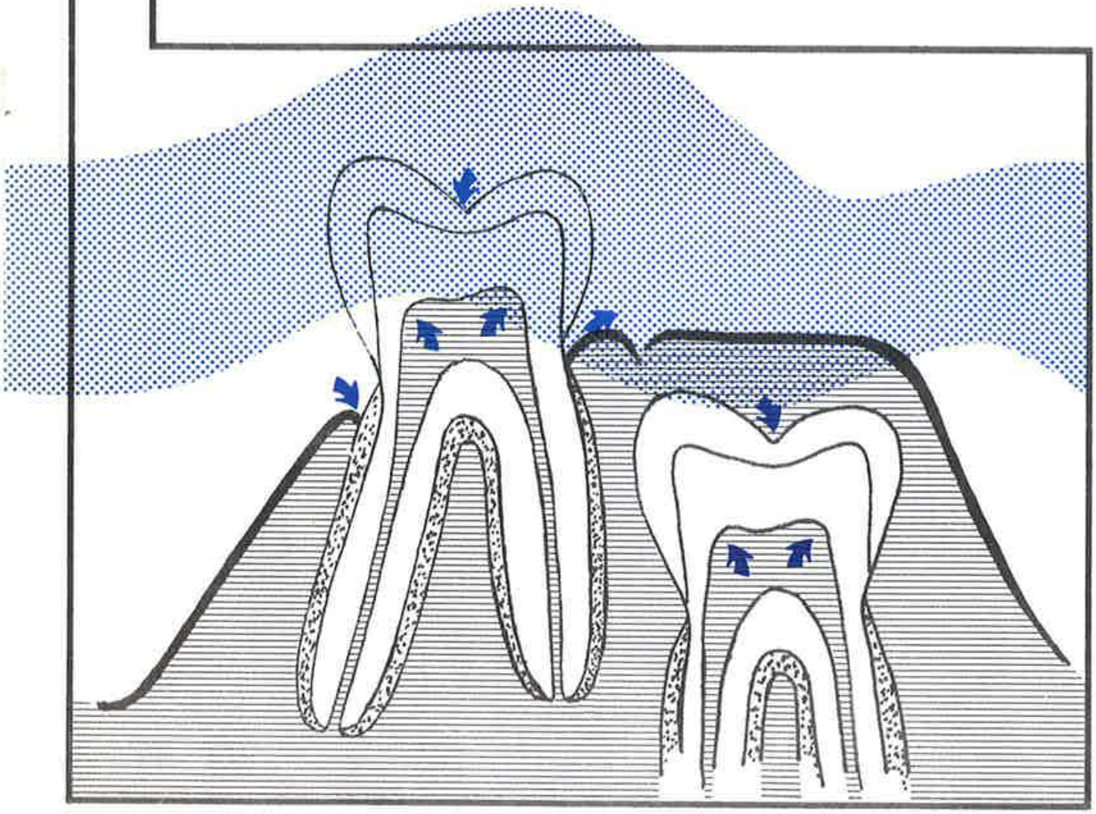
Pre- and posteruptive effect of fluoridated drinking water on dental caries experience

A study on 15-year-old children



Ton van Eck

PRE- AND POSTERUPTIVE EFFECT OF FLUORIDATED DRINKING WATER ON DENTAL CARIES EXPERIENCE

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PRE- AND POSTERUPTIVE EFFECT OF FLUORIDATED DRINKING WATER ON DENTAL CARIES EXPERIENCE

A study on 15-year-old children

Proefschrift

ter verkrijging van de graad van doctor
aan de Rijksuniversiteit te Utrecht,
op gezag van de Rector Magnificus Prof. Dr. J.A. van Ginkel,
volgens besluit van het College van Dekanen
in het openbaar te verdedigen op dinsdag 24 november 1987
des namiddags te 2.30 uur

door

ANTONIUS ADRIANUS MARINUS JOZEF van ECK

geboren op 26 maart 1948 te Schijndel

promotor: Prof. Dr. O. Backer Dirks

copromotor: Dr. A. Groeneveld

Ter nagedachtenis aan mijn vader
Voor mijn moeder
Voor Nadia,
Cathy, Anne, Fabienne en Sophie

C O N T E N T S

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Voorburg, 21 oktober 1987.

1.0 INTRODUCTION

The drinking water in The Netherlands is not fluoridated anymore for over ten years. However, the question about the effect of pre- and posteruptive administration of fluoride is still of current interest for other fluoride supplementations.

Except for the fluoride tablets and (inadvertently) swallowing fluoride toothpaste, fluoride use in The Netherlands is nowadays almost exclusively topical.

However, there are a few indications that, despite the relatively great protection of the enamel by the (topical) fluoride the dentin seems much less protected, perhaps because of lack of systemical fluoride. Many clinicians claim that in the fifties and sixties the clinical appearance of caries in the fissures became first evident by a growing discontinuity of the enamel, whereas nowadays relatively more and more deep dentinal carious lesions are observed underneath a nearly intact and hardly discoloured fissure. For the moment there is no proof for this statement, because it is also possible that in the fifties and sixties caries in fissures was treated in such an early stage that the last observation could not be made.

Extrapolation of the results of the present study to the effect of fluoride tablets may form an indication if early consumption is necessary for a maximal effect on permanent teeth.

The presence of fluoride in fossile and human teeth was discovered by Moricchini in the beginning of the nineteenth century (Gay-Lussac, 1805). This discovery forms the starting point in the history of the research about the relation between tooth enamel and fluoride. In the nineteenth century there was hardly any or no progress in this research, but since the report by Eager (1901) on the "Chiaie teeth" in Italy and the discovery of McKay that the possible cause might be fluoride in the drinking water (Mc Kay and Black, 1916) the interest of researchers was drawn to the subject.

After the discovery that fluoride in the drinking water might also be responsable for the reduction of caries experience, the concentration of fluoride in the drinking water was raised to a level of 1 mg/l in several towns in the U.S.A. and Canada, and later also in Europe in order to study the effect on dental caries. In the same period also other means of fluoride administration were introduced, e.g. topical application, fluoride tablets, fluoridated schoolwater, fluoridated milk, fluoridated salt and fluoridated toothpaste.

One of the subjects of research was the mode of action of fluoride, especially if it was systemical, topical or both.

- systemical: by the body fluids (gastro-intestinal tract, blood or lymphe and fluoride released by the bones where it has been incorporated before).

- topical: by direct contact with the erupted tooth.

An effect which could be called primary systemical can be caused by fluoride administrated before eruption such as the fluoride circulating in the body fluids surrounding the tooth, both at the outer side and in the pulp, or even incorporated in the ameloblasts. For instance, dental fluorosis is a systemical effect of the use of elevated concentrations of fluoride during tooth formation.

A secondary effect of systemical administration can be caused after eruption. Fluoride circulating in the body fluids or incorporated in the bones is released and will appear in the sulcus fluid or can be excreted in the saliva. It has then direct contact with the tooth and the action itself is of course topical.

Figure 1-1 shows the different ways by which fluoride can reach the tooth posteruptively.

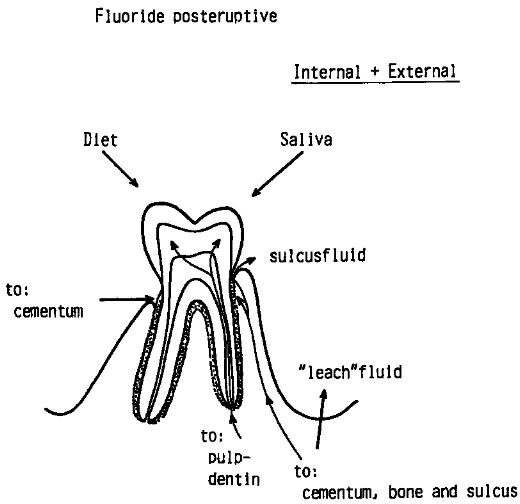


Fig. 1-1: The different ways in which fluoride can reach a tooth posteruptively.

A systemical effect can be present before and after eruption of a tooth (also called pre- resp. posteruptive period); a topical effect, however, only after eruption. Some fluoride vehicles are intended to be administered both systemically and topically, others only topically.

To the first group fluoridated water, salt or milk and fluoride tablets belong, whereas fluoride toothpaste and application solutions or gels are intended for topical use. However, by inadvertendly swallowing of the products from the latter group they also might be systemically present.

Table 1-1 summarizes if the different fluoride vehicles are administered pre- and/or posteruptively and if their action might be mainly topical, mainly systemical or both.

Table 1-1: Pre- and/or posteruptive administration of different fluoride vehicles in men and the possible systemic or topical action.

	Pre-eruptive	Posteruptive	Systemic primary	Systemic secondary	Topical
Fluoridated					
water	++	++	++	++	++
salt	++	++	++	++	++
milk	++	++	++	++	++
fluoride tablets	++	++	++	++	++
topical applications	-	++	-	+	++
fluoride mouthrinses	-	++	-	+	++
fluoride toothpastes	+	++	-	+	++

\- not present
\+ not intended use
++ intended use

It appears from the table that in men a controlled administration before and after eruption of the permanent teeth only exists for fluoridated water, milk or salt and fluoride tablets. This implicates that only these vehicles are suited to carry out a study about the pre- and posteruptive effect.

For fluoride tablets, however, dental awareness will be a factor in the use or non-use. A solution could be that they are distributed in the schools. This could also be done with fluoridated milk. However, a disadvantage of school distribution is that the study-period is limited to the school- period of the children. Fluoridated salt also has the disadvantage that its use is dependent on other circumstances and that a non-fluoridated alternative will also be for sale. This makes it difficult to carry out a controlled clinical trial.

The fluoridation of drinking water, however, has been carried out on a large scale in several countries. For a clinical experiment fluoridated water has the advantage that its use is independent of dental awareness and other factors dealing with dental care such as the availability of dentists and/or oral hygienists.

In The Netherlands water fluoridation started in Tiel on the 9th of March 1953. The year before the first examination of 15-year-old children was carried out in Tiel and in Culemborg a non-fluoridated town, where children of the same age served as a control group.

On the 24th of December 1973 the water fluoridation in Tiel was discontinued.

An indication for the existence of a reduction in dental caries experience by only pre- or only posteruptive use of fluoridated water is illustrated by figure 1-2. This figure shows the total DMF-S in 15-year-old children from Culemborg and Tiel born between 1945 and 1970. (Groeneveld, 1987). Two vertical lines have been added to the original figure, one in birth year 1947 (children who were six years of age at the start of the fluoridation in 1953) and the other in birth year 1967 (children who were six years of age at the discontinuation of the fluoridation in 1973).

It can be assumed that in the group born in 1947 part of the difference in DMF-S between Culemborg and Tiel is caused by the posteruptive use of fluoridated water. However, since the time of eruption of permanent teeth varies between the age of six and the age of twelve years, part of the reduction in this group is also caused by pre-eruptive use of fluoridated water. In the group born in 1967 the difference in DMF-S between Culemborg and Tiel is due to pre-eruptive use. However, also in this group the variation in time of eruption is the cause that this difference represents not the maximum pre-eruptive effect.

In order to assess the effect of pre- and posteruptive use of fluoridated water on dental caries experience a method will be presented in this study and this method is applied to the data from Culemborg and Tiel.

A remarkable feature in figure 1-2 is that in Culemborg the DMF-S increases between birth classes 1945 and 1954 and decreases between birth classes 1954 and 1970 to a level comparable to that in Tiel when the maximum effect of the fluoridation has been reached.

The data in this study are obtained from clinical and radiographical examinations carried out by the NIPG-TNO Caries Research Unit in Utrecht during the period 1952 - 1986 in the Tiel - Culemborg water fluoridation experiment.

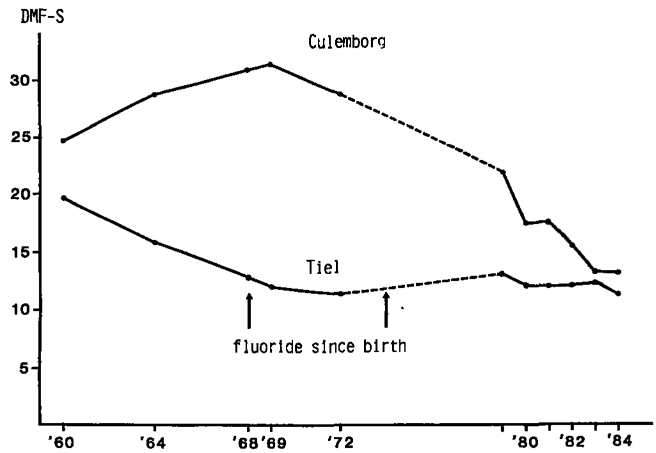


Fig. 1-2: The total DMF-S in 15-year-old children from Culemborg and Tiel born between 1945 and 1970 (Groeneveld, 1987).

The aim of the study is to assess the effect of the use of fluoridated water before and after eruption on dental caries experience.

Chapter 2.0 contains a review of the literature dealing with the systemical and topical effect, or the effect of fluoride consumption pre- and posteruptively, mainly based on the effect of fluoridated water.

In chapter 3.0 a method is presented to assess the pre- and posteruptive effect on dental caries experience using a water fluoridation experiment and the applicability of the method on the data from Culemborg and Tiel is studied.

In chapter 4.0 the demographic and social situation and the availability of dental care during the study period in Culemborg and Tiel is described.

