30. COST-BENEFIT ANALYSIS

30.1 Cost of implementation

The actual cost of a particular system of topical application of fluoride will depend on the following factors:

(a) The cost of the solutions and prophylactic pastes

For practical purposes, this can be ignored since the actual amounts used for a single person are very small.

(b) The cost of special materials

This would apply in the case of the Englander method which uses individually shaped mouthpieces. No data are available for the cost of mass-producing these appliances although Englander et al.[65] stated that 7 weeks were required for the manufacture of applicators used in a study involving 500 patients. They also stated that 23% of the applicators had to be remade during the study which lasted for 2 years.

In South Australia and Western Australia the average fee for a mouthguard is A$10.00. However, since the cost-effectiveness of this technique is so low it is not worth making a cost-benefit analysis.

(c) The value of professional time

This will obviously depend on whether the applications are made in public clinics or private practices, and by salaried dentists or dental auxiliaries.

As stated previously, Hedegard[88] stated that the cost of the school dental service in Gothenburg, Sweden, is 126 Swedish kronor an hour. Thus, in that service, the cost of implementation will vary from 189 Swedish kronor (US$25.50) for a series of 4 applications of 2% sodium fluoride by the Knutson method to 63 Swedish kronor (US$8.50) for a single application of 8% stannous fluoride by the Muhler method, and from 31 Swedish kronor (US$4.20) for a series of 4 applications of 2% sodium fluoride by the Szwejda-Knutson multiple-chair method to 50 Swedish kronor (US$6.75) for a series of 3 stannous fluoride prophylactic treatments and stannous fluoride topical applications by the multiple-chair method.

The cost of the procedure in private practice can sometimes be obtained from fee schedules. For example, in the USA[33] the average fee charged for a dental prophylactic treatment is US$9.74 and the average additional fee for one topical application of stannous fluoride is US$7.43, making a total of US$17.17 for a single prophylactic treatment and topical application. It is interesting to note that the Schedule of Fees operating in the British National Health Service makes no provision for topical applications of fluoride solutions. If topical applications were made by dental auxiliaries within the school dental service in England the cost of implementation could be estimated from the rate of remuneration for part-time staff[89] who are paid at the rate of £2.60 per 3-hour session, which is equivalent to a rate of US$2.34 per hour.

In the Netherlands, Pot[15] estimated the cost of topical applications as 15 guilders on the basis of each topical application of 4% stannous fluoride taking 15 minutes and the fee for 1 hour of dentist's time being 60 guilders.

In Yugoslavia, Jakovljevič[78] estimated the cost of a topical application of acidulated sodium fluoride at 10 dinars per child.

30.2 Savings in the cost of dental treatment

The following are the estimated savings in each of the countries for which data are presented in Tables 25 and 28. It is assumed that a saving of 1 DMF surface is equivalent to a saving of 1 restoration and that the costs per filling are US$8.00 per restoration in the USA, 50 Swedish kronor in Sweden,[90] 15 guilders in the Netherlands,[15] 23.50 dinars in Yugoslavia,[78] and £0.50 and £1.10 when done respectively by a dental auxiliary and a National Health dentist in the United Kingdom.

(a) USA

Savings in the cost of dental treatment are estimated for each of the four procedures that rated best and worst in terms of cost-effectiveness in studies conducted in the USA.

(i) Multiple-chair technique (Szwejda, 1971)[66]

Number of restorations saved in 3 years	=	1.38
Savings in cost of restorations done by a private practitioner at US$8 per restoration	=	US$11.04

(ii) Knutson technique (Cons et al., 1970)[70]

Number of restorations saved in 3 years	=	0.41
Savings in cost of restorations done by a private practitioner at US$8 per restoration	=	US$ 3.28

Stannous fluoride

(iii) Muhler technique (Mercer & Muhler, 1964)[62]

Number of restorations saved in 2 years	=	4.47
Savings in cost of restorations done by a private practitioner at US$8 per restoration	=	US$35.76

(iv) Muhler technique (Horowitz & Lucye, 1966)[75]

Number of additional restorations in 2 years	=	0.32
Increase in cost of restorations done by a private practitioner at US$8 per restoration	=	US$ 2.56

Acidulated phosphate fluoride

(v) Wellock et al., 1965[74]

Number of restorations saved in 2 years	=	2.11
Savings in cost of restorations done by a private practitioner at US$8 per restoration	=	US$16.88

(vi) Cons et al., 1970[70]

Number of additional restorations in 3 years	=	0.06
Increase in cost of restorations done by a private practitioner at US$8 per restoration	=	US$0.48

Three-agent stannous fluoride prophylactic treatment, topical, application, and dentifrice

(vii) Bixler & Muhler, 1966[82]

Number of restorations saved in 3 years	=	6.39
Savings in cost of restorations done by a private practitioner at US$8 per restoration	=	US$51.12

(viii) Horowitz & Lucye, 1966[75]

Number of restorations saved in 2 years	=	0.03
Savings in cost of restorations done by a private practitioner at US$8 per restoration	=	US$ 0.24

(b) Sweden

Sodium fluoride,

Knutson technique (Torell & Ericsson, 1965)[68]

Number of restorations saved in 2 years	=	1.98
Savings in cost of restoration at Sw. kr 50	=	Sw. kr 99.00

(c) Netherlands

Stannous fluoride

Muhler technique (Pot, 1972)[15]

Number of restorations[a] saved in 9 years	=	11.90
Number of extractions saved in 9 years	=	0.4
Savings in cost of restorations at 12 guilders per restoration	=	f.142.8
Savings in cost of extractions at 6 guilders per extraction	=	f. 2.4
Total savings	=	f.145.2

(d) Yugoslavia

Acidulated sodium fluoride (Jakovljevič, 1972)[78]

Number of restorations saved in 1 year	=	1.3
Savings in cost of restorations at 23.50 dinars per restoration	=	Din 30.55

(e) United Kingdom

Savings in the cost of dental treatment are estimated for each of the four procedures that rated best in terms of cost-effectiveness in studies conducted in the USA and when restorations are done by a dentist and a dental auxiliary.

(i) Sodium fluoride[66]

Number of restorations saved in 3 years	=	1.38
Savings in cost of restorations done by a dental auxiliary at £0.50 per restoration	=	£ 0.69
or done by a National Health dentist at £1.10 per restoration	=	£ 1.52

(ii) Stannous fluoride[62]

Number of restorations saved in 2 years	=	4.47
Savings in cost of restorations done by a dental auxiliary at £0.50 per restoration	=	£ 2.23
or done by a National Health dentist at £1.10 per restoration	=	£ 4.92

(iii) Acidulated phosphate fluoride[74]

Number of restorations saved in 2 years	=	2.11
Savings in cost of restorations done by a dental auxiliary at £0.50 per restoration	=	£ 1.05
or done by a National Health dentist at £1.10 per restoration	=	£ 2.32

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[a] Allowing 1.5 fillings for each proximal surface and 1 filling for each occlusal and cervical surface.

30.3 Cost-benefit ratios

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

Calculations based on data set out in sections 33.1 and 33.2 above give the results shown in Table 29.

From these results it will be seen that the most effective procedures, from a cost-benefit point of view, are the single topical applications of stannous fluoride and the serial applications of sodium fluoride using Szwejda's multiple-chair technique. The only other favourable cost-benefit ratio was obtained by Jakovljevič in Yugoslavia with acidulated phosphate fluoride.

There are many inconsistencies since unfavourable cost-benefit ratios were also obtained with each method. Furthermore, it is surprising that Bixler & Muhler[82] obtained a smaller cost-benefit result with the 3-agent method than Mercer & Muhler[62] obtained with a single application of stannous fluoride.

The high fees charged for the topical application procedures in the USA suggest the need to consider using auxiliary dental personnel for carrying out topical fluoride therapy.

31. PUBLIC ACCEPTABILITY

So far as is known, no objections have been raised to the use of topical applications of fluoride in either public dental services or private practices.

32. ADVANTAGES, DISADVANTAGES, AND SIDE-EFFECTS

These have been fairly summarized by Horowitz & Heifetz.[91] Sodium fluoride is stable when kept in plastic containers, the taste is not objectionable, it is not irritating to the soft tissues, and it does not stain the teeth or the margins of silicate fillings. The major disadvantage of the lengthy administration procedure can be overcome by using the multiple-chair method suggested by Szwejda.

Stannous fluoride appears to provide protection that is as good if not better, and fewer applications are required, but the solutions are unstable, have a disagreeable taste, and cause staining of teeth and the margins of fillings. The blanching of gingival tissues has been reported but this does not appear to be a matter of serious concern.

Acidulated phosphate fluoride solutions are stable, and do not cause gingival irritation or tooth staining, but the taste is unpleasant (although less so that stannous fluoride).

PART V - SELF-ADMINISTERED APPLICATIONS OF FLUORIDE SOLUTIONS

33. INTRODUCTION

Because of the relatively high cost of topical applications of fluoride solutions by professional personnel and the doubts about their cost-benefits, there is a growing volume of research on self-administration techniques. These include:

(a) toothbrushing with prophylactic paste;[81,85,92,93]
(b) toothbrushing with fluoride solutions, tablets, or gels;[13,14,94,95,96,97,98,99,100]
(c) mouth rinsing with a fluoride solution.[68,90,101,102,103,104,105,106,107]

Only the data relating to supervised toothbrushing with a fluoride solution and supervised mouth-rinsing in school are analysed in this report.

33.1 Toothbrushing with fluoride solutions

There have been considerable variations in the fluoride solutions used and the frequency of their use. In a 2-year study involving 5 000 schoolchildren in Sweden[96] a 1% solution of sodium fluoride was used 9 times over 2 years. In Canada,[94] an acidulated phosphate fluoride solution was used 4 or 5 times a year for 2 years. In the USA,[93] 206 children in school grades 7-8 brushed their teeth with a prophylactic paste and immediately afterwards brushed with flavoured acidulated phosphate fluoride gel containing 1.23% fluoride at a pH of 3.0. In Switzerland[13,14,98,99] children brushed their teeth with an amine fluoride or rinsing tablet. At Trondheim, Norway,[98] children in grades 1 and 2 rinsed their mouth with a 0.2% sodium fluoride solution every second week while children in grades 3-6 brushed their teeth with a 0.5% sodium fluoride solution every second month.

33.2 Mouth-rinsing with a fluoride solution

Sodium fluoride is the most commonly used solution for a mouth rinsing programme. Concentrations range from 0.05%[68] for daily use to 0.2% or 0.5% for weekly or fortnightly use. Potassium fluoride with manganese chloride[102] acidulated phosphate fluoride,[105] and stannous fluoride[104] have also been used but appear to have no significant advantages over sodium fluoride. The well controlled study of Torrell & Ericsson[68] suggest that the beneficial effect is improved with increasing frequency of rinsing.