In the chapter 5.0 the spread of the eruption of most permanent teeth and their median eruption time in both towns is presented using data collected in 1955 - 1959. These data are compared with those obtained from the literature.

In chapters 6.0, 7.0 and 8.0 the effect of posteruptive and additionally pre-eruptive consumption of fluoridated water for the proximal surfaces, the smooth surfaces and the fissures and pits respectively is discussed. Data collected in the period 1952 - 1972 from the start of the water fluoridation served for this part of the study.

In chapter 9.0 the effect of pre- and additional posteruptive use and also the effect of only pre-eruptive use is studied. This part is based on the discontinuation of the water fluoridation in Tiel. The data are collected in the period 1979 - 1986.

In chapter 10.0, the results of the four preceding chapters are discussed in relation to each other and compared with those of a few other studies.

2.0 REVIEW OF LITERATURE

2.1 INTRODUCTION

In this chapter a review is given concerning the effect of the consumption of both naturally and artificially fluoridated water on the prevalence of dental fluorosis (mottled enamel) and dental caries experience. A selection had to be made out of the overwhelming number of publications. After a historical outline those publications are selected, which provide separate information about the pre- and posteruptive effect of the consumption of fluoridated water on dental caries.

2.2 FLUORIDE, DENTAL FLUOROSIS AND DENTAL CARIES: a historical outline.

2.2.1 Fluoride in drinking water and mottled enamel

The presence of fluoride in fossile animal teeth was reported for the first time by MORICCHINI in 1802 (published by Gay-Lussac, 1805). A few years later he also found fluoride in human teeth (also published by Gay-Lussac, 1805).

About one century thereafter EAGER (1901) reported mottled teeth in people from the neighbourhood of Naples (known in that region as 'denti di Chiaie') and supposed that "...the etiology seemed to be connected with volcanic fumes or emanations of subterranean fires which formed a solution in the drinking waters."

McKAY, a dentist from Colorado, was the first who used the term 'mottled teeth' and described it as "...an endemic developmental imperfection of the enamel..." (McKay and Black, 1916). He suggested, as Eager did before, a correlation between mottled enamel and water composition (McKay, 1928). His publications based on scientific studies concerning the occurrence and cause of mottled teeth and its relation to caries still deserve our attention. It was his merit that the interest of chemists was focussed on the drinking water.

About fifteen years later the relation between fluoride in drinking water and mottled enamel was shown by CHURCHILL (Churchill, 1931) by spectrophotometrical analysis. SMITH (Smith et al., 1931) demonstrated this relationship by a biological experiment in the white rat. The latter found that drinking water from St. David (Arizona) (a town with serious mottled enamel), concentrated to one tenth of its original volume, caused the same dystrophy in the teeth of rats as fluoride in their drinking water.

The ultimate proof that the presence of high levels of fluoride in the drinking water is the cause of mottled enamel in men was presented in 1933 (McKay, 1933). Ten years after the change of the water supply in Oakley (Idaho) (6.0 mg F^-/l) to another source of drinking water with a low fluoride concentration, which was done on the advice of McKay, it could be demonstrated that no new mottled enamel had been formed since then.

Based on these findings Dean conducted an impressive number of studies on the epidemiology of mottled enamel in the U.S.A. (Dean, 1933; Dean, 1934; Dean et al., 1935; Dean and Elvove, 1935; Dean and Elvove, 1936; Dean, 1936; Dean and Elvove, 1937; Dean et al., 1938; Dean and Mc Kay, 1939; all papers were reprinted in Mc Clure, F.J. (ed.), Fluoride Drinking Waters, Bethesda, 1962.)

Dean developed a community severity index of dental fluorosis (Dean, 1934). Using data from nine cities he observed a positive relationship between the level of F^- in the communal water supply and the severity of mottling (Dean, 1936). This positive correlation was confirmed in a study in 3,350 children from 21 cities (Dean et al., 1939).

From these studies it is clear that consumption of water containing 1.5 mg F^-/l or more during the developmental stages of the teeth, affects the formation of the hard dental tissues.

Recently a raise of interest in dental fluorosis can be observed. In papers by Manji et al. (1986a and 1986b) the relation between fluorosis, the local mean annual maximum temperatures and the altitude in Kenya was discussed. From these studies it appears that there is a positive correlation between the prevalence of dental fluorosis on one side and the altitude and mean annual maximum temperatures on the other. Even in low fluoride areas mottled enamel was observed in high altitude areas. The reason for this is not yet clear. The higher metabolism may be of importance.

As early as in 1916 McKay observed to his surprise that the mottled teeth were not more susceptable to dental decay than normal teeth. In accordance with these findings Dean reported in 1938 that the severity of dental caries in areas with mottled enamel in the teeth was generally lower than in areas without mottled enamel in the same state. Dean said in his discussion: "Whether this mechanism functions locally, systemically, or both ways, is not known" (Dean, 1938).

2.2.2 Fluoridated water and dental caries

2.2.2.1 Naturally fluoridated water and dental caries

In 1939 Dean observed that 12 - 14-year-old children living in an area with 1.7-2.5 mg F^-/l in their drinking water had less dental caries than comparable children living in an area with 0.6-1.5 mg F^-/l in the drinking water (Dean, 1939). He concluded that "...while it seems reasonable to associate the low dental caries rates with the higher fluoride content of the communal water supplies, the possibility that the composition of the domestic waters, other than the fluorine content, may be a factor should not be overlooked..." He also stated that "...from an epidemiological standpoint, it is difficult to ascribe these differences to any cause other than the common water supply."

In another study the same author observed that persons (ages 14 - 22 years) from Bauxite (13.7 mg F^-/l) with moderate to severe mottling, who had consumed the last 12 years of their lives fluoride-free drinking water, showed a lower caries experience than children from Benton (0,2 mg F^-/l) who did not show any mottling. (Dean et al., 1941). This reduction in caries experience was independent of the severity of mottling in Bauxite.

This study gave the first indication of the existence of an intrinsic caries resistance of the teeth acquired from fluoridated water during their pre-eruptive phase.

In a paper published in 1942, Dean studied the relationship between the concentration of fluoride in the drinking waters, the degree of mottling and the DMF-T. He demonstrated that at a concentration of 1 mg F^-/l mottling was hardly present whilst caries reduction was nearly maximal. Mottling was apparently not correlated with the caries protective effect of fluoride (Dean et al., 1942).

Since mottling is caused by pre-eruptive consumption of fluoride it is not surprising that some authors suggested that the caries reduction by F^- would also be a permanent effect of pre-eruptive consumption of fluoride. One of the co-authors of Dean stated some years later that: "....it is not essential for fluorides to be continuously present in the diet for more than the first eight years of life in order that caries be inhibited"

(Arnold, 1945).

Other investigators, however, cast another light on the effect of F^- on the caries process, when consumed during the pre- and posteruptive phase of the teeth. They published studies about the relation between caries and the age at which the consumption of (naturally) fluoridated water started (Deatherage, 1943a and 1943b), or the length of time during which fluoridated water was consumed pre- and posteruptively (Weaver, 1944, Klein, 1945, 1946, 1948a and 1948b, McKay, 1948 and 1952, Russell, 1949a and 1949b and Grainger, 1955). These studies, which are discussed extensively in paragraph 2.3.1, have been selected because each of them represents a stage in the increasing knowledge about the effect of pre- and posteruptive consumption of fluoridated water.

2.2.2.2 Artificially fluoridated water

In order to prove that the lower caries experience (DMF-T) is caused by the fluoride ion and to exclude other factors in the water, an intervention study was started in Grand Rapids (Mich.). Sodium fluoride was added to the water supply of this town in 1945. The total F^- concentration was maintained at 1 mg/l. The DMF-T of continuously-resident children of 4 to 16 years of age was compared with that of children of the same age living in Muskegon (Mich.) (0.2 mg F^-/l until July 1951; thereafter 1 mg F^-/l) and with that of children living in Aurora (Ill.) (1.2 mg F^-/l from natural sources since about 50 years).

Also other artificial fluoridation studies were started in the U.S.A., Canada, The Netherlands, New Zealand and several other countries. Those publications containing data, which could contribute to an assessment of the pre- and posteruptive effect of artificially fluoridated water are listed in table 2-6.

Appendix A contains an outline of the data from these publications, which are analysed in paragraph 2.3.2.

2.3 PRE- AND POSTERUPTIVE EFFECT OF WATER FLUORIDATION: discussion of selected literature.

2.3.1 The effect of fluoridated water during the pre- and posteruptive phase of teeth on the protection against dental caries

2.3.1.1 DEATHERAGE (1943a and 1943b) examined the caries data of 2,026 male recruits (mean age 24 - 26 years) who were classified according to the fluoride levels in their drinking water, the period they used (naturally) fluoridated water and the age at examination.

Table 2-1 represents figures of the total group studied by Deatherage.

Table 2-1: Relation between DMF-T, and consumption of fluoridated water at different concentrations continuously from birth, at least during the first 8 years of life and interruptedly afterwards, or from the age of 8 years continuously (compiled from Deatherage, 1943a and 1943b). - = data not available.

	DMF-T per person		
	F^- period		
mg F^-/l in drinking water	at least from birth,	at least first 8 years,	from 8 years onward
0.0 - 0.1	10.8	10.0	-
0.5 - 0.9	7.9	8.9	-
1.0	6.2	7.3	8.4

The relevance of the studies by Deatherage is mainly historical. He is the first one who demontrated the significance of drinking water containing fluoride for the dental health of young adults in a nationwide epidemiological study.

Because he differentiated between the consumption of fluoridated water: (a) continuously since birth, (b) for at least the first eight years or (c) starting from eight years on, his study gives some impression of the importance of fluoride during the pre- and posteruptive period of the teeth.

Especially the last row of table 2-1 suggests also a posteruptive effect of fluoride. The index in the last column will be mainly the result of posteruptive F^- consumption, the pre-eruptive consumption period being rather short for teeth erupting after this age.

Because in the second column ("at least first 8 years) the total period of consumption is not known, the protection against caries may also, for a greater or lesser part, have been caused by the posteruptive use of fluoride.

For a better assessment of the relative effect of fluoride during the pre- and posteruptive phase of the teeth more detailed data of separate teeth and of the exact ages of fluoride use would have been necessary.

2.3.1.2 WEAVER analysed the results of investigations of populations living in North Shields (0.25 pm F^-) and in South Shields, Sunderland and Jarrow (1.4 mg F^-/1) (Weaver, 1944).

He came to the conclusion that:

a. "An examination of 800 children who had come under the influence of F at various ages during childhood produced results which suggest that the protection conferred on the teeth by F is obtained either during a brief period before eruption or during a brief period after eruption."

b. "The evidence obtained is, on the whole, in favour of the view that the influence of F is exerted on the teeth during the pre-eruptive period."

Table 2-2: Dental caries of permanent first molars (DMF-T) of 800 immigrants into a F area, aged 11 - 14 years and over, compared with 800 natives of similar ages, living in the same area. (Compiled from Weaver, 1944; table VI)

Age of arrival of immigrants in F area	Number of children (immigrants)	First Molar Immig.	Natives
1 year	116	1.8	1.8
2 year	78	1.9	1.9
3 year	77	1.7	2.0
3 year	60	2.0	2.0
4 year	61	1.9	1.9
5 year	52	2.0	1.9
6 year	70	2.4	1.9
7 year	47	2.7	1.9
8 year	53	2.6	2.0
9 year	53	2.5	1.8
10 year	42	2.7	2.0
11 year	44	2.5	1.8

The first conclusion will be discussed briefly (see table 2-2). In this part of the study the DMF-T of first molars of 800 11 - 14-year-old children, natives of the F area were compared with 800 children who immigrated into this area at various ages. Weaver stated that only the data of the first molar were of statistical value . From the results in the table he concluded that: "...all groups of children who arrived in the F area before about six years of age tended to derive equal benefit irrespective of their age at arrival." and also that: "...those who arrived at about 8 years of age or later were no worse off than if they had arrived at 7 years of age."

The first molar erupts during the sixth year of life. Based upon the data, presented below in table 2-2, both conclusions can be upheld.

Because Weaver uses the DMF-T index, dental caries of the occlusal surface will nearly exclusively be responsable for this figure.

2.3.1.3 KLEIN was the first who studied extensively the question whether there was an effect on caries increment of drinking water containing fluoride during the pre- and/or posteruptive period of the teeth on caries increment (Klein, 1945 and 1946).

In the first study carried out during worldwar II in the USA he examined two groups of relocated Japanese children 8 to 14 years of age in 1943 and reexamined these children in 1945. Both groups had consumed F^--free drinking water before 1943. One group consumed F^--free drinking water also during the two-year period of the study, the other group was moved to an area with drinking water containing 3 mg F^-/1. Klein observed that in the F^--area teeth of children in the 8 - 10 years age group, which had already erupted at the start of the study and which were free from dental caries showed about 60% reduction in caries increment as compared with children of the non F^--area after two years, thus showing a posteruptive effect of fluoride (table 2-3).

Table 2-3: Caries increment after two years in relocated Japanese children 8 - 10 years of age at the start of the study.

F^- in drinking water between 1943 and 1945	Percentage of teeth that becomes carious between 1943 and 1945. boys	girls
3 mg/lroup	15.8	13.2
0.0 mg/1	38.2	30.5

However, in children over 11 years of age caries incidence was not affected significantly by either the presence or absence of fluoride in the drinking water.