In Gothenburg, Sweden, supervised mouth-rinsing with 0.12% sodium fluoride was introduced in 1960 as an integral part of the school dental service.[90] The programme started in 1960 with the two youngest age groups mouth-rinsing once a month. This was extended to a new age group in each new school year. From 1962 onwards the frequency of rinsing was increased from once a month to once a fortnight. By 1966, all 40 000 children in the elementary schools were involved in the rinsing programme. A similar pilot programme was commenced in Eire in 1968.[107]

The procedure followed in Gothenburg[90] is briefly as follows: the mouth-washing in schools is supervised by dental nurses; each nurse is in charge of about 5 000 children. The children rinse their mouth vigorously with 10 ml of 0.2% sodium fluoride for 2 minutes. They are instructed not to eat or drink for 30 minutes afterwards, and the rinsing is repeated every fortnight.

34. EFFECT ON THE PREVALENCE AND SEVERITY OF DENTAL CARIES

34.1 Toothbrushing with fluoride solutions

Results from Canada,[94] Sweden,[96] USA,[95] Switzerland,[13,14,98,99] and Norway[100] are set out in Table 30. Percentage reductions range from 14-40 DMFT and 10-50 DMFS. It is not possible to determine the absolute reductions in DMFS or DMFT from the Swedish data. The Norwegian data supplied by Bjørnsson[100] are expressed as the mean number of filled surfaces per child per year in each of the school grades 1-6. Since the number of children at each school is given, it is possible to calculate weighted averages. At Trondheim 10 schools had an active fluoride programme and 13 schools had either no fluoride programme or an intermittent one. The 5 259 children in the fluoride group had 17 535 tooth surfaces filled in 1970/71 (mean of 3.3 per child) compared with 34 028 tooth surfaces filled for 6 179 children (5.5 per child) in the non-fluoride group.

34.2 Mouth-rinsing with a fluoride solution

From the data in Table 31 it is possible to draw the following conclusions:

(a) Provided school authorities are willing to cooperate, mouth-rinsing with fluoride solutions is a feasible and useful procedure.

(b) No data are available on the effect of mouth-rinsing on caries in the decidous dentition.

(c) Children aged 6-8 years do not appear to derive any benefits so far as the permanent teeth are concerned.

(d) Substantial benefits can be obtained by children aged 10 years and over, and the extent of the benefit appears to be related more to the frequency of rinsing than to the strength of the solution. Daily rinsing with 0.05% sodium fluoride by 10-year-olds gave a reduction of 4.92 DMFS (49%) in 2 years; weekly rinsing with 0.2% sodium fluoride by 10-year-olds gave a reduction of 1.27 DMFS (43%) in 2 years; fornightly rinsing with 0.2% sodium fluoride by 10-year-olds gave a reduction of 2.15 DMFS (21%) in 2 years; and fortnightly rinsing with 0.5% sodium fluoride by 10-year-olds gave a reduction of 4.36 DMFS (22%) in 3 years.

(e) The beneficial effects of mouth-rinsing are gradually lost after mouth-rinsing is discontinued.[103]

(f) A combination of manganous chloride and potassium fluoride appears to be more effective than either sodium fluoride alone or a combination of manganous chloride and sodium fluoride. However, further confirmatory work is required before the evidence can be accepted as conclusive.

35. THE MANPOWER REQUIRED AND THE TIME TAKEN TO IMPLEMENT THE PROCEDURE

All of the studies reported here were conducted in schools under the supervision of either teachers[94,104,105] or dental auxiliaries.[68,96,98,99,100,102,103]

The toothbrushing regimen in the USA[95] was supervised by the mothers of the schoolchildren taking part in the programme.

In the programme in Oslo, Norway[100] the supervision of toothbrushing with a 0.5% sodium fluoride solution by children in grades 1-6 and the topical application of 2% sodium fluoride in the high-risk group in grades 3-6 for a total of 31 271 children in the fluoride programme required about 20 000 hours of dental hygienists' time.

In the Gothenburg mouth-rinsing programme[90] each dental nurse is in charge of about 5 000 children.

36. EFFECT OF THE PROCEDURE ON THE NEED FOR DENTAL TREATMENT

36.1 Toothbrushing with fluoride solutions

Since the results from the clinical trials are expressed as savings in DMFS (Table 30), and assuming for the Canadian,[94] USA,[95] and Swiss[13,14,98,99] results that each new DMF surface requires 1 restoration, the number of restorations saved varies from 0.27 to 1.84 per child. In the Norwegian studies[100] the actual savings in the number of filled surfaces per child in school grades 1-6 ranged from 0.74 in Oslo to 2.2 in Trondheim.

36.2 Mouth-rinsing with a fluoride solution

Since the results from the clinical trials of mouth-rinsing are expressed as savings in DMFS, it is possible to get a reasonable estimate of the savings in restorative treatment. However, it is necessary to repeat, as shown in Annex 2, that these estimates are very rough approximations. Assuming that each new DMF surface requires 1 restoration, the number of restorations saved in 10-year-old children in the USA would vary from 1.27 in 2 years for children rinsing once a week[105] to a maximum of 4.92 restorations in 2 years for children rinsing each day,[62] and 4.36 restorations for children rinsing once a fortnight for 3 years.[103]

More direct evidence concerning the savings in the cost of dental care are available in a report by Torell.[106] After several pilot studies a regimen of supervised mouthwashing with 0.2% sodium fluoride solution was introduced in 1960 as an integral part of the school dental service in Gothenburg, Sweden. All children in the 8 age groups in the elementary schools were given the mouthwashes under the supervision of dental nurses. This treatment was extended to a new age group each school year. In 1960 when no age groups had mouthwashes 12 546 children received dental treatment. Treatment time was 26 793 hours (equivalent to 46.8 children treated per 100 hours). During 1960-61 the number of fillings done averaged 4.7 per child per year. In 1963 when the 2nd, 3rd, 4th, and 5th age groups were receiving fluoride mouthwashes, 17 140 children were treated in 24 187 hours (equivalent to 71.0 children per 100 hours). During 1963-64 the number of fillings done averaged 2.9 per child. Thus, there was an average saving of 1.8 fillings per child in that year. If the savings in 1961-62 and 1962-63 were proportionate to the number of age groups included in the mouthwashing programme (2 in 1961 and 3 in 1962) the estimated savings in the number of fillings per child in those years would be 0.9 and 1.3, respectively, making a total saving in 3 years of 4.0 fillings per child, which is not very different from the savings of 4.36 DMFS in 3 years found by Koch.[103]

37. COST-EFFECTIVENESS

From the data supplied by Bjørnsson[100] for the Oslo toothbrushing programme it is possible to calculate the cost-effectiveness of the programme in 1970/71 as follows:

Number of participants in the fluoride programme = 31 271

Reduction in the number of fill surfaces resulting from the fluoride programme = 22 882

Number of hours devoted to the programme by dental hygienists = 20 000

$$\text{Cost-effectiveness ratio} = \frac{\text{Number of surfaces saved}}{\text{Number of hours of clinical time for implementation}} = \frac{22\ 882}{20\ 000} = \underline{1.1}$$

An analysis of the mouth-rinsing data of Torell[106] described in paragraph 38.2 gives the following results:

Number of participants in the fluoride programme 1962/63	=	17 140
Savings in fillings in 1962/63 at 2.9/child	=	49 706
Number of hours devoted to the programme	=	24 187

$$\text{Cost-effectiveness ratio} = \frac{\text{Number of fillings saved}}{\text{Number of hours of clinical time for implementation}} = \frac{49\ 706}{24\ 187} = \underline{1:2.1}$$

38. COST BENEFIT ANALYSIS

38.1 Toothbrushing with fluoride solutions

38.1.1 Norway (Oslo)[102]

The cost of the brushing programme carried out 4 times a year in school grades 1-6 plus topical applications of 2% sodium fluoride for 15-20% of the 3rd grade was as follows:

Number of children in the fluoride programme	=	31 271
Total number of saved tooth surfaces 1970/71	=	22 882
Total expenses on salaries of dental hygienists	=	NKr330 000
Cost of implementation	=	NKr330 000
Gross expenses per filled surface	=	NKr 56.00
Total savings for 22 882 saved surfaces	=	NKr 1 281.392

$$\text{Cost-benefit ratio} = \frac{\text{Cost of implementation}}{\text{Savings in cost of dental treatment}} = \frac{330\ 000}{1\ 281.392} = \underline{1:3.9}$$

38.1.2 Switzerland[13]

Marthaler[13] suggests that the cost per child ranges from Sw.F 2 to Sw.F 6 per child per year. Thus in 8 years the cost would vary from Sw.F 16 to Sw.F 48 per child.

In 14-year-olds after 8 years of brushing with a fluoride solution the saving in DMFS per child	=	Sw.fr. 14.8
Thus savings in costs at Sw.F 15 per filled surface	=	Sw.F 222

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

$= \frac{16}{222}$ to $\frac{48}{222}$

= 1:13.9 to 1:4.6

38.2 Mouth-rinsing with a fluoride solution

38.2.1 USA

According to Horowitz et al.[105] the cost of supplies consisting of paper cups, paper napkins, and fluoride solutions is about US$0.31 per child per year or US$0.62 in 2 years. Since the programme is administered in schools by schoolteachers no additional charges are included for salaries.

The savings in DMFS per child in 2 years	= 1.27
Savings in cost of fillings at US$8 per saved surface	= US$10.16

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

$= \frac{0.62}{10.16}$

= 1:16.4

38.2.2 Sweden

The costs of the Gothenburg programme have been detailed by Torell[90] as follows:

Cost of implementation (Swedish kronor)

1 dentist at 10 hours/week	=	14 600
1 head dental nurse	=	33 600
10 dental nurses	=	363 600
Paper cups and fluoride tablets	=	14 600
Travelling costs	=	6 600
		Sw. kr 433 000

Savings in costs of fillings

Decrease in number of fillings per child per year	=	2.3
Number of children	=	40 000
Total decrease in fillings	=	92 000
Cost per filling	=	Sw. kr 50
Total savings	=	Sw. kr 4 600 000

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

$= \frac{433\ 000}{4\ 600\ 000}$

= 1:10.6

39. PUBLIC ACCEPTABILITY

Provided school authorities are willing to cooperate, all the evidence supports mouth-rinsing as a simple and feasible procedure. The fact that it has been successfully incorporated into the school system at Gothenburg and that such a large number of children take part indicates that its acceptability is high.