In the second paper on the same studygroup he presented the separate data concerning the effect of fluoridated water on the first and second molars and the first and second bicuspids. In this study he compared the caries incidence in sound permanent teeth, already present in the mouth at the beginning of the study period with permanent teeth erupting during the study period.

His conclusions can be compiled as follows:

Teeth which were already present in the mouth also show a protection by the use of fluoridated water.

Teeth which had most recently erupted were those which were most protected against caries attack.

Caries free teeth present in the mouth at the start of the study showed less caries reduction by fluoride than those erupting during the exposure period.

Klein was the first to demonstrate clearly a reduction in caries increment by solely posteruptive use of fluoridated water. Moreover, the higher reduction in the teeth erupting during the study suggests an extra protection if fluoride is present just before and just after eruption.

However, the teeth most at risk - thus with caries at the beginning of the study - were excluded from the group "erupted at the start of the study". The difference between the two groups of teeth - (1) erupted and caries free and - (2) not erupted - is, that the not erupted teeth have a much shorter period "at risk" than those already erupted.

In 1948 Klein examined several groups of 15 - 19 years old lifetime residents and immigrants in New Jersey (1.3 - 2.2 mg F^-/l). He compared groups of children who consumed (naturally) fluoridated water during different periods with children of the same age from the non-fluoride towns of Hagerstown and

Williamstown-Clayton (Klein, 1948a and 1948b). Children who had consumed fluoridated water from birth onward showed the greatest reduction of dental caries. Migrants showed smaller reductions (see table 2-4).

If the children were classified according to the age at which the consumption of fluoridated water started (0, 5, 10 and 15 years), the reduction decreased as the age at start of the consumption increased.

The data in table 2-4 show that the caries reduction increases as the age at which the consumption starts decreases. The reduction observed in the front teeth and the premolars of children who had consumed fluoridated water from the age of 10 years onward must be due to a posteruptive effect of fluoride. The fact that a higher reduction is attained if fluoridated water is used from birth suggest the existence of a pre-eruptive effect.

Table 2-4: The DMF-T per 100 children of different teeth in 15-19 years old children moving to the New Jersey area (1.3 - 2.2 mg F^-/l) (Compiled from Klein, 1948b, table 4).

	I1sup.	I2sup.	Csup.	P1s+i.	P2s+i.	M1s+i.	M2s+i.
start of F^- use at 15 years	51	49	11	60	107	278	180
Percentage reduction of DMF-T with respect to this group in children who started to consume F^-:							
at 10 years	10	20	18	33	50	-10	16
at 5 years	57	55	100	45	60	9	25
from birth	100	100	100	77	93	59	76

2.3.1.4 McKAY (1948) published a study concerning seven five-year age groups from 10 to 40 years from Madison (0.05 mg F^-/l) and from Colorado Springs (life-long 2.6 mg F^-/l from a natural source). These were also compared with 218 immigrants coming into Colorado Springs who had dental fluorosis. The author concluded that:

> "the inhibitory effect, once acquired, is permanent and is not diminished by later migrations. It is not necessary that the use of fluorinated water be continued", but he also stated that "teeth formed prior to the use of fluoridated water may experience some benefit."

In a review about waterfluoridation four years later the same author stated that: "...it is not necessary to continue use of fluoridated water after the enamel has been calcified" (McKay, 1952).

2.3.1.5 RUSSELL (1949a) examined 339 children from Mitchell (South Dakota), 11 - 15 years of age, who had consumed accidentally fluoridated drinking water containing 1.15 mg F^-/l during 18 months after birth and prior to the eruption of the first molar (age 0 - 5 year). About 5% of the boys and about 10% of the girls showed very mild or mild dental fluorosis, demonstrating the presence of fluoride during calcification. However, no inhibition of dental caries could be demonstrated in this group, either compared with a retrospective controlgroup or with children of the same ages in Hagerstown (no fluoride). He finally concluded that:

> "these findings tend to weaken the hypothesis that the mechanism whereby dental caries is inhibited through exposure to fluoride-bearing drinking waters depends essentially upon the deposition of fluorine in dental enamel during the period of calcification."

In the second part of his study Russell (1949b) compared the DMF-T index of continuously resident children of Mitchell with that of immigrant children with a previous fluoride exposure of at least 1.0 mg/l during at least one year and at most 11.8 years.

The children were divided into three age groups 8 - 10, 11 - 13 and 14 - 16 years old respectively and into three groups according to the exposure to fluoride:

A. Continuously resident children (no fluoride, except for the 14-16 years old children who were exposed to accidentally fluoridated water (1.15 mg/l) during 18 months prior to eruption.

B. Children with fluoride exposure of about 2.0 mg F^-/l entirely prior to the age of six years (mean period of exposure 3.6 years).

C. Children with exposure of about 2.0 mg F^-/l both before and after the age of six years, ranging from a period of seven years for the 8 - 10 years old children to 11.8 years for the 14 - 16 years old children.

Group A did not show any reduction as was demonstrated before (Russell, 1949a) and can be considered as a control group.

Group B showed only a small reduction for the 8 - 10 years old children as compared with group A.

Group C showed a marked reduction of dental caries in the 11 - 13 and 14 - 16 years old age groups.

Based upon these studies Russell also defined the following working hypothesis:

1. Fluorides may be incorporated into tooth enamel either during the process of calcification or after eruption and when so incorporated are effective in the inhibition of dental caries.

2. This inhibitory effect tends to persist as long as fluoride exposure is continued but tends slowly to be lost after fluoride exposure is discontinued, particularly in teeth highly susceptible to caries; hence

3. Periodic or continuous renewal of the fluoride content of tooth enamel is required for maintainance of the maximum caries-inhibitory effect.

Items 2 and 3 of this working hypothesis mean an important extension of the conclusions expressed by Klein (1948a) and McKay (1948) one year before. Still some additional comments can be made to the observations by Russell:

Prior to the age of six years about 50% of the first molars has already erupted (Schilstra, 1961; Carlos and Gittelsohn, 1965). The caries reduction in a part of the children of group B could also be ascribed to the posteruptive exposure of early erupting first molars. This exposure happened during a short but very important period, namely during and immediately after eruption, a stage often called the posteruptive maturation. So it is difficult to discriminate if the inhibition of dental caries in group B has been caused by pre- or by posteruptive exposure or both. The data of his study suggest anyhow that in order to maintain a reduction obtained by pre-eruptive use of fluorides it is necessary to continue the use fluoride posteruptively.

2.3.1.6 GRAINGER and Coburn studied caries scores of surfaces in deciduous and permanent first molars as related to the age of children upon moving into the fluoride regions of Aylmer (1 mg F^-/l) and South Dorchester (0.8 mg F^-/l) in Ontario, Canada (Grainger and Coburn, 1955).

The first permanent molar of 9 - 13-year-old children with a mean age of 11.5 years, who had started to consume fluoridated water before the age of five years, showed less dental caries than that of children who moved into the fluoridated region after their sixth birthday. The earlier they moved into the F^- area between the age of 3 1/2 and six the greater was the difference and it became maximal if they had moved at the age of 3 1/2 years or before.

It is striking that this effect was much more pronounced in occlusal fissures and buccal or lingual pits than in the mesial and distal surfaces.

According to the author his findings are in agreement with Weaver's observation "... that the theoretically possible topical effect from drinking such a low concentration of F^- is slight."

Grainger also stated that "...although initial lesions might form, the caries penetration might be retarded in the teeth of individuals exposed to fluoride at the later stages of secondary calcification."

2.3.1.7 EVALUATION

The review of these studies reveals a shift in the opinion about the effect of fluoride:

At first it was thought that pre-eruptive use provided a life-long protection against dental caries. As has been pointed out above, this was probably suggested by the fact that the incorporation of higher concentrations of fluoride also permanently affected the structure of the hard dental tissues and so caused mottled enamel. McKay even persevered in his opinion about the permanent protection by pre-eruptive fluoride consumption in his paper from 1952 (Weaver, 1944; McKay, 1948, 1952; Grainger and Coburn, 1955).

However, the studies by the other authors also demonstrated caries reduction in a greater or lesser degree by posteruptive consumption of fluoridated water (Klein, 1945, 1946; Russell, 1949a, 1949b).

Controlled experiments with artificial water fluoridation enable to give more detailed information about this subject, because some of the parameters such as the concentration of the F^- in the drinking water, the relation between the start of F^- consumption and the age of the subjects is then known much more precisely.

Table 2-6: Summary of artificial water fluoridation studies reviewed in this chapter.

Study- and controltown + ppm F^-	Country	Date of start	Author and year of publication	Age groups (years)	teeth or surface	clinical and/or X ray	control
Grand Rapids (1.0) Muskegon (0.2)	USA	01.01.45	Arnold, 1957	6 - 17	all T	c	retro
			Arnold, 1962	12 - 17			
			Hayes et al., 1956	17	M1 T	c+r	control
Newburgh (1.2) Kingston (0.05)	USA	02.05.45	Ast et al., 1956	6 - 16	all S M1, M2	c+r	control
Tiel (1.1) Culemborg (0.1)	Nether-lands	09.03.53	Backer Dirks et al., 1961a	10 - 15	all S	r	control
			Backer Dirks et al., 1961b	9,12,13	all S	c+r	control
			Backer Dirks et al., 1961c	10 - 15	all S	c+r	control
			Backer Dirks et al., 1963	8 - 15	all S	c+r	control
			Backer Dirks, 1966	7 - 15	all S	c+r	control
			Backer Dirks, 1967	7 - 15	all S	c+r	control
			Kwant et al., 1969	7 - 15	all S	c+r	control
			Kwant et al., 1972	7 - 15	all S	c+r	control
			Kwant et al., 1973	7 - 15	all S	c+r	control
Hastings (1.0)	New Zealand	1954	Ludwig, 1985 Ludwig and Pearce, 1963 Ludwig, 1965 Ludwig, 1971	5 - 16	all S	c+r	retro
Brandon (1.0)	Canada	01.03.55	Connor and Harwood, 1963	6 - 14	all T M1 T	c	retro

2.3.2 Dental caries in relation to the period of consumption of fluoridated water: Survey of relevant studies

A survey of the controlled water fluoridation projects and the publications discussed below is presented in table 2-6. Appendix A shows, for convenience, a schematical outline of each of these studies. The conclusions of each author are discussed below.

2.3.2.1 GRAND RAPIDS - MUSKEGON studies

Dean and, after his retirement ARNOLD published a series of papers about the first intervention study concerning fluoridated water (Arnold et al., 1953, 1956, 1962; Arnold, 1957a). In January 1945 the fluoride concentration of the drinking water in Grand Rapids was adjusted to a level of 1 mg/l while Muskegon served as a control town. However, six years later also in Muskegon the water was fluoridated so that children from this town could not serve anymore as a reliable controlgroup. From this moment on Arnold used a retrospective controlgroup from Grand Rapids (children of the same age groups examined in 1944) for the study.

Arnold examined groups which started the consumption of fluoridated water at different ages and observed a decrease in the percentage reduction of DMF-T combined with an increasing age at start. However, groups with a higher age at start of the fluoridation were also examined at a higher age.

Longitudinal studies, however, have demonstrated that the percentage reduction in DMF-T tends to decrease with increasing age. Backer Dirks (1967), who published longitudinal caries data of the first molar, compared children from Tiel who had started to drink fluoridated water at the age of three years and nine months with a group born in the same year from Culemborg who had used fluoride-free drinking water. His study revealed that between the examination ages of 9 and 15 years the reduction was remarkably stable in the buccal smooth surface and the proximal surfaces. However, the percentage reduction in the pits and fissures decreased in this period from 29 to 11. Since for this tooth the caries of the pits and fissures forms such a large part of the total caries score, the DMF-T is mainly determined by the DMF-S of fissures and pits. This means that in the first molar the percentage reduction of DMF-T also decreases at increasing age.

An explanation for this phenomenon could be that the caries attack in Culemborg is so strong that nearly all surfaces are already decayed, whereas in Tiel still lesions can develop. In this case fluoride should only retard the development of carious lesions.

Arnolds way of comparing the percentage reduction in two different age groups, which had also different ages at the start of the water fluoridation, makes it impossible to draw any definite conclusion about the exact age at which the caries reducing action of fluoride administration starts. Besides, the total DMF-T index which is published makes further differentiation impossible.

These problems are also encountered in other papers from that period with the same design, one by the same author (Arnold, 1962) and others by Ast et al. (1956 and 1962). The study by Backer Dirks et al. (1961a) also has the same design, but these authors use data of separate surfaces.

In the paper of 1962 Arnold observed that there was a 50 to 63% reduction of DMF-T in children born shortly after the start of the fluoridation (aged 12 to 14 years in 1959) and 48 to 50%

in children less than two years of age at the start of the fluoridation (aged 15 to 17 years in 1959). The use of DMF-T and the different examination ages of these two groups of children are the cause that the data are not fully comparable. As a result the conclusion that consumption of fluoridated water starting shortly after birth would result in a greater reduction than if it starts at the age of two years can not be confirmed by this method.

Using data obtained from the same fluoridation project HAYES et al. (1957) analysed separately the data of the first molar at 16 years of age. He could demonstrate a topical effect for all surfaces of the first molar. Hayes also showed that the percentages reduction of the first molar for the different types of surfaces varied with the larger values for the buccal and lingual surfaces.

2.3.2.2 NEWBURGH - KINGSTON study

In the study of AST et al. (1956) a decrease of reduction can be observed as the age at examination increases, even in those children who had used fluoridated water since birth. For this feature is referred to the comment on the study by Arnold.