40. ADVANTAGES, DISADVANTAGES, AND SIDE-EFFECTS

Horowitz, Creighton & McClendon[105] claim the following advantages for mouth-rinsing very little time is involved, the technique of application is easy to learn, few treatment materials are required, non-dental personnel with minimal training can easily supervise the procedure, and frequent treatments can be administered easily with minimal interruption of a school's academic programme.

No side-effects have been reported, but the taste of the solution is objectionable to some children and the possibility of overdosages should not be overlooked. Swerdloff & Shannon[104] improved the taste of the solution with a grape flavouring. Care should be taken to ensure that solutions are kept out of the reach of children and mouth-rinsing by children should be supervised by responsible adults. If 10 ml of 0.5% sodium fluoride, the rinsing dose recommended by Koch,[103] were swallowed the fluorine intake would be 50 mg of sodium fluoride or 22.6 mg of fluorine. This would be equivalent to drinking at one sitting 22.6 litres of water containing 1 ppm of fluoride.

CONCLUSIONS

No attempt has been made to compare and contrast the cost-benefits of fluoridation with other methods of using fluoride for the prevention of caries, and I hope readers of this report will not attempt to use the data for that purpose. There are several reasons for this. With one exception, fluoridation trials have been assessed by cross-sectional (prevalence) studies whereas virtually all clinical trials of other methods of using fluoride have been longitudinal (incidence) studies. This alone suggests that no valid comparisons can be made. But there are other and more cogent reasons.

In the first place, whereas fluoridation studies have given consistent and uniformly good results, the clinical trials of other methods, especially topical applications, are so inconsistent and conflicting that they demand an urgent and impartial inquiry. It would appear that there are serious deficiencies in the currently accepted design of clinical trials of preventive agents. There are also other and less agreeable possibilities.

In the final analysis, the most important effect of a preventive measure is a reduction in the need for, and cost of, dental treatment. This cannot be determined with any acceptable degree of reliability from def and DMF data. In most cases, the investigators responsible for the clinical trial and those responsible for the treatment of the subjects concerned are different people who use different criteria and different methods for the detection of clinical caries. This is an important matter in the case of fluoridation, even though the extent of the reduction in caries is so obvious that it is detectable by very coarse methods of diagnosis. But it is a matter of critical importance when the benefits can only be detected by using the most careful and standardized diagnostic and statistical techniques.

The second reason is that there is no consistent relationship between cross-sectional def and DMF data, increments of new cavities, and the number of restorations required. This is so because the number of restorations varies not only with the number of new lesions, but also with the types of cavity, the type of treatment available and provided. The prevalence of secondary caries, and on the frequency with which restorations are replaced.

Despite the obvious flaws in this report, it at least reveals that cost-effectiveness and cost-benefit analyses are important. What is needed now is to define an appropriate methodology so that such assessments can be made logically, accurately, and reliably. This type of analysis would also be valuable as an aid in determining whether or not an expensive clinical trial should be undertaken. It is certain that a great deal of time and effort has been wasted on the unnecessary replication of clinical trials of procedures which an initial cost-benefit analysis would have revealed to be worthless. It is my hope that further cost-effectiveness and cost-benefit analyses of caries prevention will be made and appropriate methodologies developed.

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Annex 1

TABLE 1. REDUCTION IN DMF TEETH AFTER A LIFETIME'S EXPOSURE TO FLUORIDATED WATER

Locality		No. of years of water fluoridation	Absolute reductions in DMF teeth									
			Age (years)									
			6	7	8	9	10	11	12	13	14	15
Hastings	(NZ)	10	1.18	2.01	2.49	2.37	3.02	-	-	-	-	-
Grand Rapids	(USA)	15	0.59	1.20	1.68	1.93	2.58	3.43	4.60	6.15	5.57	6.26
Newburgh	(USA)	10	-	0.30	0.70	1.60	1.80	-	-	-	-	-
Watford	(United Kingdom)	11	-	-	1.30	1.60	1.60	1.60	2.10	2.20	2.60	-
Holyhead	(United Kingdom)	11	-	-	0.90	1.30	1.30	0.80	-	-	-	-
Tiel	(Netherlands)	18	-	1.20	-	2.30	-	3.50	-	6.10	-	7.10
Tabor	(Czechoslovakia)	13	-	-	-	-	1.35	1.93	2.51	3.14	-	-
			Percentage reductions in DMF teeth									
Hastings	(NZ)	10	83.7	73.1	66.8	53.3	55.1	-	-	-	-	-
Grand Rapids	(USA)	15	75.6	63.5	56.9	49.5	52.4	53.3	59.0	63.2	50.9	50.2
Newburgh	(USA)	10	-	30.0	36.8	51.6	45.0	-	-	-	-	-
Watford	(United Kingdom)	11	-	-	54.2	51.6	44.4	34.8	-	-	-	-
Holyhead	(United Kingdom)	11	-	-	45.0	48.1	37.1	22.2	-	-	-	-
Tiel	(Netherlands)	18	-	56.0	-	57.8	-	52.5	-	56.8	-	51.5
Tabor	(Czechoslovakia)	13	-	-	-	-	57.7	49.3	60.2	51.2	-	-

TABLE 2. REDUCTIONS IN DMF TEETH IN CHILDREN BORN BEFORE WATER FLUORIDATION BEGAN AT HASTINGS (NZ) IN 1954

(Results after 10 years' experience of fluoridation)

Age when fluoridation began (years)	Age at time of examination (years)										
	6	7	8	9	10	11	12	13	14	15	16
1	0.86	1.54	1.72	1.82	3.12	3.72					
2	0.72	1.48	1.45	1.48	2.32	3.56	4.31				
3	0.59	1.27	1.18	1.21	1.41	2.85	4.08	4.61			
4	0.39	1.06	0.92	0.95	1.33	2.14	3.68	4.95	5.51		
5	0.19	0.70	0.66	0.46	1.16	1.72	3.29	4.30	5.50	7.04	
6		0.35	0.44	-0.03	0.57	1.29	2.32	3.65	4.72	5.58	5.03
7			0.22	-0.02	-0.02	0.72	1.35	2.92	3.93	4.98	3.28
8				-0.01	-0.01	0.15	0.97	2.19	1.88	4.38	3.01
9						0.10	0.60	1.32	1.73	3.47	2.74
10						0.05	0.40	0.45	-0.01	2.56	1.57
11							0.20	0.30	0.15	1.61	0.40
12								0.15	0.10	0.66	0.09
13									0.05	0.44	-0.18
14										0.22	-0.15
15											-0.08

TABLE 3. REDUCTIONS IN DMF TEETH IN CHILDREN BORN BEFORE WATER FLUORIDATION BEGAN AT TIEL (NETHERLANDS) IN 1953 AND AT BASEL (SWITZERLAND) IN 1961

Age when fluoridation began (years)	Tiel (Netherlands) Age at time of examination (years)				
	9	11	13	15	17
4	0.6	0.7	3.4	4.6	4.5
8	-	-	-	1.9	-

Age when fluoridation began (years)	Basel (Switzerland) Age at time of examination (years)								
	7	8	9	10	11	12	13	14	15
2	1.5								
3		1.6							
4			1.3						
5				1.3					
6					1.6				
7						2.4			
8							2.6		
9								3.0	
10									1.8

TABLE 4. REDUCTIONS IN def TEETH AFTER A LIFETIME'S EXPOSURE TO FLUORIDATED WATER

Locality		No. of years of fluoridation	Absolute reductions in deft							
			Age (years)							
			3	4	5	6	7	8	9	10
Hastings	(NZ)	10	-	-	4.34	4.54	3.04	-	-	-
Grand Rapids	(USA)	10	-	2.07	2.87	3.48	3.03	2.47	1.59	0.49
Watford	(United Kingdom)	8	2.10	2.30	3.80	-	-	-	-	-
Watford	(United Kingdom)	11	-	-	-	3.20	3.70	-	-	-
Holyhead	(United Kingdom)	10	2.70	3.50	2.50	3.40	3.60	-	-	-
Tiel	(Netherlands)*	19	-	-	4.27	-	-	-	-	-
			Percentage reduction in deft							
Hastings	(NZ)	10	-	-	51.7	49.8	35.7	-	-	-
Grand Rapids	(USA)	10	-	49.4	53.4	54.1	48.2	42.7	34.6	17.2
Watford	(United Kingdom)	8	77.7	63.9	70.4	-	-	-	-	-
Watford	(United Kingdom)	11	-	-	-	56.8	57.8	-	-	-
Holyhead	(United Kingdom)	10	69.2	61.4	46.2	56.7	52.9	-	-	-
Tiel	(Netherlands)*	19	-	-	49.4	-	-	-	-	-

* Additional data to be supplied when results of examinations have been analysed.

TABLE 5. ABSOLUTE REDUCTIONS IN def TEETH IN CHILDREN BORN BEFORE WATER FLUORIDATION BEGAN AT GRAND RAPIDS, USA

Age when fluoridation began (years)	Age at time of examination (years)						
	4	5	6	7	8	9	10
1	1.00	1.34	1.84	0.57	1.66	0.93	0.46
2	0.76	1.48	1.65	1.46	0.87	0.73	0.23
3	-1.21	0.29	1.05	1.09	1.03	0.26	0.41
4		-0.78	0.70	0.45	0.90	0.18	0.48
5			-0.55	0.18	0.71	0.16	-0.02
6				-0.37	0.68	0.48	-0.22
7					-2.22	0.14	0.32
8							0.0
9							-

TABLE 6. REDUCTIONS IN TOTAL DMF SURFACES AFTER EXPOSURE TO FLUORIDATED WATER AT HASTINGS (NZ) AND TIEL (NETHERLANDS)

Age when fluoridation began (years)	Locality	Age at time of examination (years)									
		7	8	9	10	11	12	13	14	15	16
Unborn	Hastings	3.78	5.09	5.30	6.50	-	-	-	-	-	-
	Tiel	2.31	-	5.34	-	8.14	-	13.78	-	18.15	-
1	Hastings	-	-	-	-	8.48	-	-	-	-	-
2	Hastings	-	-	-	-	-	9.88	-	-	-	-
3	Hastings	-	-	-	-	-	-	12.14	-	-	-
4	Hastings	-	-	-	-	-	-	-	15.56	-	-
5	Hastings	-	-	-	-	-	-	-	-	21.93	-
6	Hastings	-	-	-	-	-	-	-	-	-	17.73

TABLE 7. REDUCTIONS IN DMF SPECIFIC SURFACES AFTER EXPOSURE TO FLUORIDATED WATER AT HASTINGS (NZ) AND TIEL (NETHERLANDS)

Age at examination	Absolute (and percentage) reductions in DMFS							
	Pit and fissure		Proximal		Buccal-lingual		Total	
	Hastings	Tiel	Hastings	Tiel	Hastings	Tiel	Hastings	Tiel
6	2.04		-		-		2.13	
7	3.40	1.72 (56%)	0.18	0.17 (79%)	0.05	0.43 (91%)	3.78	2.31 (61%)
8	4.11		0.78		-		5.09	
9	3.48	3.08 (55%)	1.28	0.99 (82%)	0.53	1.64 (88%)	5.30	5.34 (65%)
10	3.12		2.16		1.24		6.50	
11	3.12	3.34 (45%)	3.89	2.85 (78%)	0.97	1.95 (89%)	8.48	8.14 (62%)
12	4.83		3.72		1.33		9.88	
13	3.66	4.65 (44%)	5.74	6.24 (83%)	2.74	2.88 (84%)	12.14	13.78 (64%)
14	4.83		8.00		2.96		15.56	
15	6.30	4.88 (38%)	11.67	8.93 (77%)	3.99	4.33 (86%)	21.93	18.15 (61%)
16	4.65		9.49		3.61		17.73	

TABLE 8. THE EFFECT OF 10 YEARS' WATER FLUORIDATION ON DENTAL TREATMENT FOR HASTINGS, (NZ), CHILDREN AGED 2-1/2 to 13-1/2 YEARS

	Hastings Fluoridated	Gisborne Non-fluoridated	New Zealand (1965)
Number children enrolled	4 798	6 464	456 049
Total number fillings	12 650	33 032	2 324 017
Mean number fillings per child	2.64	5.11	5.10
Total number extractions	269	965	74 826
Mean number extractions per child	0.06	0.15	0.16

TABLE 9. SAVINGS IN DENTAL TREATMENT IN 5- AND 6-YEAR OLD CHILDREN WITH LIFELONG EXPOSURE TO FLUORIDATION AT NEWBURGH, USA

Type of treatment	Initial age (years)	Period of initial care mean per child	% saving	Period of incremental care									
				2nd* $\bar{x}$	Year (%)	3rd $\bar{x}$	Year (%)	4th $\bar{x}$	Year (%)	5th $\bar{x}$	Year (%)	6th $\bar{x}$	Year (%)
1 surface filling	5	0.18	20	0.16	40	0.30	60	0.38	70	0.29	55	0.49	79
	6	0.06	7	0.27	44	0.40	77	0.48	75	0.28	65	-0.03	-
2 surface filling	5	1.26	60	0.46	47	0.42	39	0.54	61	0.12	15	0.28	47
	6	1.49	62	0.39	42	0.63	61	0.52	55	0.35	60	0.19	44
3+ surface filling	5	0.35	83	0.03	60	0.07	64	0.05	56	0.10	100	0.10	100
	6	0.47	81	0.06	67	0.06	55	0.03	50	-0.03	-	0	-
Total fillings	5	1.79	52	0.66	46	0.79	47	0.95	63	0.51	35	0.89	68
	6	2.01	52	0.71	44	1.09	65	1.03	62	0.59	59	0.16	21
Extractions	5	0.19	56	0.13	68	0.11	69	0.02	18	0.11	58	-0.08	-
	6	0.28	46	0.07	37	0.05	33	0.09	90	0.11	55	0.04	57

* $\bar{x}$ = mean per child.

TABLE 10. DENTAL TREATMENT TO PERMANENT AND PRIMARY TEETH OF WHITE CHILDREN AT GAINESVILLE (FLUORIDATED WATER) AND WOONSOCKET (UNFLUORIDATED WATER)

Age (years)	Locality	Treatment series	Number of permanent and deciduous teeth per child		Savings per child			
					Fillings		Extractions	
			Filled	Extracted	No.	%	No.	%
5-13	Gainesville	1st	2.9	0.2	1.77	38	0.7	78
5-16	Woonsocket	1st	4.67	0.9				
5-13	Gainesville	2nd	2.0	0.2	3.94	66	0.61	75
5-16	Woonsocket	2nd	5.94	0.81				
5-13	Gainesville	4th	1.7	0.1	1.2	41	0.1	50
	Gainesville	1st	2.9	0.2				

TABLE 11. SAVINGS IN DENTAL TREATMENT TO PERMANENT TEETH AFTER LIFETIME'S EXPOSURE TO WATER FLUORIDATION AT TIEL COMPARED WITH LIFETIME RESIDENTS OF CULEMBORG (UNFLUORIDATED WATER)

Age (years)	Locality	Number of fillings required per child	Savings per child at Tiel		
			Fillings No.	%	Extractions No.
7	Culemborg	3.73			
	Tiel	1.54	2.19	58	0.06
9	Culemborg	8.81			
	Tiel	3.10	5.71	64	0.15
11	Culemborg	13.70			
	Tiel	5.57	8.13	59	0.45
13	Culemborg	23.11			
	Tiel	8.39	14.72	63	0.66
15	Culemborg	30.62			
	Tiel	12.20	18.42	60	1.35

TABLE 12. SAVINGS IN DENTAL TREATMENT TO PERMANENT TEETH IN LIFETIME RESIDENTS AGED 11 - 14 YEARS OF TABOR, CZECHOSLOVAKIA, AFTER 13 YEARS OF FLUORIDATION

	Tabor before water fluoridation 1957/58	Tabor 1 - 5 years after the beginning of fluoridation 1959/63	Tabor 6 - 13 years after the beginning of fluoridation 1964/71
Number of children enrolled	302	855	1 618
Total number fillings	895	1 423	1 870
Mean number fillings per child per year	2.96	1.66	1.16
Average savings per child per year	-	1.30	1.80
Percentage savings in number of fillings required	-	44	61

TABLE 13. COMPARATIVE DATA FOR THREE SCHOOL DENTAL CARE PROGRAMMES AT GAINESVILLE, RICHMOND, AND WOONSOCKET, USA
(Fluoridation in operation at Gainesville for 4-1/2 years prior to the first treatment Series)

Locality	Treatment Series			
	1st	2nd	3rd	4th
Percentage of new patients among total patients:				
Gainesville	100	38	39	26
Richmond	100	35	22	17
Woonsocket	100	48	23	19
Dentist man-hours per child				
Gainesville	0.8	0.8	0.5	0.5
Richmond	2.9	1.9	1.2	0.8
Woonsocket	3.3	2.8	1.7	1.4
Children for whom treatment was completed per dentist-year				
Gainesville	1 270	1 303	2 031	1 867
Richmond	530	743	1 009	1 343
Woonsocket	384	470	714	848

TABLE 14. SAVINGS IN COSTS OF DENTAL TREATMENT IN 5- AND 6-YEAR-OLD CHILDREN WITH A LIFETIME'S EXPOSURE TO WATER FLUORIDATION AT NEWBURGH, USA (IN THE YEAR OF INITIAL CARE)

Age (years)	Type of treatment	Savings per child	Fee schedule as basis for estimate of cost savings		
			New York 1966	New York 1970	USA 1970
5	1 Surface filling	0.18	0.90	1.33	1.41
	2 Surface filling	1.26	12.60	16.68	15.76
	3+ Surface filling	0.35	5.25	6.66	6.06
	Extractions	0.19	1.14	1.96	1.73
	Total per child		19.99	26.63	24.96
6	1 Surface filling	0.06	0.30	0.44	0.47
	2 Surface filling	1.49	14.90	19.73	18.64
	3+ Surface filling	0.47	7.05	8.94	8.14
	Extractions	0.28	1.68	2.89	2.55
	Total per child		23.93	32.00	29.80

TABLE 15. SAVINGS IN COSTS OF DENTAL TREATMENT IN 5- AND 6-YEAR-OLD CHILDREN AT NEWBURGH (INCREMENTAL CARE YEARS)
(based on 1966 New York fee schedules)

Age (years)	Type of treatment	Period of incremental care									
		2nd year saving US$		3rd year saving US$		4th year saving US$		5th year saving US$		6th year saving US$	
5	1 Surface filling	0.16	0.80	0.30	1.50	0.38	1.90	0.29	1.45	0.49	2.45
	2 Surface filling	0.46	4.60	0.42	4.20	0.54	5.40	0.12	1.20	0.28	2.80
	3+ Surface filling	0.03	0.45	0.07	1.05	0.05	0.75	0.10	1.50	0.10	1.50
	Extraction	0.13	0.78	0.11	0.66	0.02	0.12	0.11	0.66	-0.08	-0.48
	Total savings per child		7.75		7.41		8.17		4.81		6.27
6	1 Surface filling	0.27	1.35	0.40	2.00	0.48	1.40	0.28	1.40	-0.03	-0.15
	2 Surface filling	0.39	3.90	0.63	6.30	0.52	5.20	0.35	3.50	0.19	1.90
	3+ Surface filling	0.06	0.90	0.06	0.80	0.03	0.45	0.03	0.45	0.00	-
	Extraction	0.07	0.42	0.05	0.30	0.09	0.54	0.11	0.66	0.04	0.24
	Total savings per child		6.57		9.40		7.59		6.01		1.99

TABLE 16. CHAIR-TIME FOR INITIAL AND INCREMENTAL CARE FOR 5- AND 6-YEAR-OLDS AT NEWBURGH, 1962-68

Age (years)	Year	Mean time (minutes) per child		Differences	Annual savings for 450 5-year-olds and 450 6-year-olds
		Newburgh	Kingston		
5	1962	41.5	71.5	30.0	13 500
6	1962	62.3	93.6	31.3	14 085
6	1963	21.8	32.3	10.5	4 725
7	1963	26.3	36.4	10.1	4 545
7	1964	22.7	38.8	16.1	7 245
8	1964	17.5	34.6	17.1	7 695
8	1965	19.1	36.2	17.1	7 695
9	1965	18.9	40.1	21.2	9 540
9	1966	27.0	37.4	10.4	4 680
10	1966	17.0	20.2	13.2	5 940
10	1967	18.9	38.8	19.9	8 955
11	1967	24.2	27.6	3.4	1 530

TABLE 17. SAVINGS IN COSTS OF DENTAL TREATMENT IN CHILDREN AT WATFORD AFTER 11 YEARS OF FLUORIDATION (COMPARED WITH CONTROL CITY OF SUTTON) (36)

Age (years)	Savings in number of dmf or DMF teeth per child	Number of children examined	Savings in cost of fillings per child	Total savings in cost of fillings
3	0.6	133	£1.62	£215.46
4	0.5	131	1.34	175.54
5	1.2	111	3.24	359.64
6	1.6	130	4.32	561.60
7	1.6	172	4.32	743.04
8	0.8	95	2.16	205.20
9	0.9	135	2.44	329.40
10	1.1	115	2.96	340.40
11	0.9	200	2.44	488.00
12	1.5	134	4.06	544.04
13	1.2	132	3.24	427.68
14	0.9	90	2.44	219.60
		1 578		£4 609.60

Assumption: Saving of 1 dmf or DMF tooth = saving of two 2-surface amalgam fillings, which at current fees = £2.70.