He compared the DMF-T of the first and the second permanent molar at the same age. This is not correct since the former erupts at about the age of six whereas the latter erupts at about the age of 12, resulting in a six years longer exposure to caries attack for the first molar than for the second. Comparison of the DMF-index of the first molar at 6-9 years with the second molar at 13 years, and the DMF of the first molar at 10-12 years with the 16 years old for the second molar would be better and shows an about equal reduction (see table 2-7).

Table 2-7: Percentage caries reduction in first and second molars after comparable posteruptive periods (compiled from table 4 & 6, Ast et al., 1956). - = no data available.

M1			M2		
Age (years) at examination	at start F/H2O	Percentage reduction	Age (years) at examination	at start F/H2O	Percentage reduction
6- 9	0-1	53	13	3 - 4	51
10-12	1-3	30	16	6 - 7	29
13-14	4-5	14	-		
16	7/8	4	-		

In the age group of 10-12 years in the fluoride free town of Kingston nearly all first molars are already carious. As a consequence there is only a very limited increase until the age of 16. In the fluoridated town of Newburgh, however, an increase of the percentage of carious first molars between the age of 10-12 and 16 years is still possible and can be observed, until at the age of 16 years the same level as in Kingston is nearly reached. The second molar shows an increase of DMF-T between the ages of 13 and 16 years in both towns. Also in this tooth the reduction decreases from 51% at the age of 13 years to 29% at the age of 16 years. This could be an indication that fluoride only retards the development of dental caries.

Regrouping of the data of this study in the way it has been done above, shows that for both teeth in the first years after eruption the percentage reduction decreases with age.

2.3.2.3 TIEL - CULEMBORG study

Discussing the results after 5 1/2 years of fluoridation Backer Dirks and coworkers tried to understand the differences in caries inhibition for various teeth and tooth surfaces as an expression of a difference in fluoride accessibility (Backer Dirks et al., 1961b).

The results showed a marked reduction of caries experience for the buccal and distal surfaces of the first molar solely by the use of fluoridated water after the eruption of these molars.

They observed a reduction of 10% in occlusal surfaces of the first molar in 12-year-old children, who had started to consume fluoridated water at the age of seven years, whereas nine years old children, who had started consumption at the age of four years showed a reduction of 29%.

This difference is probably due to the fact that the latter group received fluoride before and during eruption, whereas the former only received fluoride posteruptively.

Protection during the period of eruption may be especially important for the occlusal fissures since they tend to become carious soon after eruption.

The mesial and distal surfaces of the first molar in twelve years old children from Culemborg had a DMF-S index of 1.5 and 1.1 respectively and in children from Tiel, who had started to consume fluoridated water at the age of seven years, 1.3 and 0.8 respectively. For nine years old from Culemborg these indexes were 0.8 and 0.4 respectively, whereas in children of that age from Tiel who had started to drink fluoridated water at the age of four years the same surfaces showed 0.4 and 0.2 DMF-S respectively per child.

In the twelve-year-old children from Tiel (start of F^- consumption at the age of seven) the authors observed a much smaller caries reduction in the mesial than the distal surface, whereas in the nine-year-old children (start of F^- consumption at the age of four) the percentage reduction in these two surfaces showed no difference. They gave the following explanation for this fact:

A. Higher caries-susceptibility of the mesial surface caused by the contact with the distal surface of the deciduous second molar, which also causes a relatively poor condition for posteruptive fluoride adsorption.

B. The lack of protection immediately after eruption in children aged seven years at the start of the water fluoridation. For the distal surface this is of less importance since this is a free smooth surface and since the formation of lesions starts later at this surface.

In another paper published in that year the same authors presented the results after 6 1/2 years of fluoridation (Backer Dirks et al., 1961a (Dutch version) and 1961b (English version)). The assumption that maximal inhibition of the proximal caries occurs if the children receive fluoridated water from the age of five years was made in a rather early stage of this water fluoridation project, even too early to draw any reliable preliminary conclusion about the relation between the age at start of the fluoridation and the maximal effect. For a definite conclusion it is necessary to have the data of children who consumed fluoridated water from birth onward.

In 1966 Backer Dirks studied the relation between the percentage reduction and the age at start of the fluoridation for the distal surface of the first molar (Backer Dirks, 1966). One year later he did the same for the different surfaces of the same tooth (Backer Dirks, 1967). Figure 2-1 shows the percentage reduction of cavities in the different surfaces of first molars in nine groups of 15-year-old children from Tiel, compared with the same surfaces in children from Culemborg. In Tiel each successive group started to use fluoridated water at a younger age between 15 and three years.

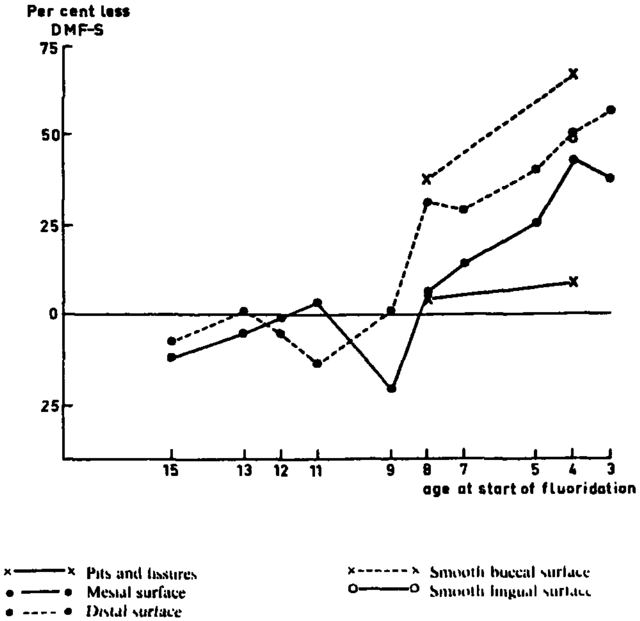


Fig. 2-1: Percentage less DMF or DF surfaces in ten groups of children aged 15 years each with a different age at start of the water fluoridation in Tiel (Backer Dirks, 1967).

Although the design of this method was excellent to assess the effect of the use of fluoridated water in a surface of one tooth posteruptively and additionally also pre-eruptively, it was at that moment not yet possible to show the data of those groups which started consumption before the age of four years since fluoridation started in 1953. The period of use before eruption was too short to assess the effect of the use of fluoridated water during the whole pre-eruptive period.

KWANT evaluated the Tiel - Culemborg project after 13 1/2 years of fluoridation (Kwant et al., 1969).

In this paper the authors compared teeth with a different age at the start of the fluoridation. Figure 9 of this study, showing the different stages of development of the premolars and molars at the start of the water fluoridation has been reproduced below (fig. 2-2).

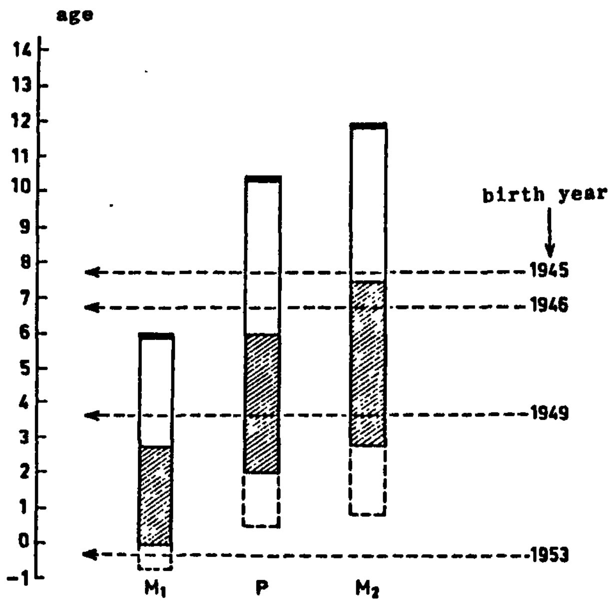


Fig. 2-2: Stage of tooth development at the start of the fluoridation. The arrows indicate the mean age at start of the water fluoridation for children born in 1945, 1946, 1949 and 1953. The dotted part of the columns represents the period of matrix formation and the shaded part represents the period of calcification. The top of the stave indicates the mean time of eruption.

Already after four years of fluoridation a significant caries reduction of the proximal surfaces is obtained in children whose age ranged from 11 - 15 years. As the authors stated, the elder children in each group from Tiel started consuming fluoridated water at a higher age. Besides, they have more cavities than the younger children of the group, so that they have a relatively great influence on the total number of cavities if groups are taken together.

From the statement of these authors that the maximum effect might become greater than that registered in 1965, because not all children had consumed fluoridated water from birth onward, it can be deduced that they too supposed the existence of a reducing effect of pre-eruptive fluoride consumption.

The data of 10 longitudinal groups followed from 7 to 15 years of age showed a small caries reducing effect for the pits and fissures of the first molar by posteruptive consumption. If also fluoridated water was consumed during the pre-eruptive phase from birth on, the reduction increased up to 65% at seven years. However, this effect decreased to 30% at the age of 13. Already after the age of nine, the caries increment of this surface is greater in Tiel than in Culemborg. Also these data form an indication that fluoride should retard the development of dental caries.

The free smooth surfaces also showed a very important caries reducing effect when fluoride was used only posteruptively. Simultaneously, just as in the proximal surfaces, there is a considerable increase in the number of carious lesions in children from the control town of Culemborg born in later years and examined at the same age during the study period (1953-1965).

As compared to children in Culemborg children in Tiel, aged eight and seven years at the beginning of the water fluoridation had a caries reduction of 66 and 70% respectively in smooth surfaces at the age of 13 and 12 years. They showed only a small number of cavities. Between these ages and the age of 15, however, this number was nearly doubled, though still numerically very small. The percentage reduction remained unaffected.

The results of this study give rise to a few comments:

- For a more precise assessment of the effect on the caries experience by solely posteruptive consumption of fluoridated water, versus pre- and posteruptive consumption, data of all teeth and surfaces have to be available separately.

- The increase of the percentage reduction in the free smooth surfaces between children born in Culemborg and Tiel either eight years before (1945) or one year after (1954) the start of the water fluoridation in Tiel is mainly due to the increase of dental caries in Culemborg. Therefore the difference in caries prevalence of the free smooth surfaces of children born in Tiel in 1945, 1949, 1953 and 1954 is small. However, because of the important increase of dental caries in Culemborg between 1950 and 1965, the relative contribution to the total effect by additional pre-eruptive consumption of fluoridated water is much greater if each group of Tiel is compared with its control group in Culemborg .

Kwant et al. also discussed the results of the caries study after 16 1/2 years of water fluoridation in Tiel (Kwant et al., 1972; Kwant et al., 1973).

Since children born in Tiel aged 15 years, had consumed fluoridated water from birth onward it could be seen that the maximum effect of fluoridation is reached when fluoride is available from birth.

According to the authors water fluoridation caused a significant posteruptive caries reduction in the free smooth surfaces

They observed also that for the proximal surfaces the maximum effect was reached if fluoridation started when the children were about one year old. According to the authors consumption of fluoridated water during pregnancy did not cause an extra inhibition of dental caries in these surfaces.

A striking difference between the 1972-publication and the one from 1973 occurs at the interpretation of Fig. 4 concerning a longitudinal survey of proximal cavities in children born in 1944, 1949 and 1954. In the former paper the authors stated that between the caries scores of children born in 1949, with a mean age of 3 3/4 years at the start of the fluoridation, and of children born in 1954, one year after the start of the water fluoridation, who must have benefitted maximally, there is such a small difference, that it appears that the minimal value already has been reached in the former group. In the 1973 study, however, they added that:

> "because of the constant increase in the number of lesions since 1953 each class must be compared with his own control group, in this case the class born in Culemborg in 1949".

Concluding from this correct way of comparison it appears that the percentage reduction is 10% smaller in children aged 3 3/4 year at the start of the water fluoridation than in the group which was born in that year (see table 2-8).

The longitudinal study of children from Culemborg and Tiel, who were nine-year-old at the start of the fluoridation, showed the same DMF-S for proximal surfaces in both towns at the age of 11. However, from then on the caries increment in Tiel was less than in Culemborg, which resulted in a 30 % reduction of caries increment between 11 and 15 years. This could point to a posteruptive effect of fluoride.

Table 2-8: The DMF-S and the caries reduction in proximal surfaces in 15-year-old children from Culemborg and Tiel who were resp. 3 3/4 and -1 1/4-year-old at the start of the fluoridation.

Year of examination	DMF-S proximal surfaces Culemborg	Tiel	percentage reduction
1949	7.5	2.6	65%
1953	9.7	2.3	75%

The DMF-S for fissures and pits in premolars and molars of children born in 1945, 1946, 1949, 1953 and 1954 showed a smaller difference between the two towns than that for the proximal surfaces. "The curves for the Culemborg children are very similar. They show that the number of new pit and fissure cavities per year has remained almost stable throughout the study in contrast to the increasing number of proximal lesions."

In Tiel the number of cavities decreased with each succeeding year of birth. The difference between children born in 1953 and those born in 1954 could either be caused by chance or might be an indication of an effect caused by prenatal administration of fluoride.

Palatinal pits in front teeth showed an almost equal reduction for 15-year-old children from Tiel born in 1949, 1953 and 1954 (thus +4, 0, and -1 year of age at start of the water fluoridation) 65%, 65% and 71% respectively, which means that hardly any effect of fluoridation before the age of four years can be observed.