TABLE 18. SAVINGS IN COSTS OF DENTAL TREATMENT IN CHILDREN WITH A LIFETIME'S EXPOSURE TO FLUORIDATION AT TIEL (NETHERLANDS)

Age (years)	Estimates based on def and DMF teeth			Estimates based on DF specific surfaces***		
	Savings per child		Savings in total costs (Guilders)	Savings per child		Savings in total costs (Guilders)
	Fillings	Extractions		Fillings	Extractions	
5	8.54*		102.48			
7	2.90**	0.05	35.10	2.19	0.06	26.64
9	5.88	0.07	70.98	5.71	0.15	69.42
11	7.95	0.31	97.26	8.13	0.45	100.26
13	13.37	0.57	163.86	14.72	0.66	180.60
15	14.92	1.12	185.76	18.42	1.35	229.14

* Savings in deciduous teeth only 1 deft less = 2 fillings saved.

** Data for children born in 1954, 1 DFT less = 2.5 fillings saved; 1 MT less = 1 extraction saved (from Pot (15), table 1).

*** From Pot (15), tables 3 and 5, amended.

TABLE 19. COST-BENEFIT RATIOS FOR CHILDREN IN THE NETHERLANDS BORN IN 1954 ACCORDING TO ABSOLUTE REDUCTION IN DF SPECIFIC SURFACES AND DMF TEETH

Age (years)	Basis of estimate	Savings in total costs (guilders)	Cost-benefit ratios based on <u>per capita</u> costs of 50 cents and 60 cents per year		
			Pot's estimate	50 cents	60 cents
5	deft	102.48	-	1 : 41.0	1 : 34.2
7	DF-SS	26.64	1 : 6.2	1 : 7.6	1 : 6.3
	DMFT	35.10	1 : 8.8	1 : 10.0	1 : 8.4
9	DF-SS	69.42	1 : 11.8	1 : 15.4	1 : 12.9
	DMFT	70.98	1 : 14.2	1 : 15.8	1 : 13.1
11	DF-SS	100.26	1 : 15.8	1 : 18.2	1 : 15.2
	DMFT	97.26	1 : 16.2	1 : 17.7	1 : 14.7
13	DF-SS	180.60	1 : 24.0	1 : 27.8	1 : 23.2
	DMFT	163.86	1 : 23.3	1 : 25.2	1 : 21.0
15	DF-SS	229.14	1 : 31.1	1 : 30.6	1 : 25.5
	DMFT	185.76	1 : 23.2	1 : 24.8	1 : 20.6

TABLE 20. SUMMARY OF RESULTS OF COST-BENEFIT ANALYSES

Locality	Age groups (years)	No. of years since fluoridation began	Length of time on which calculations are based	Cost-benefit ratio	
				Excluding salary savings	Including salary savings
Hastings (NZ)	2 1/2 - 15	10	1	1 : 4.4	1 : 6.6
Newburgh (USA)	5 - 6	15	5	1 : 4.1	1 : 6.4
Gainesville (USA)	5 - 13	5-1/2	5-1/2	1 : 12.7	1 : 37.4
Watford (United Kingdom)	3 - 14	11	11	1 : 2.5	-
Tiel (Netherlands)	5	16	5	1 : 34.2 - 1 : 41.0	-
	7	16	7	1 : 6.3 - 1 : 10.0	-
	9	16	9	1 : 12.9 - 1 : 15.8	-
	11	16	11	1 : 14.7 - 1 : 18.2	-
	13	16	13	1 : 21.0 - 1 : 27.8	-
	15	16	15	1 : 20.6 - 1 : 30.6	-
Tabor (Czechoslovakia)	11 - 14	13	13	1 : 26.8	-
Basel (Switzerland)	6 - 14	5	5	1 : 4.4	-

TABLE 21. ABSOLUTE AND PERCENTAGE REDUCTIONS IN DMFT AFTER 8 YEARS OF SCHOOL FLUORIDATION (USA)

Age (years)	Pike County, Ky., USA		Elk Lake, Pa., USA	
	Reduction in DMFT per person	Percentage reduction	Reduction in DMFT per person	Percentage reduction
6	0.57	56.4	0.58	67.4
7	1.05	48.4	1.19	54.8
8	1.05	35.8	1.12	41.2
9	1.74	44.6	1.14	30.6
10	1.92	37.4	0.92	20.5
11	2.49	37.2	2.51	39.5
12	3.02	36.9	3.60	40.2
13	3.03	34.2	4.82	44.3
14	3.77	33.8	3.94	33.2
15	3.99	32.5	4.12	30.9
16	3.15	24.6	3.72	24.9
17	1.58	12.6	2.35	16.6
6 - 17	2.35	32.8	2.62	33.9

TABLE 22. REDUCTIONS IN DENTAL CARIES RESULTING FROM THE USE OF FLUORIDE TABLETS

I. EFFECTS ON DECIDUOUS DENTITION

Author	Initial age (years)	Length of study (years)	Type of vehicle	Absolute reductions per person		Time of initial administration
				deft	defs	
Hennon et al.[52,53]	0 - 2	5-1/2	0.5/1.0 mg F vitamin tablet	4.15	9.62	Pre- and posteruptive
Prichard[54]	0	6	1.0 mg F tablet	3.84	not stated	Pre- and postnatal
	0 - 2	6	1.0 mg F tablet	2.52	not stated	Postnatal
Kailis et al.[55]	0	4-1/2 - 6	1.0 mg F tablet	4.80	not stated	Pre- and postnatal
	0 - 2	4-1/2 - 6	1.0 mg F tablet	3.28	not stated	Postnatal
II. EFFECT ON PERMANENT DENTITION						
				Absolute reduction		
				DMFT	DMFS	
Hennon et al.[52,53]	0 - 2	5-1/2	0.5/1.0 mg F vitamin tablet	1.40	3.10	Pre- and posteruptive
Marthaler[56]	6 - 7 (school)	8	0.5/1.0 mg F tablet	5.12 at 14 years	13.82	Pre- and posteruptive
				4.38 at 15 years	15.35	Pre- and posteruptive
De Paola & Lux[57]	6 - 10 (school)	2	1.0 mg F chewable tablet	0.38	1.20	Posteruptive
Marthaler[13]	6	8	0.5/1.0 mg F tablet	-	1.72 average for 6-14 year-olds	Pre- and posteruptive

TABLE 23. RESULTS FROM THE ADMINISTRATION OF FLUORIDE TABLETS IN VIENNA (REPORTED BY BINDER (112))

Age (years)	Control group		Experimental group		Administration		Reduction in DMFT per child	
	No.	DMFT per child	No.	DMFT per child	Age (years)	No. of years	mean	%
6	710	1.08	7 133	0.38	0 - 6	6	0.70	70
10	232	4.32	6 198	1.92	0-10	10	2.40	55
			273	2.67	6-10	5	1.65	38
14	7 487	8.97	3 084	5.12	0-14	14	3.85	43
			1 915	7.43	6-10	5	1.54	17

TABLE 24. SAVINGS IN NUMBER OF FILLINGS PER CHILD RESULTING FROM THE ADMINISTRATION OF FLUORIDE TABLETS

Country	Author	Age at beginning (years)	Age at end (years)	Length of study (years)	Total savings in no. of fillings*	Average savings in no. of fillings per child per year*
			Deciduous teeth			
USA	Hennon et al.[52,53]	0 - 2	5-1/2 - 7-1/2	5-1/2	10.38	1.9
Australia	Prichard et al.[54]	0	6	6	9.6	1.6
	Prichard et al.[54]	0 - 2	6 - 8	6	6.3	1.05
	Kailis et al.[55]	0	4-1/2 - 6	4-1/2 - 6	12.0	2.4
	Kailis et al.[55]	0 - 2	4-1/2 - 8	4-1/2 - 6	8.2	1.6
			Permanent teeth			
USA	Hennon et al.[52,53]	0 - 2	5-1/2 - 7-1/2	5-1/2	3.5	0.6
Switzerland	Marthaler[56]	6 - 7	14	8	12.8	1.6
	Marthaler[56]	6 - 7	15	8	10.95	1.3
USA	De Paola & Lux[57]	6 - 10	8 - 12	2	1.0	0.5
Austria	Binder[112]	0	6	6	1.75	0.3
		0	10	10	6.0	0.6
		0	14	14	9.6	0.7
		6 - 10	10	5	4.1	0.8
		6 - 10	14	5	3.8	0.8

* Assuming with Pot[15] that 1 saved dmf tooth equals 2 fillings saved; and 1 saved DMF tooth equals 2.5 fillings saved.