The data of the pit and fissure cavities in the first and second molars and the premolars provide a rough idea about the additional contribution of pre-eruptive fluoride to posteruptive consumption only, at the age of 15. They are compiled in table 2-9.

Table 2-9: reduction of fissure and pit caries in 15-year-old children from Tiel who had started to consume fluoridated water at different ages with respect to comparable children from Culemborg (from Kwant et al., 1972).

year of birth	1945	1949	1953	1954
mean age at start F/H2O (1953)	7 3/4	3 3/4	-1/4	-1 1/4
number of children (C/T)	100/100	107/109	126/138	135/147
FIRST MOLAR %reduction	8	11	23	30
PREMOLARS %reduction	14	50	64	56
SECOND MOLAR %reduction	15	38	43	42

The first molar erupts at about the age of 5 1/2 - 6 1/2 years. Through the posteruptive use of fluoridated water there are between 8 and 11 per cent fewer fissure and pit cavities. By an additional pre-eruptive use of fluoride the reduction rises up to 30%. Maximally seven percent of this reduction (= 2.1% of the total) could be due to prenatal fluoridation, but can also be the result of standard error.

The premolars erupt between the age of 10 and 12 years. Also for these teeth it can not be assessed what is the effect of pre- and posteruptive supplementation of fluoride. The differences between the percentages of 1949, 1953 and 1954 show that the variation is very large. Nevertheless the difference between 1945 and 1949 shows that if consumption of fluoridated water starts between the age of eight and four years there is still an increase of the effect which can be attributed to the use of fluoridated water before eruption.

The second molar erupts at about the age of 12 and it is impossible to calculate the effect of posteruptive fluoridation only because relevant groups are not studied. The figures, however, show that fluoridation in an early stage of tooth development (start between age eight and age four) causes a considerable augmentation of the effect.

2.3.2.4 HASTINGS study

Comparison between the examinations by LUDWIG and Pearce from 1963, 1965, 1971 and the base-line data from 1954 reveals that free smooth surfaces show the greatest reduction. Proximal surfaces also show a considerable reduction. Both reductions increase if consumption of fluoridated water starts at a younger age. The occlusal surfaces show a much smaller reduction which hardly increases under this condition.

This increase of reduction between the 1963 and the 1971 study suggests the existence of a supplementary caries reducing effect by pre-eruptive fluoride administration. Initially Ludwig had chosen a study design with a control town (Napier). Because of the presence of molybdenum in the diet, this town was, - as appeared later, - not reliable anymore as control. This is the reason that the actual design of the study is not fully suited to discriminate between a pre- and posteruptive effect, since a retrospective controlgroup was used.

Nevertheless, comparison of the percentages reduction of the three types of tooth surfaces (occlusal, proximal and free smooth) in 15- and 16-year-old children, as presented in table 2-10, can provide some indication of the effect of posteruptive use of fluoridated water only versus pre- and posteruptive use. The children were examined in 1963, 1964 and 1970, and they were 6 and 7, 5 and 6, and 0/ -1 year of age respectively at the start of the water fluoridation,

Comparison of the percentage reduction between 15-year-old children in 1963 and 16-year-old in 1964, which group partly consisted of the same children, (aged six years at the start of the water fluoridation) shows that these are about the same for each category of tooth surfaces. Only in the group of the free smooth surfaces a decrease of reduction could be detected.

Comparison, however, between the percentages reduction within an age group in the different examination years (1963, 1964 and 1970) shows a marked increase of reduction for the occlusal and proximal surfaces in the 15- and 16-year-old group, whereas the free smooth surfaces again show only a small increase. From these results it could be concluded that at the age of 16 the percentage reduction of caries in occlusal and proximal surfaces doubles if the use of fluoridated water had started at birth instead of at the age of six years, whereas in the free smooth surfaces an earlier start of consumption causes hardly a greater reduction.

TABLE 2-10: Percentages reduction of dental caries in occlusal, proximal and free smooth surfaces of 15- and 16-years-old children from Hastings examined in 1963, 1964 and 1970, compared with the base-line examination in 1954 in the same town. (Compiled from Ludwig, 1963, 1965 and 1971).

Surfaces	Occlusal			Proximal			Free smooth		
Year of examination	1963	1964	1970	1963	1964	1970	1963	1964	1970
Percentage reduction:									
at age 15:	30	38	39	46	58	73	82	84	87
age at start F/H2O:	6	5	-1	6	5	-1	6	5	-1
at age 16:	15	30	34	33	47	67	71	70	88
age at start F/H2O:	7	6	0	7	6	0	7	6	0

2.3.2.5 BRANDON study

In the study by CONNOR (1963) the existence of a posteruptive effect can be concluded from the data concerning 12 - 14-year-old children. This effect is rather small except for the upper incisors where the contribution of posteruptive consumption to the reduction is much larger than that of an additional pre-eruptive consumption. On the other hand the data of the first molar in 12 - 14-year-old children suggest that in these teeth no posteruptive reduction is present.

This author also presumes the existence of a pre-eruptive caries reducing effect of water fluoridation, which is confirmed by his remark that another survey will probably be carried out in 1966 when the maximum benefit of water fluoridation would be evident in the 6 - 8 and 9 - 11 year age groups. Unfortunately no publication of such an examination could be found.

2.3.3 Reviews about pre- and posteruptive caries reduction

Reviews about different water fluoridation projects discussing also the pre- and posteruptive effect have been published by ARNOLD (1957b), MARTHALER (1960, 1967, 1979) and BACKER DIRKS (1963). Horowitz (1973) also reviewed the various ways of systemic and topical fluoride administration without, however, discussing to which extent the effect is due to pre- or posteruptive administration.

A few outlines of the reviews by the first three authors will briefly be discussed below.

2.3.3.1 Arnold discussed a.o. the results of the Grand Rapids - Muskegon study, the Brantford study and the Newburgh - Kingston study.

About the Grand Rapids study he communicated that:

> "When the study was started it was generally assumed that the beneficial effects of fluoridation, if they did occur, would be observed in persons whose teeth were formed while the individual was using fluoridated water supply. Little if any benefit was expected on teeth which had already been formed."

Comparing the results of 16-year-old children in the period 1945 - 1954, who were 16 - 7 years old at the start of the fluoridation (see Appendix A) he stated that:

> "...there have been definite and significant reductions in dental caries prevalence in this group of children."

The upper half of table 3 of his paper, referring to the Grand Rapids - Muskegon study is represented below in table 2-11.

Table 2-11: DMF-T of permanent teeth in children 5-16 years of age from Grand Rapids (Mich.) in different years of examination.

DENTAL CARIES FINDINGS, PERMANENT TEETH IN GRAND RAPIDS AND MUSKEGON, MICHIGAN, SCHOOL CHILDREN 5-16 YEARS OF AGE, ACCORDING TO YEAR OF EXAMINATION

Age last Birth-day	Basic Exam. 1944-1945	Average Number of DMF [1]) permanent teeth per child [2]) GRAND RAPIDS, MICHIGAN									
		1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
5	0.11	0.08	0.05	0.04	0.04	0.03	0.03	0.05	0.02	0.02	0.02
6	0.78	0.56	0.23	0.37	0.26	0.38	0.26	0.26	0.23	0.19	0.19
7	1.89	1.72	1.11	1.09	1.04	0.76	1.03	0.84	0.90	0.71	0.69
8	2.95	3.27	2.54	2.62	2.30	2.16	1.77	1.58	1.50	1.41	1.27
9	3.90	—	2.98	3.12	2.67	2.48	2.38	2.04	2.02	1.83	1.97
10	4.92	—	3.70	3.56	3.51	3.56	3.17	2.93	2.71	2.41	2.34
11	6.41	—	4.24	3.56	4.32	4.69	4.36	3.67	3.49	3.12	2.98
12	8.07	9.53	7.62	7.03	8.32	7.02	7.10	5.89	5.04	4.76	3.87
13	9.73	10.76	8.92	8.47	8.34	8.11	7.21	6.60	5.87	5.12	5.05
14	10.95	11.90	9.41	9.50	9.41	8.90	8.55	8.21	7.23	5.92	6.78
15	12.48	12.68	11.26	11.94	10.61	11.80	10.12	8.91	9.04	9.75	8.07
16	13.50	13.00	9.33	12.47	13.50	11.83	11.35	11.06	10.14	9.53	9.95

A longitudial section has been made for children born in 1940, 1941 and 1942, who were 5, 4, and 3 years old respectively at the start of the fluoridation, by putting ___, - - - and .... under the DMF-T figures in order to follow these three groups between the age of 5 and the age of 15 years.

There is an increasing reduction for each group which benefitted from waterfluoridation in an earlier stage of tooth development. Cross-sectional comparison of age-groups shows that this trend continues till the group which consumed fluoridated water from the age of one year onward. This can be considered to be an indication for the existence of a pre-eruptive effect.

2.3.3.2 Marthaler (1960) discussed the publications by Klein (1946), Russell (1949a and 1949b), Ast et al. (1956), Arnold et al. (1956) and Arnold (1957a and 1957b). He summarized the results of the studies of Klein and Russell in the following observations:

1. Teeth influenced by fluoridated drinking water only before eruption are more resistant towards caries. This resistance will disappear in subsequent years. Thus, the protection is assumed to be a reversible one.

2. Teeth exposed to fluoridated drinking water from the time of eruption also show protection against caries attack.

3. There is a smaller degree of protection by exposure to fluoridated drinking water beginning some years after eruption has been completed.

Analysing the results of the Grand Rapids study as published by Arnold et al. (1956) and Arnold (1957a), and of the Newburgh - Kingston study as published by Ast et al. (1956) Marthaler made the following statements:

1. More than half of the dental enefit to be expected from water fluoridation is obtained when the fluoridation starts at the age of five years.

2. With each year the fluoridation sets in before the sixth year of life, the protection is increased.

3. The uptake of fluorine does not necessarily have to take place in a specific stage of the enamel development. A protective effect may be attained during calcification as well as during

enamel maturation before or after eruption.

4. Little or no additional protective effect is produced when fluoridated drinking water is already available to the mother during pregnancy.

Marthaler also stated that five-year results of water fluoridation studies can lead to misinterpretation.

The same author discussed the literature concerning water fluoridation seven years later (Marthaler, 1967) in a study comparing this method of caries prevention with other methods of increasing fluoride ingestion using tablets, domestic salt and milk as fluoride carriers.

He stated that: "...the first two years of life are unimportant for the protection of permanent teeth. On the other hand it seems to be essential that the fluoride supplement is continued throughout life.

The author repeated these statements one year later (Marthaler, 1968)

In another extensive review (Marthaler, 1979) the author discussed besides the publications mentioned in the previous review also papers dealing with waterfluoridation by Arnold (1962), Russell and Hamilton (1961), Backer Dirks (1963), Connor and Harwood (1963) and Kwant et al. (1973). The results were compared with those of systemic fluoride administration by tablets and salt.

He stated that: "during the last two decades interest has shifted from systemic to topical effects of fluoride." As a result of the analysis in this study the author concludes that it "...indicates that systemic fluorides are important for obtaining maximum benefit regarding pit and fissure caries and, to a lesser degree, regarding approximal surfaces. However, continued post-eruptive supply of fluorides is indispensable since otherwise the advantage of systemic fluoride will be lost."

2.3.3.3 Backer Dirks (1963) compared the results of the Culemborg - Tiel study with those from fluoridation studies in the USA. He presented caries data for the different types of toothsurfaces separately, especially of the first molar. However, for the assessment of the pre- and posteruptive effect he compared children of different ages who also started the consumption of fluoridated water at a different age, which is not a correct way of comparison (see comment to the study by Arnold above). He stated that if the fluoridation started at the age of four and five years the effect on the number of proximal surfaces was still about maximal.

For the pits and fissures it seemed that "... to produce an effect fluoride must be present in an early stage of tooth formation."

The smooth buccal surfaces, studied in the first molar showed the highest protection and they were also the surface with the greatest reduction caused by the use of fluoride during the posteruptive phase only.

2.3.3.4 The more recent literature about pre- and posteruptive effect of water fluoridation is mainly based upon the studies listed above. Apart from these also fluoride tablet studies (see review by Horowitz, 1973 and Marthaler, 1979) and experimental caries in rats (see review by Larson, 1977) have been used to study the pre- and posteruptive reduction on caries increment.

The difficulty with fluoride tablets, however, is, that users and/or their parents mostly have a greater overall dental awareness, which is hardly to exclude. The problems related with the study design have been discussed recently (Tijmstra, 1985; Widenheim et al., 1985).

A condition for the existence of an effect of prenatal use of fluoridated water is that an effect of pre-eruptive use is present in any case. The existence of an effect of the consumption of fluoridated water prenatally was suggested by Blayney and Hill (1964) and Tank and Storvick (1964).

Carlos et al. (1962) studied the effect of extra prenatal use of fluoridated water in deciduous teeth of children living in Newburgh. Backer Dirks (1967) used data from Grand Rapids and Muskegon for his study of the same subject and Horowitz (1967) carried out a study in Minneapolis. In none of these three studies an extra effect of the use of fluoridated water in the prenatal period on dental caries could be found.

Nevertheless, the possibility that maternal ingestion of fluoride before birth would cause a supplementary caries reduction was the subject of a symposium in 1980 (Driscoll, 1981; Glenn, 1981; Stamm, 1981; Stookey, 1981; Thylstrup, 1981). However, all authors, except one, strongly doubt the possibility of any benefit to the permanent teeth of prenatal fluoride administration.