TABLE 25. REDUCTIONS IN DENTAL CARIES RESULTING FROM VARIOUS TOPICAL APPLICATIONS OF FLUORIDE SOLUTIONS BY PROFESSIONAL PERSONNEL

Agent	Reference	Technique	Length of study (years)	Age (years)	Total reduction in DMFS (mean)	Total reduction in DMFS (%)	Annual reduction in DMFS (mean)	No. of applications
2% NaF	Galagan & Knutson[67]	Knutson	1	7-15	1.11	35	1.11	4
	Torell & Ericsson[68]	Knutson	2	10	1.98	20	0.99	4
	Muhler[69]	Knutson	2	6-15	1.64	36	0.82	4
	Cons et al.[70]	Knutson	3	6-11	0.41	11	0.14	4
	Szwejda[66]	Knutson multiple-chair	3	6-10	1.38	40	0.46	4
	Szwejda[66]	Muhler 30-sec	3	6-10	0.61	19	0.20	4
	Englander et al.[64]	Englander NaF gel in tray	4	11-14	4.46	69	1.11	221
8-10% SnF_2	Howell et al.[71]	Knutson	2	6-15	2.66	59	1.33	4
	Mercer & Muhler[62]	Muhler	2	5-15	4.47	69	2.23	1
	Howell et al.[71]	Muhler	2	6-15	2.96	65	1.48	1
	Mercer & Muhler[62]	Mercer & Muhler	2	5-15	3.95	61	1.97	4
	Peterson & Williamson[72]	Muhler	2	9-13	1.45	24	0.72	2
	Muhler[61]	Muhler	1	17-38	0.48	16	0.48	1
	Cons et al.[70]	Muhler	3	6-11	0.38	8	0.13	3
	Wellock et al.[74]	Muhler	1	8-12	0.01	-	0.01	1
	Horowitz & Lucye[75]	Muhler	2	8-11	+0.32	+ 8	+0.16	2
	Pot[15]	Muhler	9	twins	9.20	33	1.0	17
Acidulated phosphate fluoride (APF)	Englander et al.[65]	Englander	2	11-14	3.25	75	1.62	245
	Englander et al.[64]	Englander	4	11-14	4.74	73	1.18	231
	Wellock et al.[74]	Muhler	2	8-12	2.11	51	1.05	1
	Horowitz & Doyle[76]	Muhler	3	10-13	3.56	41	1.19	6
	Bryan & Williams[77]	Englander	2	8-12	2.70	37	1.35	2
	Szwejda[66]	Knutson multiple-chair	3	6-10	0.91	26	0.30	4
	Horowitz & Doyle[76]	Muhler	3	10-13	2.41	28	0.80	3
	Horowitz & Doyle[76]	APF gel	3	10-13	2.10	24	0.70	3
	Szwejda[66]	Muhler 30-sec	3	6-10	0.59	18	0.20	3
	Cons et al.[70]	Englander	3	6-11	0.68	18	0.23	3
	Cons et al.[70]	Muhler	3	6-11	+0.06	+ 2	+0.02	3
	Jakovljevic[78]	Knutson	1	1st grade	1.30	81	1.3	2

TABLE 26. REDUCTIONS IN DENTAL CARIES RESULTING FROM TOPICAL APPLICATIONS OF FLUORIDE SOLUTIONS IN COMMUNITIES WITH OPTIMAL LEVELS OF FLUORIDE IN WATER

Agent	Reference	Technique	Length of study (years)	Age (years)	Total reduction in DMFS (mean)	Total reduction in DMFS (%)	Annual reduction in DMFS	No. of applications
1.1% NaF drops	Englander et al.[79]	Englander	1.5	11-15	0.62	29	0.42	258
8-10% SnF_2	Muhler[69]	Muhler	1	6-14	0.74	28	0.74	1
	Horowitz & Heifetz[80]	Muhler	3	7-9	0.50	21	0.17	3
	Horowitz & Heifetz[80]	Dudding & Muhler	3	7-9	0.90	4	0.30	3
SnF_2, zirconium silicate paste and SnF_2 dentifrice	Lang et al.	self-applied	1.5	6-10	2.64	39	1.76	4
			1.5	6-10	3.03	53	2.02	4
			1.5	6-10	2.55	46	1.70	4

TABLE 27. REDUCTIONS IN DENTAL CARIES RESULTING FROM PROFESSIONALLY ADMINISTERED PROPHYLAXES WITH A FLUORIDE PROPHYLAXIS PASTE AND TOPICAL APPLICATIONS OF STANNOUS FLUORIDE IN COMBINATION WITH A FLUORIDE PROPHYLAXIS

Agent and technique	Reference	Length of study (years)	Age (years)	Total reduction in DMFS (mean)	Total reduction in DMFS (%)	Annual reduction in DMFS (mean)	No. of applications
SnF_2 prophylaxis + SnF_2 dentifrice	Bixler & Muhler[82]	3	5-18	4.09	37	1.36	3
	Scola & Ostrom[83]	2	18-22	2.36	42	1.18	2
SnF_2 prophylaxis	Bixler & Muhler[82]	3	5-18	3.83	35	1.28	3
	Scola & Ostrom[83]	2	18-22	0.67	12	0.33	2
	Horowitz & Lucye[75]	2	8-11	+0.23	+ 6	+0.11	2
APF prophylaxis	Peterson et al.[84]	2	10-13	1.08	18	0.54	2
SnF_2 prophylaxis +	Bixler & Muhler[82]	3	5-18	5.20	48	1.73	3
SnF_2 topical (Dudding & Muhler)	Scola & Ostrom[83]	2	18-22	3.45	61	1.72	2
	Scola & Ostrom[83]	2	18-22	2.61	45	1.30	2
	Scola[85]	2	18-22	2.30	59	1.15	2
	Horowitz & Lucye[75]	2	8-11	0.03	2	0.01	2
	Szwejda[66]	3	6-10	0.62	19	0.21	3
Szwejda-Knutson (multiple-chair)	Szwejda[66]	3	6-10	1.26	36	0.42	3
SnF_2 prophylaxis + SnF_2 topical + SnF_2 dentifrice	Bixler & Muhler[82]	3	5-18	6.29	58	2.09	3

TABLE 28. COST-EFFECTIVENESS OF TOPICAL APPLICATIONS OF FLUORIDES

Agent	Author	Technique	Length of study (years)	Total Reduction in DMFS	Total application time (hours)	Cost Effectiveness: Surfaces saved per hour	Cost Effectiveness: Rank (1 - 46)
Sodium fluoride	Galagan & Knutson[67]	Knutson	1	1.11	1.5	0.74	30
	Toroll & Ericsson[68]	Knutson	2	1.98	1.5	1.32	25
	Muhler[69]	Knutson	2	1.64	1.5	1.09	27
	Cons et al.[70]	Knutson	3	0.41	1.5	0.27	36
	Szwejda[66]	Szwejda-Knutson Multiple – chair	3	1.38	0.25	5.52	3
	Szwejda[66]	Muhler - 30 sec	3	0.61	0.25	2.40	14
	Englander et al.[64]	NaF gel in tray	4	4.46	11.00	0.41	34

TABLE 28. (Continued)

Agent	Author	Technique	Length of study (years)	Total Reduction in DMFS	Total application time (hours)	Cost Effectiveness	
						Surfaces saved per hour	Rank (1 - 46)
Stannous fluoride	Mercer & Muhler[62]	Muhler	2	4.47	0.5	8.94	1
	Howell et al.[71]	Knutson	2	2.66	1.5	1.73	19
	Howell et al.[71]	Muhler	2	2.96	0.5	5.92	2
	Mercer & Muhler[62]	Mercer & Muhler	2	3.95	2.0	1.97	18
	Peterson & Williamson[72]	Muhler	2	1.45	1.0	1.45	24
	Muhler[61]	Muhler	1	0.48	0.5	0.96	29
	Cons et al.[70]	Muhler	3	0.38	1.5	0.25	37
	Wellock et al.[74]	Muhler	1	0.01	0.5	0.02	43
	Horowitz & Lucye[75]	Muhler	2	+0.32	1.0	+0.32	46
	Pot[15]	Muhler	9	9.20	4.25	2.16	17

TABLE 28. (Continued)

Agent	Author	Technique	Length of study (years)	Total Reduction in DMFS	Total application time (hours)	Cost Effectiveness	
						Surfaces saved per hour	Rank (1 - 46)
Acidulated phosphate fluoride	Englander et al.[65]	APF gel in mouthpiece	2	3.25	24.5	0.13	39
	Englander et al.[64]	APF gel in mouthpiece	4	4.74	23.1	0.21	38
	Wellock et al.[74]	Muhler	2	2.11	0.5	4.22	5
	Horowitz & Doyle[76]	Muhler	3	3.56	3.0	1.19	26
	Bryan & Williams[77]	APF gel in rubber tray	2	2.70	1.0	2.70	11
	Szwejda[66]	Szwejda/Knutson multiple-chair	3	0.91	0.25	3.64	6
	Horowitz & Doyle[76]	Muhler	3	2.41	1.50	1.61	20
	Horowitz & Doyle[76]	APF gel	3	2.10	1.50	1.47	22
	Szwejda[66]	Muhler 30-sec	3	0.59	0.40	1.47	22
	Cons et al.[70]	Muhler	3	+0.06	1.5	+0.04	44
	Cons et al.[70]	APF gel in wax tray	3	0.68	1.5	0.45	33

TABLE 28. <u>(Continued)</u>

Agent	Author	Technique	Length of study (years)	Total reduction in DMFS	Total application time (hours)	Cost Effectiveness	
						Surfaces saved per hour	Rank (1 - 46)
Stannous fluoride in fluoridated area	Muhler[69]	Muhler	1	0.74	1.0	0.74	30
	Horowitz & Heifetz[80]	Muhler	3	0.50	1.5	0.33	35
	Horowitz & Heifetz[80]	Dudding & Muhler	3	0.09	1.5	0.06	40
Sodium fluoride drops	Englander et al.[79]	mouthpieces	1.5	0.63	12.9	0.05	41

TABLE 28. (Continued)

Agent	Author	Technique	Length of study (years)	Total reduction in DMFS	Total application time (hours)	Cost Effectiveness: Surfaces saved per hour	Cost Effectiveness: Rank (1 - 46)
Prophylactic pastes and combinations	Scola & Ostrom[83]	prophylaxis with SnF_2	2	0.67	1.0	0.67	32
	Bixler & Muhler[82]	prophylaxis with SnF_2	3	3.83	1.5	2.55	13
	Horowitz & Lucye[75]	prophylaxis with SnF_2	2	+0.23	1.0	+0.23	45
	Peterson et al.[84]	prophylaxis with APF	2	1.08	1.0	1.08	28
	Bixler & Muhler[82]	proph. with SnF_2 + SnF_2 dentifrice	3	4.09	1.5	2.73	10
	Scola & Ostrom[83]	proph. with SnF_2 & SnF_2 dentifrice	2	2.36	1.0	2.36	15
	Bixler & Muhler[82]	proph. with SnF_2 & SnF_2 topical	3	5.20	1.5	3.47	8
	Scola & Ostrom[83]	proph. with SnF_2 & 15 - sec SnF_2 topical	2	3.45	1.0	3.45	9
	Scola & Ostrom[83]	proph. with SnF_2 & 4 - min SnF_2 topical	2	2.61	1.0	2.61	12
	Scola[85]	proph. with SnF_2 & 15 - sec SnF_2 topical	2	2.30	1.0	2.30	16
	Horowitz & Lucye[75]	proph. with SnF_2 & 4 - min SnF_2 topical	2	0.03	1.0	0.03	42
	Szwejda[66]	proph. with SnF_2 & 30 - sec SnF_2 topical	3	0.62	0.40	1.55	21
	Szwejda[66]	proph. with SnF_2 & SnF_2 topical multiple-chair	3	1.26	0.35	3.60	7
	Bixler & Muhler[82]	proph. with SnF_2 & SnF_2 topical + SnF_2 dentifrice	3	6.39	1.5	4.26	4