Studies and reviews from the last decade, especially those from Scandinavia more and more stress on the topical effect of fluoride, stating that systemic effects are of borderline significance (Fejerskow et al., 1981; Thylstrup et al., 1982).

3.0 A THEORETICAL MODEL FOR A CLINICAL STUDY TO ASSESS THE RELATIVE CONTRIBUTION OF PRE- AND POSTERUPTIVE FLUORIDE ADMINISTRATION THROUGH FLUORIDATION OF DRINKING WATER TO THE REDUCTION OF DENTAL CARIES EXPERIENCE

3.1 GENERAL

From the review of the literature it appears that there is no consensus between the different authors about the contribution to the *reduction of dental caries* experience by the consumption of fluoridated water before and after the eruption of a tooth.

Since no fluoridation project has been designed specifically to study this subject a design is proposed of such a study under ideal circumstances and conditions.

The second part of this chapter deals with the application of this method to the Culemborg - Tiel results in order to collect the optimal information about the pre- and posteruptive effect.

The start and the discontinuation of an artificial water fluoridation project are particularly suited for a study of its possible pre- and posteruptive reducing effect on caries experience, because in a cross-sectional study the increasing effect at start and the decreasing effect after discontinuation gives an age-related relation with the reduction of caries experience (DMF-S).

The caries activity varies from tooth to tooth and from surface to surface. Caries is the result of the ecological condition in the local plaque and the caries susceptibility of the local enamel.

To assess the pre- and posteruptive effect of fluoride on various teeth and surfaces the following parameters are of importance:

1. the period of fluoride consumption.
2. the age of the various teeth at eruption.
3. the caries status and the percentage reduction.

3.2 DENTAL ASPECTS AND CONDITIONS

3.2.1 Tooth development, eruption and dental caries

Because the enamel and dentin of deciduous teeth have a relatively short formative period (1 - 1 1/2 years), which would necessitate a high frequency of examination, this study will be confined to permanent teeth. The longer period between development and eruption of permanent teeth allows a longer interval between consecutive examinations. In practice semi-annual or annual examinations will occur. The distribution of birthdates within one year and the variation in the time of eruption of teeth will produce a result which is the average for one year.

Since permanent teeth are erupting at different ages between about the age of five and the age of thirteen years and, since the onset of caries at the various surfaces of each tooth occurs during different age periods, each category of surfaces has to be considered separately in order to obtain a clear image of the effects. Because caries susceptibility for each surface is different, a DMF-S index for each category of tooth surfaces is needed.

For a detailed standardized examination of dental caries in approximal surfaces the use of bite-wing radiographs is essential.

The age of the person examined and the interval between eruption of the teeth and examination has to be known. Moreover, this interval has to be long enough to give dental caries the opportunity to form a cavity. This interval is different for each category of surfaces: in occlusal surfaces caries may start soon after eruption and shows a rapid progression into a cavity; in proximal surfaces caries generally starts later and progresses slowly. Caries in free smooth surfaces i.e. buccal or lingual, may start early, but shows a very slow progression into a cavity (Backer Dirks, 1961).

Because most of the primary carious lesions in permanent teeth develop between the age of about 5 1/2 and 20 years the study has to be focussed on this age group (Barr, 1949; Barr et al., 1957).

3.3 EPIDEMIOLOGICAL ASPECTS AND CONDITIONS

3.3.1 Choice and composition of the groups

As for every intervention study an experimental and a control group are necessary. Because the caries rates were far from stable during the last decades a control group has to be from a comparable non-fluoridated town examined in the same years as the experimental town. A retrospective control group from the experimental town could introduce a substantial bias. Both groups must have the same composition with respect to sex and age and be comparable in social status and dental care. At the base-line examination(s) the groups must be similar with respect to the presence of dental caries.

3.3.2 Fluoride consumption

To study the size of the effect of fluoridated drinking water at different stages of tooth development, the moment of start and end of consumption of fluoridated water and the time of eruption of the teeth studied have to be known. Selfevidently the fluoride concentration of the drinking water has to be kept constant during the study-period, whereas the fluoride content of the drinking water in the control town has to remain low throughout the duration of the study.

3.4 STUDY DESIGN UNDER IDEAL CIRCUMSTANCES AND ITS PRACTICAL IMPLICATIONS

3.4.1 Yearly repeated cross-sectional study with tooth surfaces as the unit of measurement

A yearly repeated cross-sectional study of the same age groups could fulfil the required conditions.

A study period which includes the start and the discontinuation of water fluoridation is optimal for the assessment of the pre- and posteruptive effect.

Persons in experimental and control group of the same age, however, born in successive years, will be examined, at regular intervals so that for each consecutive group their age at start and later at discontinuation of the water fluoridation is decreasing. Hence, fluoride exposure of permanent teeth will range successively from no fluoride at all via fluoride exposure exclusively posteruptively, fluoride pre- and posteruptively and after discontinuation fluoride exclusively pre-eruptively to no fluoride at all.

At the start and after the end of the experiment the minimal number of birth classes which must be included will be equivalent to the age of the persons examined.

Ideally the study should be designed in such a way that the caries in the various categories of surfaces (fissures and pits, proximal, free smooth surfaces), will be examined at the same interval after eruption. This period will be called 'X' and must be long enough for dental caries to develop into a cavity. 'X' will vary for the three categories of surfaces since caries starts at a different time and at a different speed. Presently these intervals will be called respectively: X_o, X_p and X_s and must be known before the study is started. The consequence of this design is that for each tooth type at a different age, series of cross-sectional examinations must be carried out. The great number of examinations makes the execution of this design impossible for practical reasons. Nevertheless this 'ideal' design will be described below with adaptations to the practical situation.

3.4.2 Eruption

Except the third molar, which erupts later, all permanent teeth erupt at different ages between five and 13 years. Each child shows within certain limits different eruption times. Ideally a nearly continuous range of examinations with small intervals of each year class should be undertaken between the age of 5 and the age of 14. Since this is practically impossible a semi-annual or annual interval between examinations could form a compromise. In each child the eruption of each permanent tooth should be recorded at each examination, starting at the age of 5. A period 'X' after eruption of a tooth the caries status of each surface must be examined.

In practice such a study-design is hardly feasable since all year classes should appear each (half) year between the age of five and some years over the age of 13 years to examine the eruption of the teeth and to assess the caries status of only a part of all tooth surfaces.

The different values for X_o, X_p and X_s also cause a rise of the number of examinations and complicate such a study design still more.

3.4.3 Yearly repeated cross-sectional study with children as the unit of measurement

It is more realistic to examine each (half) year children of the same age. If all permanent teeth except the third molars are included in the study, this age must be some years higher than 13 years. The disadvantage of such a study-design is that the posteruptive period is different for the comparable surfaces of the various teeth. In order to rule out results caused only by the period at risk of the teeth, occasionally caries data at a younger age should be known as well.

Using this design, children of the same age in study and control group, born in successive years will be examined. As has been described above the children in the successive years of examination will have had a decreasing age at the start and at the end of the fluoridation.

3.4.4 Study at the start of the fluoridation

The first group of children has to be examined just before or just after fluoridation starts to evaluate the comparability of study and control group. This has been explained in paragraph 3.4.1.

In successive years there will be an increasing period of posteruptive contact with the extra fluoride for the teeth already erupted. Teeth which erupt at start of the fluoridation will show the maximal posteruptive effect. Teeth erupting after fluoridation has started may show - if present - an additional increasing pre-eruptive effect besides the maximal posteruptive effect.

In order to study a maximal pre- and posteruptive effect of fluoride consumption the study has to be continued until it contains a group of children whose first erupting permanent tooth (the first molar) has not yet started to form. Since the formative phases of all teeth start in utero and mineralization of the enamel of the first molar around birth, the study has at least to be continued until the examination of an age-group, which is born nine months after the start of the fluoridation.

This part of the study is suited to study first the separate posteruptive effect and later the supplementary pre-eruptive effect.

3.4.5 Study at the end of the fluoridation

If fluoridation is discontinued the reverse effect will occur of the one at start.

In the cross-sectional study -in which yearly persons of the same age are examined - the first group consumed fluoridated water continuously from conception on. This is just before the discontinuation of the fluoridation. For groups which are born in the following period and examined at the same age this means that posteruptive fluoride consumption ended each subsequent year one year earlier, until it was only consumed during the whole pre-eruptive period, so that teeth erupting at the end of the fluoridation period will show the maximal effect of pre-eruptive consumption without posteruptive continuation.

The persons examined in the years thereafter will have consumed fluoridated water during a decreasing period before the eruption of their teeth. The last groups will use fluoridated water during the first years of life and finally in the prenatal period only, thus in the earliest stage of tooth formation and mineralization.

An aspect involved with the part of the study which deals with the examination of children of the same age at the end of the study-period is, that there will be an increasing interval between the end of the fluoridation and the moment of examination. This implicates that a pre- and/or posteruptive effect which existed at the moment fluoridation was stopped (e.g. at age 10) could have disappeared meanwhile. The decrease of the reduction may become more important if the interval between the end of fluoride consumption and the examination is longer. Anyhow, such possible disappearance of a fluoride effect could give an indication of the importance of life-long fluoride administration.

3.5 SCHEMATIC PRESENTATION OF THE POSSIBLE RESULTS OF A CROSS-SECTIONAL STUDY

A presentation of the cross-sectional study design is given below.

3.5.1 At the start of the fluoridation

With the data obtained by the above-mentioned method it is possible to assess the relative contribution of pre- and posteruptive fluoride consumption to the total reduction of caries experience for each surface of each separate tooth.

For the schematic presentation of the cross-sectional study it is assumed that:

- in each successive year group of the same age the same number of surfaces is at risk,
- formation, mineralization, maturation and eruption of each tooth type took place in the same age periods,
- the surfaces are examined with the same interval after eruption.
- during the first years of fluoridation the pre- or posteruptive contribution to the reduction is a first grade

function of the duration of fluoride consumption until the maximum reduction is attained.

There will be several possibilities. After the start of the fluoridation these are the following:

Control group:

1. The DMF index of the control group remains constant throughout the study period (fig. 3-1).
2. The DMF index of the control group increases during the study period (fig. 3-2).
3. The DMF index of the control group decreases during the study period (fig. 3-3).
4. The DMF index of the control group fluctuates during the study period (combination of fig. 3-2 and 3-3; not shown).

Study group:

In the cross-sectional study each successive year the children received the fluoridated water one year earlier. Except for the coincidence of the start of the water fluoridation with the examination (ex.), the coincidence of the start of the water fluoridation with the following five developmental stages is of special interest (fig. 3-4 - fig. 3-7):

- with the examination (ex.)
- with the eruption (er.)
- with the end of the calcification period (end)
- with the start of the calcification period (start)
- with the start of the formation period (form.)

Fig. 3-1/3-7 Hypothetical course of the DMF-S curves of one category of surfaces in study and control group in a cross-sectional study at start of the fluoridation:

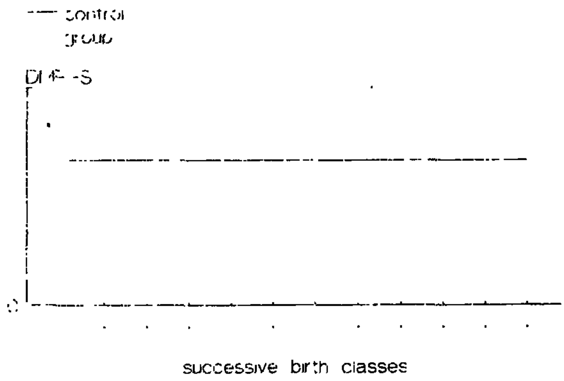


Fig. 3-1: control group with a stable DMF index in successive examination years

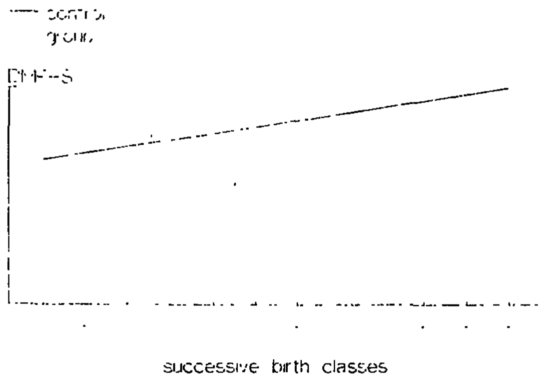


Fig. 3-2: control group with an increasing DMF index in successive examination years

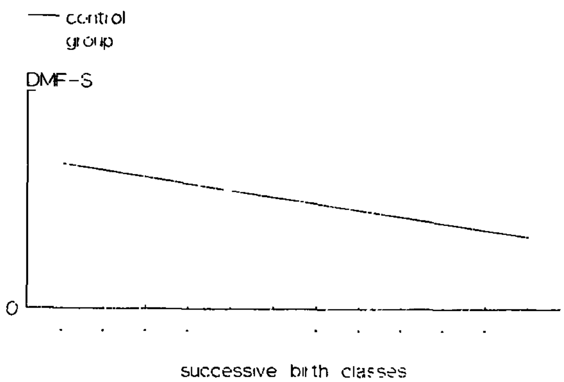


Fig. 3-3: control group with a decreasing DMF index in successive examination years

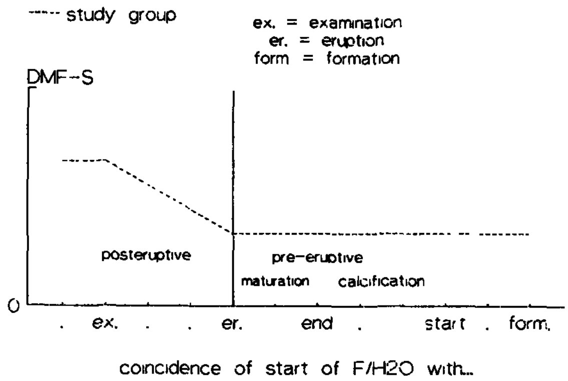


Fig. 3-4: DMF index of the study group if only posteruptive use of fluoride shows an effect

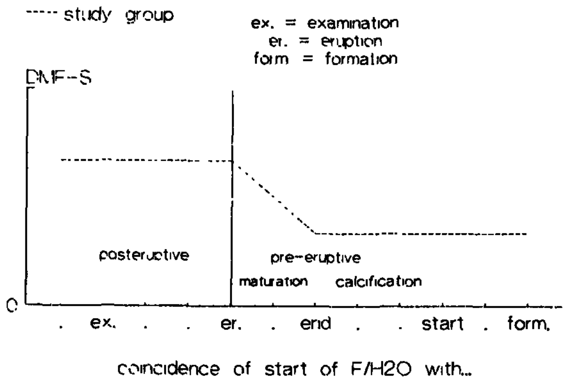


Fig. 3-5: DMF index of the study group if only pre-eruptive use of fluoride during the maturation phase shows an effect.