TABLE 29. COST-BENEFIT OF TOPICAL APPLICATIONS OF FLUORIDE

Agent	Country	Author	Length of study (years)	No. of applications	Cost of implementation	Savings in cost-of treatment	Cost-benefit ratio
Sodium fluoride	USA	Szwejda[66]	3	4	US$ 5.25	US$ 11.04	1:2.1
	USA	Cons et al.[70]	3	4	US$ 51.51	US$ 3.28	1:0.06
	Sweden	Torell & Ericsson[68]	2	4	SKr189.00	Skr 99.00	1:0.5
Stannous fluoride	USA	Mercer & Muhler[62]	2	1	US$ 17.17	US$ 35.76	1:2.1
	USA	Horowitz & Lucye[75]	2	2	US$ 34.34	US$ 2.56	-
	Netherlands	Pot[15]	9	17	f.255	f. 145.2	1:0.6
Acidulated phosphate fluoride (APF)	USA	Wellock et al.[74]	2	1	US$ 17.17	US$ 16.88	1:0.98
	USA	Cons et al.[70]	3	3	US$ 51.51	US$ 0.06	-
	Yugoslavia	Jakovljevič[78]	1	2	Din.20	Din. 30.55	1:1.5
3-agent stannous fluoride	USA	Bixler & Muhler[82]	3	3	US$ 51.51	US$ 51.12	1:1.0
	USA	Horowitz & Lucye[75]	2	2	US$ 34.34	US$ 0.24	-

TABLE 30. REDUCTIONS IN DENTAL CARIES FROM TOOTHBRUSHING WITH A FLUORIDE SOLUTION IN SCHOOLS

Authors	Initial age	Length of study (years)	Agent	Frequency	Absolute reductions per person		DMFS		Absolute reductions in no. of fillings per person per year
					DMFT	(%)	(Mean)	(%)	
Bullen et al.[94]	6-8 years	2	APF	Once every 6 weeks	-		0.9	15	0.45
Berggren & Welander[96]		2	NaF	9 times in 2 years	-		N.A.[a]	25	-
Horowitz & Heifetz[95]	grades 7 & 8	1	prophylactic paste and APF gel	5 times a year	0.23	14	0.27	10	0.27
Marthaler et al.[13,14,98,99]	6 years	8	fluoramine solutions + rinsing tablets	4-6 times a year	5.33	40	14.75	50	1.84
Bjørnsson[100]									
Oslo	grades 1-6		NaF	4 times a year			0.74[b]	11	0.74
Trondheim	grades 1-6		NaF	Grades 1-2 rinsing once every 2 weeks Grades 3-6 brushing with 0.5% NaF 6 times a year			2.2[b]	40	2.2

[a] Not available.

[b] Savings in filled tooth surfaces.

TABLE 31. REDUCTIONS IN DENTAL CARIES RESULTING FROM FLUORIDE MOUTHWASHES IN SCHOOLS

Authors	Initial age (years)	Length of study (years)	Agent	Frequency	Absolute reductions per person			
					DMFT		DMFS	
					(Mean)	(%)	(Mean)	(%)
Torell & Ericsson[68]	10	2	0.5% NaF	Once a day			4.92	49
	10	2	0.2% NaF	Once a fortnight			2.15	21
De Paola et al.[101]	6-8	3	1.0% NaF (APF) 0.25% NaF (APF)	Three times a year	0.02	1	0.58	13
Gerdin & Torell[102]	10-11[a]	4	0.2% KF + $MnCl_2$	2 min per week	2.44	21	-	-
	10-11[a]	4	0.2% NaF + $MnCl_2$	2 min per week	0.26	2	-	-
Koch[103]	10	3	0.5% NaF	Once a fortnight	0.93	11	4.36	22
	10	5	0.5% NaF	Once a fortnight for 3 years only	0.93	8	3.75	11
Swerdlow & Shannon[104]	11-15	1/2	0.1% SnF_2	Once a day	0.19	33[b]	0.26	31[b]
Horowitz et al.[105]	6	2	0.2% NaF	Once a week	0.18	25[b]	0.21	16[b]
	10	2	0.2% NaF	Once a week	0.84	15	1.27	43

[a] Comparisons with 0.2% NaF as Control.

[b] Not significant.

ANNEX 2

THE UNRELIABILITY OF CROSS-SECTIONAL DMF DATA FOR ESTIMATING INCREMENTS AND COSTS

The only direct comparison that can be made between the reduction in DMF surfaces and the cost of fillings is between the data pertaining to children aged 11-1/2 - 13-1/2 years and 13-1/2 - 16 years in the report of Denby & Hollis from New Zealand[19] and the data in the 1954-1964 report of Ludwig.[8]

In Tables A1 and A2 the numbers of DMF surfaces in children aged 6 - 16 years are set out. In this case, the data for 1964 have been adjusted to conform to the number of children present and examined in 1954.

TABLE A1. DMFS IN CHILDREN AGED 6 - 16 YEARS AT HASTINGS, 1954 AND 1964

Age (years)	No. of children in 1954	DMFS 1954	DMFS 1964*	Difference
6	216	530	70	460
7	246	1 214	283	931
8	202	1 452	425	1 027
9	145	1 319	550	769
10	157	1 170	748	1 022
11	122	1 821	847	974
6-11	888			5 183
12	139	2 806	1 449	137
13	147	3 896	2 110	1 786
14	128	4 323	2 330	1 993
15	88	3 743	1 812	1 931
13-15	363	11 962	6 252	5 710
16	41	1 788	1 061	727

* Adjusted for age to the number of children examined in 1954.

From Table A1 it will be seen that the total reduction in the number of DMFS after 10 years' fluoridation in 363 children aged 13-15 years was 5 710. The number of children aged 13-1/2 - 15 years enrolled for treatment by general practitioners at Hastings in 1965 was 1 360. Thus the estimated number of DMFS saved in 1 year in 1 360 children:

$$= \frac{5\ 710 \times 1\ 360}{10 \times 363}$$

$$= 2\ 135$$

$$= 1.57 \text{ per child per year.}$$

In section 6.2.1 (p.7) it was estimated that the savings in the cost of fillings per child aged 13-15 was NZ$ 5.72. Since the number of tooth surfaces saved per child per year was 1.57, and assuming that each surface required 1 filling, the average cost of a filling per child should be $\frac{5.72}{1.57}$ = NZ$ 3.64

TABLE A2. DMF OCCLUSAL, PROXIMAL, AND GINGIVAL SURFACES AT HASTINGS, 1954 and 1964

Age (years)	No. of children in 1954	Occlusal surfaces		Proximal surfaces		Gingival surfaces	
		1954	1964	1954	1964	1954	1964*
6	216	513	65	12	-	5	-
7	246	1 141	246	56	13	17	4
8	202	1 228	397	184	27	40	-
9	145	981	477	257	70	81	4
10	157	1 045	556	506	169	219	24
11	122	1 010	630	668	193	143	25
12	139	1 594	923	999	482	213	28
13	147	1 818	1 280	1 612	768	466	63
14	128	1 946	1 356	1 921	897	456	77
15	88	1 551	997	1 774	740	418	67
16	41	730	539	845	457	213	65

* Adjusted to the number of children examined in 1954.

An even better estimate should be possible from a consideration of specific types of tooth surface by accepting the presumption that occlusal and gingival surfaces require 1-surface restorations and proximal surfaces require 2-surface restorations. Data on the involvement of specific surfaces calculated from Ludwig's report,[8] with the 1964 results adjusted to the number of children examined in 1954, are set out in Table A2.

The reduction in the number of DMF occlusal surfaces (after 10 years' fluoridation) in 408 children aged 11-13 years = 1 589

The reduction in the number of DMF gingival surfaces in the same group = 706

Thus, the total reduction of occlusal and gingival surfaces that would require simple amalgam fillings in children aged 11-13 years = 2 295 or 5.62/child

Since fluoridation had been in operation for 10 years, the saving compared with Hastings in 1954 is equivalent to 5.62/10 = 0.562 simple amalgam fillings per child per year

According to Denby & Hollis,[19] however, the actual saving in the number of simple amalgam fillings per child per year at Hastings compared with a non-fluoridation community = 2.501 - 0.578

= 1.923

Thus the actual saving in simple amalgam fillings was almost 4 times the number that might have been expected from the survey results of Ludwig.

The reduction in the number of proximal surfaces after 10 years' fluoridation in 408 children aged 11-13 years = 1 836

= 4.50 per child

= 0.45 per child per year

According to the Denby & Hollis report,[19] the savings in the number of compound amalgam and silicate cement fillings at Hastings compared with a non-fluoridation community

= (2.098 + 0.764) - (0.437 + 0.242)

= 2.183 per child

The actual saving is again about 4 times what might be expected from the results of the survey.

Since data for DMF surfaces for the years 1955 - 1963 are not available, it is difficult to calculate the annual increments. About the only way this can be done is to determine from the 1964 data for, say, 12-year-olds, the mean number of DMF surfaces and subtract from this the mean number of surfaces in 11-year-olds, and call this value the mean 11-12 year increment. The same can be done for 12-13-year-olds and for 13-14-year-olds. These calculations from the data in Table A2 result in the following average increments per child in 11-1/2 - 13-1/2-year-old children at Hastings:

Occlusal surfaces . . . 1.81

Gingival surfaces . . . 0.31

Proximal surfaces . . . 1.81

The equivalent numbers of simple and compound restorations required would be 1.94 and 1.81 per child instead of the actual numbers of fillings done, namely, 0.58 and 0.68. Therefore, this method is also unreliable.

From the data for the tenth year of fluoridation at Grand Rapids (Arnold et al.[9]), it is possible to calculate year by year increments for DMF teeth. This can be done in two ways. First, the Hagerstown method.[108] This involves taking the mean number of DMF teeth for children aged 7 years in, say, 1946, and subtracting the mean number of DMF teeth for children aged 6 in 1946. The result is the expected average increase in carious permanent teeth in a group of children in that year between the ages of 6-1/2 and 7-1/2 years in 1946-1947. The alternative method is to take the average number of DMF teeth in children aged 7 years in 1947 and subtract the average number of DMF teeth in children aged 6 in 1946. The result is the average increment in children who proceed from age 6-1/2 in 1946 to 7-1/2 in 1947. The results of these calculations are set out in Table A3.

These results serve to emphasize the difficulties associated with the use of cross-sectional studies to demonstrate the effectiveness of a preventive measure, despite the very large number of children (3 000 - 5 000) examined each year. Sampling errors result in negative increments in several instances. Furthermore, despite the publication of year-by-year def rates, annual increments cannot be calculated because of the unknown number of deciduous teeth which are exfoliated each year and because the status of the exfoliated teeth is unknown.

The Gainesville, Richmond, and Woonsocket data are valuable from the point of view of clarifying the relationship between DMF teeth, DMF increments, and the number of restorations required. According to the Woonsocket data for the first and second treatment series,[24] the average annual increment of decayed permanent teeth, estimated from differences in prevalence rates at individual ages (the Hagerstown method), was 1.31 teeth per child in the first treatment series and 1.43 teeth per child in the second. To measure and express the

TABLE A3. ANNUAL INCREMENTS IN DMF TEETH PER 100 PERSONS AT GRAND RAPIDS, USA, 1944/45 TO 1954*

Age (years)	Baseline data 1944/45	Increments by the two methods																			
		1945	1946	1946	1947	1947	1948	1948	1949	1949	1950	1950	1951	1951	1952	1952	1953	1953	1954
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
6-7	78	111	33	88	86	72	67	78	50	38	65	77	78	58	64	67	48	59	57
7-8	189	106	65	143	151	153	121	126	112	140	101	74	55	66	66	60	51	70	56
8-9	295	105	3	44	68	50	5	37	18	32	22	61	27	46	44	52	33	42	56
9-10	390	102	20	72	58	44	39	84	89	108	69	79	55	89	67	69	39	58	51
10-11	492	149	68	54	14	0	76	81	118	113	80	119	50	74	56	78	41	71	57
11-12	641	166	321	338	476	347	476	400	270	233	243	274	153	212	137	155	157	164	75
12-13	807	166	85	130	85	144	131	2	21	109	19	11	50	71	2	83	8	36	29
13-14	973	122	32	49	58	103	94	107	56	79	44	34	100	161	63	136	5	80	166
14-15	1 095	153	31	185	253	244	111	120	239	290	122	157	36	70	83	181	252	383	215
15-16	1 248	102	315	193	121	53	156	289	122	3	45	123	94	215	123	110	49	22	20
16	1 350																		
		1 282	103	910	1 342	1 210	1 276	1 324	1 053	1 145	718	1 009	578	1 062	701	991	683	941	782
Mean increment per 100 children		128	10	91	134	121	128	132	105	115	22	101	58	106	70	99	68	94	78

* 1 = Hagerstown method (see Annex 2, p. 79)

2 = Alternative method (see Annex 2, p. 79)

workload, all teeth requiring fillings, whether or not they had been previously filled, were counted as "carious". Teeth indicated for extraction were also counted as carious.

From the data in Table A4 it can be calculated that approximately 9% of DMF teeth were decayed <u>and</u> filled. For example, in the first treatment series the mean number of DMF teeth per child aged 5 - 16 years was 7.76; teeth extracted (M) = 0.66; teeth filled (F) = 1.321. Thus the number of decayed teeth (D) = 7.76 - (0.66 + 1.32) = 5.78. Of these, 0.33 teeth were indicated for extraction, leaving 5.45 teeth that were decayed and filled. The number of decayed and filled teeth = (7.09 - 6.39) = 0.70 = 9% of the total DMF. This approximates closely the claim by the Indian Health Service[34] that the average life of a filling is 10 years.

From the data from Woonsocket[24] and those in Table A4, the following conclusions can be drawn:

During the first series the mean DMF for children aged 5-16	=	7.71
Number of carious teeth	=	6.39
Number of teeth extracted	=	0.66
Thus, number of teeth to be restored	=	5.73
Average increment	=	1.31
Thus, total number of teeth to be restored	=	7.04
Number of teeth filled at first series (Table A4)	=	4.60
Thus, backlog to be restored at second series (= 2.44) plus the backlog to be extracted (0.66 - 0.32), i.e., 0.28	=	2.72
At the second series the number of carious teeth for filling or extraction	=	5.30
Thus, the actual treatment increment between first and second series which is 1.27 teeth higher than the increment computed from the DMF rates (1.31)	=	2.58
The number of teeth restored at the second series	=	3.87
The number of teeth extracted at the second series	=	0.66
		4.53
So that the backlog of untreated lesions at the end of the second series was only 5.30 - 4.53	=	0.77

These calculations support the contention of McKendrick[109] when he says "The mean annual caries increment per child must ... be found. The common form of rapid inspection is not enough. A thorough examination should be carried out by standard techniques on a random sample stratified by age. Neither DMF teeth nor DMF surfaces indices are enough by themselves, since a tooth or surface may be both filled and decayed. The mean number of new carious lesions arising in each year must be known, including the number of failed fillings."

The findings from the review of the literature on this point are summarized in Table A5.

TABLE A4. DENTAL CARIES PREVALENCE IN PERMANENT TEETH OF CHILDREN, FIRST AND SECOND TREATMENT SERIES, WOONSOCKET, R.I., USA

(Number of teeth per child)

Age last birthday (years)	Carious[1]	Filled[2]	Carious and/or filled[3]	Missing: Total	Missing: Extracted	Missing: Extractions indicated	DMF
1st treatment series							
5-16[4]	6.39	1.32	7.09	0.99	0.66	0.33	7.76
5	0.41	0.00	0.41	0.00	0.00	0.00	0.41
6	1.51	0.03	1.53	0.01	0.00	0.01	1.53
7	2.79	0.14	2.85	0.04	0.02	0.02	2.87
8	3.62	0.33	3.77	0.21	0.08	0.13	3.85
9	4.25	0.50	4.43	0.29	0.14	0.15	4.57
10	5.30	0.83	5.59	0.61	0.33	0.28	5.92
11	6.57	0.98	7.03	0.80	0.54	0.35	7.57
12	8.85	1.31	9.56	1.38	0.80	0.58	10.36
13	9.90	2.21	11.03	1.54	0.98	0.56	12.01
14	10.70	2.91	12.56	2.21	1.54	0.67	14.10
15	11.88	2.33	13.16	2.67	1.83	0.84	14.99
16	10.90	4.24	12.21	2.00	1.69	0.31	14.90
2nd treatment series							
5-16[4]	5.30	3.87	7.84	0.77	0.66	0.11	8.50
5	0.48	0.00	0.48	0.00	0.00	0.00	0.48
6	1.82	0.04	1.83	0.01	0.01	0.00	1.83
7	3.24	0.26	3.33	0.07	0.01	0.06	3.34
8	3.56	1.17	4.15	0.12	0.03	0.09	4.18
9	3.96	2.17	5.08	0.16	0.08	0.08	5.16
10	4.90	3.06	6.64	0.33	0.22	0.11	6.85
11	6.14	3.56	8.20	0.46	0.34	0.12	8.65
12	7.68	4.50	10.53	0.81	0.64	0.18	11.16
13	8.72	5.85	12.52	1.15	0.96	0.19	13.47
14	8.52	7.24	13.49	1.38	1.20	0.18	14.67
15	8.31	8.62	14.12	2.05	1.88	0.17	16.00
16	6.23	9.92	13.65	2.70	2.58	0.12	16.23

[1] Includes carious teeth <u>only</u>, those <u>both carious</u> and <u>filled</u>, and those <u>indicated for extraction</u>.

[2] Includes filled teeth only and those both carious and filled.

[3] Based on actual number of carious teeth, filled, or carious and filled. Teeth that are both carious and filled are counted only once.

[4] Average of the rates for ages 5-16.

ANNEX 3

RECORDING REQUIREMENTS FOR TREATMENT

In an oral health survey conducted in five countries, Davies, Horowitz, & Wada[110] found that the methods and criteria for the assessment of dental caries recommended in Oral Health Surveys[111] were satisfactory. The half-mouth assessment provided a satisfactory estimate of caries experience in the complete dentition. However, these authors recommended that the caries status of each tooth should be recorded in one series of boxes and the treatment required for each tooth (if any) be recorded at the same time in a separate series of boxes. If the treatment required was extraction, separate codes were used to define the reason as caries, periodontal disease, or to allow for a full denture. If it was considered advisable, an additional code could be used to cover extractions required for orthodontic reasons.

It was recommended that the type of treatment required should be assessed in relation to the nature and extent of the treatment services available in the country in which the survey was being made.

The following codes and criteria were suggested:

CODES

	Code No.
No treatment required	0
1-surface restoration	1
2-surface restoration	2
3-surface restoration	3
More than 3-surface restoration	4
Requiring extraction because of caries	5

Teeth indicated for extraction for prosthetic reasons

This category is used for teeth that do not require to be extracted because of caries or periodontal disease but rather because a full denture is planned. Individually, these teeth could be saved, but because their number within an arch is not adequate for function they must be extracted to make way for a denture.

Requiring extraction because of periodontal disease . . .	6
Requiring extraction for a full denture	7
Other reason	8
(specify . . . .)	

CRITERIA

Teeth indicated for extraction because of caries

A tooth is recorded as indicated for extraction because of caries when:

A. caries has so destroyed the crown that it cannot be restored;

B. caries has exposed the pulp; or

C. only the roots remain.

Teeth indicated for extraction because of periodontal disease

A tooth is recorded as indicated for extraction because of periodontal disease when:

A. periodontal disease is so advanced that there is loss of function;

B. the tooth is mobile when finger-pressure is exerted alternately on the facial and lingual surfaces of the tooth, and extraction is the only possible treatment.

TABLE A5. RELATIONSHIP OF DMF TEETH AND DMFS INCREMENTS TO THE NUMBER OF FILLINGS AND EXTRACTIONS REQUIRED

Source	Age (years)	Average annual increment per child	No. of restorations needed per child	Ratio of fillings to increment
Ast et al.[20]	5 - 6 at Newburgh	(dft + DMFT) 0.19	0.77	4:1
	5 - 6 at Kingston	(dft + DMFT) 0.67	1.43	2.1:1
Ludwig[8] and Denby & Hollis[19]	6 - 11-1/2 at Hastings	(DMFT) 0.53	0.91	(1.7:1)
	11-1/2 - 13-1/2 at Hastings	(DMFT) 1.79	1.26	(0.7:1)
	11-1/2 - 13-1/2 at Hastings	(DMFS) 3.75	1.26	(0.3:1)
		(DMFS proximal) 1.81	0.68	(0.4:1)
		(DMFS occl. & ging.) 1.94	0.58	(0.3:1)
Law, Johnson & Knutson[24]	5 - 16 at Woonsocket	(DMFT) 1.3	2.58	(1.95:1)

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