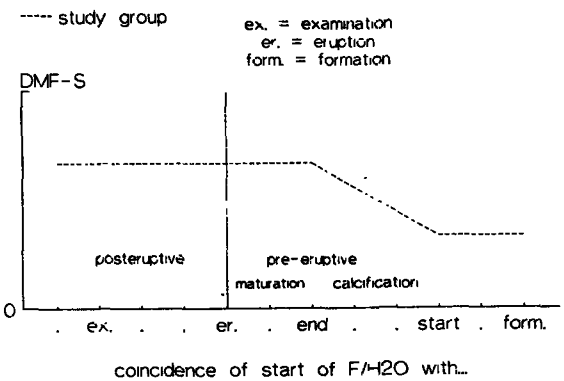


Fig. 3-6: DMF index of the study group if only pre-eruptive use of fluoride during calcification shows an effect.

The course of the curve of the DMF values of successive years in the study group can be expressed by a formula:

$$DMF_{test} = DMF_{contr} - (R_{post} + R_{pre}) \qquad \text{(Formula 3-1)}$$

R_{post} is the contribution of posteruptive consumption of fluoride to the reduction of caries experience.

R_{pre} is the contribution of pre-eruptive consumption of fluoride to the reduction of caries experience.

Hypothesis: R_{post} and R_{pre} are both positive values.

Figures 3-4 - 3-7 give a schematic presentation under the various hypotheses of the pre- and posteruptive effect. In each figure the results are shown if the fluoridation starts in the year of examination or earlier (see horizontal ax).

1. ($R_{post}=0$ and $R_{pre}=0$). Since the caries reducing activity of water fluoridation has been proved this presumption can be omitted.

2. ($R_{post}>0$, $R_{pre}=0$). This possibility is shown in figure 3-4. The reduction starts as soon as the fluoridated water comes in contact with the tooth and its environment and reaches its full expression if the start of the fluoridation coincides with the eruption of the tooth.

3a. $R_{post}=0$ and $R_{pre}>0$ during maturation. This possibility is shown in figure 3-5. The reduction starts here only if fluoride was present shortly before the eruption and reaches its full expression at the end of the mineralization.

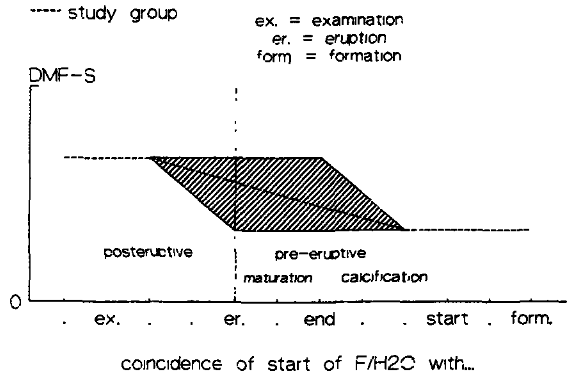


Fig. 3-7a: DMF index of the study group if pre- and posteruptive use of fluoride show an effect and if the DMF index of the control group remains stable in successive examinations.

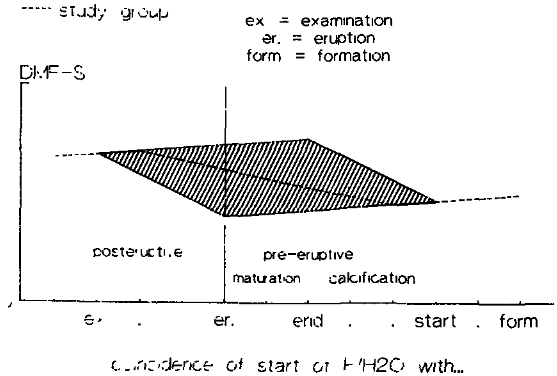


Fig. 3-7b: DMF index of the study group if pre- and posteruptive use of fluoride show an effect and if the DMF index of the control group increases in successive examinations.

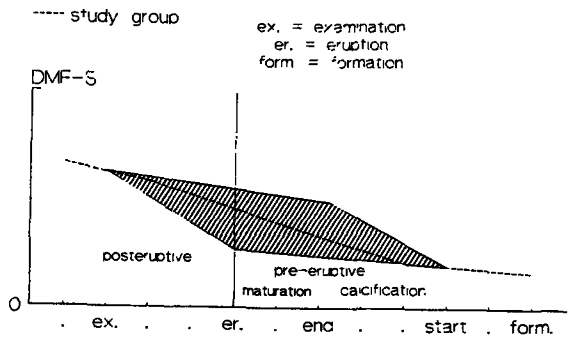


Fig. 3-7c: DMF index of the study group if pre- and posteruptive use of fluoride show an effect and the DMF index of the control group decreases in successive examinations.

3b. $R_{post}=0$ and $R_{pre}>0$ during mineralization. This is represented by figure 3-6. The reduction starts at the moment that fluoride was present in the last phase of mineralization and reaches its full expression if fluoride was already present at the start of the mineralization.

3c. $R_{post}=0$ and $R_{pre}>0$ during maturation and mineralization. The curve will be in the area between the graphs of figures 3-5 and 3-6. The more the contribution of consumption in an early stage is pronounced, the more the curve will be shifted to the right.

4. $R_{post}>0$ and $R_{pre}>0$. The curve will be in the area between the curves of figures 3-4 and 3-6. In figure 3-7a the full drawn lines are the curves of figures 3-4 and 3-6. Here also the curve will be shifted to the right if early consumption of fluoride has more effect. An example of the effect is represented by the dotted line in figure 3-7a.

The greater the effect of posteruptive fluoride is, the earlier a reduction will be observed in the cross-sectional study.

The greater the effect of pre-eruptive fluoride is, the later a reduction will be observed in the cross-sectional study.

The basis for a clinical trial is that there will exist a constant relation between the number of cavities in study and control group if the effect of water fluoridation is excluded.

Under the hypothesis that the maximal reduction in the study group is a percentage of the number of cavities in the control group, the ratio between both groups will be constant. The four possibilities in the control group mentioned above must affect the number of DMF-S in the study group. If, at successive examinations, the DMF index in the control group increases, the DMF index in the study group will also increase proportionally to the control group, thus diminishing the reduction in number of cavities (fig. 3-7b). If the DMF index in the control group decreases the graph of the study group will be steeper than that of the control group (fig. 3-7c).

Since, in the control group, the caries experience will probably not remain constant over the long period of the study (in the Culemborg - Tiel study 34 years) only the percentage reduction between control and test group is the relevant unit of measurement and not the difference in the number of cavities.

3.5.2 At discontinuation of the fluoridation

If water fluoridation is discontinued the reverse effect of the one at start will occur; now the posteruptive effect is first lost.

If the number of DMF-S in successive examination years is constant in the control town the following features can be observed in the graph of the control group.

1. $R_{post}>0$, $R_{pre}=0$. This possibility is shown in figure 3-8. The reduction will decrease shortly after discontinuation and if discontinuation and eruption coincide no reduction can be observed anymore.

2a. $R_{post}=0$ and $R_{pre}>0$ during maturation. This possibility is shown in figure 3-9. Here the reduction decreases if eruption and discontinuation of the fluoridation coincide and has disappeared at the coincidence of the discontinuation and the end of the mineralization.

Fig. 3-8/3-11 Hypothetical course of the DMF-S curve of one category of surfaces in the study group in a cross-sectional study after discontinuation of the fluoridation:

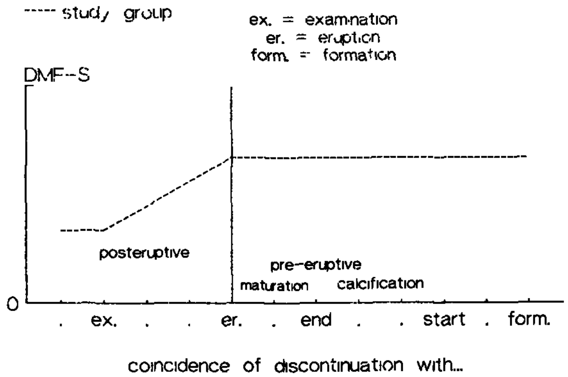


Fig. 3-8: DMF index of the study group if only posteruptive use of fluoride shows an effect.

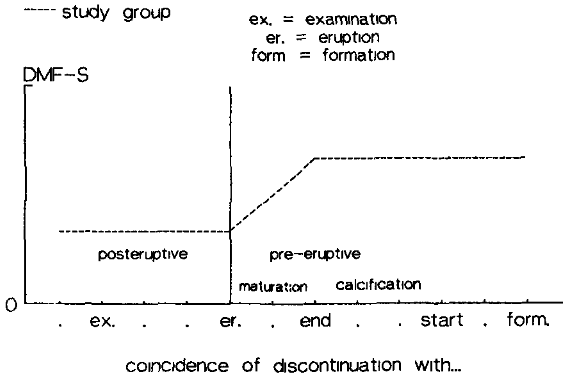


Fig. 3-9: DMF index of the study group if only pre-eruptive use of fluoride during the maturation phase shows an effect.

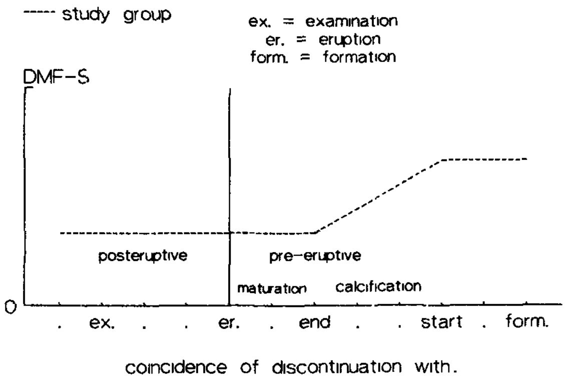


Fig. 3-10: DMF index of the study group if only pre-eruptive use of fluoride during calcification shows an effect.

2b. R_{post}=0 and R_{pre}>0 during mineralization. This is represented by figure 3-10. The reduction decreases at the coincidence of discontinuation and the end of the mineralization period. At the coincidence of the start of the mineralization period and the discontinuation no reduction can be observed anymore.

2c. R_{post}=0 and R_{pre}>0 during maturation and mineralization. The curve will be in the area between the graphs of figures 3-9 and 3-10 (not presented) The more the contribution of consumption in an early stage is pronounced, the more the curve will be shifted to the right.

3. R_{post}>0 and R_{pre}>0. The curve will be in the area between the curves of fig. 3-8 and 3-10. As at the start of the fluoridation the curve will be shifted to the right if early consumption of fluoride has more effect. An example has been given in figure 3-11a.

Assuming the above mentioned proportional relationship between the DMF indices in study and control group, the four possibilities in the control group will also affect the number of DMF-S in the study group at discontinuation of the fluoridation.

If, at successive examinations, the DMF index in the control group increases (decreases), the DMF index in the study group will increase (decrease) more than with a constant level of the control group. (See fig. 3-11b for the increase and fig. 3-11c for the decrease).

It will be clear that here too the percentage reduction of the DMF *in the study group in relation to the control* is the *only* variable which can be used to assess the effects of water fluoridation.

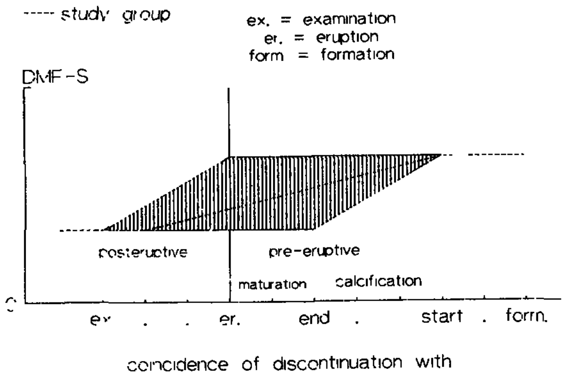


Fig. 3-11a: DMF index of the study group if pre- and posteruptive use of fluoride show an effect and if the DMF in the control group remains stable in successive examinations.

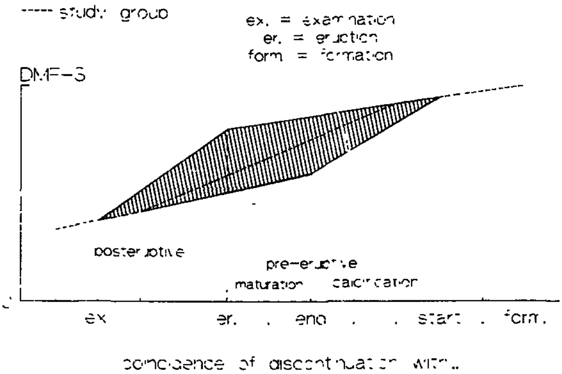


Fig. 3-11b: DMF index of the study group if pre- and posteruptive use of fluoride show an effect and if the DMF in the control group increases in successive examinations.

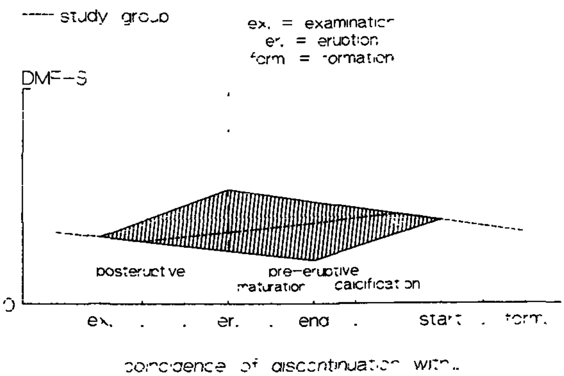


Fig. 3-11c: DMF index of the study group if pre- and posteruptive use of fluoride show an effect and if the DMF in the control group decreases in successive examinations.

3.6 PRACTICAL DESIGN OF THE STUDY AND DISTURBING INFLUENCES

3.6.1 Hypothetical design

In order to reduce the number of data, the results of the same category of surfaces (occlusal, proximal and smooth surfaces) of different teeth will be combined. This is done on the hypothesis that each of the three categories of the different teeth will react similarly to the extra fluoride. In this case the coincidence of the time of eruption and the start of the water fluoridation in the study group is used as the point of reference. E.g. the DMF of proximal surfaces of premolars, molars and front teeth which erupted on average four years before the start of the water fluoridation belong to one group, while proximal surfaces of teeth erupting three years before water fluoridation belong to the next group and so on.

The first group of children is to be examined before the water fluoridation started.

The last group has to be the one that received fluoridated water from conception on, so that the mineralizing tooth benefitted from water fluoridation during the whole formative period.

If all permanent teeth, except the third molars are to be included in the study, its duration extends from one year before birth (to measure a possible prenatal effect on the first molar) until enough years will have elapsed after the eruption of the second molar, so that dentinal lesions may also develop in this tooth.

Since the progression of lesions depends on the type of surface (i.e. proximal, occlusal, free smooth surface) also this period might differ in various surfaces. For the moment an age between 15 and 20 years will be chosen as a limit, since this allows a period of three to eight years to develop caries in the last erupting tooth, i.c. the second molar. For practical reasons the age at examination cannot be chosen too high in order to avoid a too long duration of the study period, so that the age of 15 years seems to be an acceptable minimum.

3.6.2 General disturbing influences

In practice the DMF in test and control group will be influenced by different disturbing variables such as small variations of the time of onset of mineralization and maturation and greater variations of the time of eruption, variation of age at the time of examination (variation of one year) and variation of caries susceptability of the children. These variables cause the spread of the DMF index both in test and control group and will find their expression in the standard error of the mean of the DMF index.

- Variation of the time of onset of mineralization and maturation and of the moment of eruption will cause a smooth transition from the higher horizontal part of the curve to the descending part in the curve of the F^--group (see fig. 3-7).

- Variation of the moment of eruption and of the moment of examination will cause a smooth transition from the descending part of the curve to the lower horizontal part in the curve of the F^--group (see fig. 3-7).

- Variation of the individual DMF scores within a year class together with examination, notation and calculation errors causes the standard error of the mean DMF index.

- Differences between the mean DMF scores of different year classes cause the generally undulating course of the curve over several years.

Another disturbing factor is the possible influence of occlusal 'preventive' fillings in fissures that eventually would never reach the stage of cavitation, especially in the first and second molars. To what extent this takes place may be assessed in a longitudinal study. If the filling was made between two subsequent clinical examinations of which at the first the examiner scored the surface as sound, the diagnosis 'filling' at the next examination within a year may cast doubt on the presence of a cavity at the time the filling was made.

If preventive fillings are made, both in study and control group, proportional to the number of definite cavities, there will be no influence on the rate of reduction.

For proximal surfaces the possible influence on surfaces of a tooth erupting adjacent to an already erupted tooth needs some discussion.

It has been demonstrated that some years after eruption there is a very high correlation in caries score between adjacent surfaces even if they have a different time of eruption (cf. $P2_{dist.}$ and $M1_{mes.}$) (Barr, 1949; Backer Dirks 1961; Backer Dirks, 1965). Because adjacent proximal surfaces of teeth with a different time of eruption also have different fluoride histories they may distort the conclusion.

At the start of the fluoridation the condition of proximal surfaces, already present, which are not, or only partially, influenced by water fluoridation and show already a cavity, may cause a delay of the maximal effect on later erupting contact surfaces. Perhaps this can be ruled out by the comparison of surfaces which do not undergo such an influence by a contact surface already present. The distal surface of the first and of the second permanent molars could serve here as a control, because in the first years after eruption these surfaces can be considered as free smooth surfaces and are not influenced by an adjacent surface already erupted.

3.6.3 Caries experience and caries increment

Since it is also possible to assess the effect of fluoride in a longitudinal study using caries increment. A short explanation of the difference between caries increment and caries experience follows below.

If in a study group as well as in a control group the mean number of DMF-S per child is four at the age of eight years and, if four years later the DMF-S in the control group is eight, whereas the DMF-S in the study group is six, the reduction in caries increment is 50% (2:4). However, the reduction in caries experience is only 25% (2:8). If the use of caries preventive means is started after some cavities have developed already, the percentage reduction in caries experience will always be less than the percentage reduction in caries increment assessed from the moment of start of the use. For the water fluoridation this means that the percentage reduction of caries experience will be less than the percentage reduction in caries increment if the water fluoridation starts after eruption of the teeth. If the water fluoridation starts at the time of eruption or before, the percentage reduction in caries experience is equal to that in caries increment from the time of eruption.

If water fluoridation is discontinued after eruption of the teeth the reverse effect of the one at start will occur. At discontinuation the study group may show a lower DMF-S than the control group. From then on the caries increment in the study group may be (nearly) equal or even more than in the control group, because in the former group there are more surfaces at risk. As a result no reduction in caries increment, or even a negative one, can be observed after a few years. However, the caries experience may still show a reduction. The following example will illustrate this effect.

It is supposed that at the discontinuation of the water fluoridation the mean number of DMF-S per child in eight-year-old children of the study group is two and that the DMF-S index in children of the same age in the control group is four. If four years later the DMF-S in the control group is eight, whereas the DMF-S in the study group is six, there is no reduction in caries increment. However, the reduction in caries experience is still 25% (2:8).

If the water fluoridation is discontinued before or at the time of eruption, the percentage reduction in caries experience is equal to that of the caries increment from the time eruption.

The difference between caries experience and caries increment, caused by the cavities already present at the start of the fluoridation, has consequences for the hypothetical curves of figures 3-4, 3-7, 3-8 and 3-11.

For the explanation below it is supposed that pre- and posteruptive use of fluoridated water each contribute 50% to the total effect.

If the fluoridation starts between the examination and the time of eruption, the caries experience in figures 3-4 and 3-7 will be represented by a curve which crosses the actual line at 'ex.' and 'er.'. However, between these two points this curve will be situated above the actual one, because, from the coincidence of the start of the fluoridation and the examination ('ex.') on, a decreasing number of DMF-S is already present at the start of the fluoridation in each subsequent year.

At the discontinuation a similar effect can be observed. The curve in figures 3-8 and 3-11 will also cross the actual one at 'ex.' and 'er.', but will be situated below the actual line between these two points. This is caused by the fact that from the coincidence of the discontinuation of the fluoridation and the examination on, a decreasing number of surfaces is protected by posteruptive fluoride.

Thus, if fluoridation is started or discontinued after eruption the effect observed in caries experience hurries after the one observed in caries increment.

3.7 SUITABILITY OF THE TIEL-CULEMBORG DATA FOR THIS STUDY-DESIGN

3.7.1 Availability of data

The second part of this chapter deals with the question to which degree the design of the water fluoridation experiment Tiel - Culemborg and the data available from that study match the above mentioned conditions.

In table 3-2 the year classes to be examined for a study of the pre- and posteruptive effect have been compiled. This table is independent of the age of examination. For the mean ages at which hard tissue formation begins and for the mean age of eruption the table after Logan and Kronfeld, slightly modified by Schour, has been used. The part of this table referring to the permanent dentition is presented in table 3-1.

Table 3-2 and table 3-3 can serve for the start as well as for the discontinuation of the water fluoridation. In the legend of these tables the text referring to the discontinuation has been put in brackets.

Table 3-1: mean ages of start of mineralization and eruption of permanent teeth (compiled from Logan and Kronfeld, 1933, slightly modified by Schour).

CHRONOLOGY OF DENTITION IN MAN*

Dentition	Arch	Tooth	Crown—Morphologically Definitive Age	Eruption Age	Root Definitive Age
Permanent	Upper	Incisor (C)	4–5 years	7–8 years	10 years
		Incisor (L)	4–5 years	8–9 years	11 years
		Cuspid	6–7 years	11–12 years	13–15 years
		Bicuspid (1st)	5–6 years	10–11 years	12–13 years
		Bicuspid (2nd)	6–7 years	10–12 years	12–14 years
		Molar (1st)	2½–3 years	6–7 years	9–10 years
		Molar (2nd)	7–8 years	12–13 years	14–16 years
		Molar (3rd)	12–16 years	17–21 years	18–25 years
	Lower	Incisor (C)	4–5 years	6–7 years	9 years
		Incisor (L)	4–5 years	7–8 years	10 years
		Cuspid	6–7 years	9–10 years	12–14 years
		Bicuspid (1st)	5–6 years	10–12 years	12–13 years
		Bicuspid (2nd)	6–7 years	11–12 years	13–14 years
		Molar (1st)	2½–3 years	6–7 years	9–10 years
		Molar (2nd)	7–8 years	11–13 years	14–15 years
		Molar (3rd)	12–16 years	17–21 years	18–25 years

(* Slightly modified from Logan and Kronfeld) Schour, I: Noyes' Oral Histology and Embryology, ed. 8, Philadelphia, Lea & Febiger, 1960.

Nevertheless table 3-2 is adapted in order to cope with some limitations of the Culemborg - Tiel experiment:

1. Because during the whole study period only three age classes older than 15 years have been examined in the Culemborg - Tiel experiment, 15 years is the maximum age at examination for this study.

2. Since no children have been examined who were 15 years old before 1952 the group which had this age in 1952 forms the start for the study-period.

3. Each four years one year class of 15-year-old has not been examined in 1954, 1958, 1962 and 1966).

Year classes which should have been examined are indicated by '+'. If the start or discontinuation of the water fluoridation coincides with the eruption of a tooth '+' has been replaced by 'e'. The ages at this coincidence have been rounded off to whole years. The coincidence for the onset of mineralization and the start or discontinuation of the water fluoridation has been indicated by 'm' Also these ages have been rounded off to whole years. An '*' has been added to the data which are not available in the Culemborg - Tiel study.

The maximal interval between eruption and examination that can be studied is determined by the last erupting tooth i.e. the second molar. This interval is four years and the end has been indicated by 'f'. Also for other teeth the moment of four years after eruption has been indicated by 'f'. As has been pointed out above, for a full comparability with the second molar all other tooth surfaces should be examined four years after eruption, at age 'f', in each year between moment 'f' and one year before the coincidence of the start of the water fluoridation and the start of the water mineralization, moment 'm'.

In order to obtain the data for the assessment of the posteruptive and additional pre-eruptive (pre-eruptive and additional posteruptive) reducing effect on caries experience in 15-year-old children the data from table 3-2 have to be classified according to the relation between the time of eruption and start or discontinuation of the fluoridation. This is shown in table 3-3.

The year classes in this table are arranged in such a way that examinations in one row contain data of surfaces where the period between eruption and the start of the fluoridation is the same.

Table 3-2: Year classes to be examined in the cross-sectional study at the start (discontinuation) for the assessment of the posteruptive and additional pre-eruptive (pre-eruptive and additional posteruptive) reducing effect on caries experience.

- m - coincidence of start of mineralization and start (discontinuation) of the fluoridation.
- e - coincidence of eruption and start (discontinuation) of the fluoridation.
- f - examination four years after the coincidence of the start (discontinuation) of the fluoridation and the eruption.
- + - other year classes to be examined.
- * - data not available

Age at start (discontinuation) of fluoridation	I1		I2		C		P1		P2		M1		M2	
	sup	inf	sup	inf	sup	inf	sup	inf	sup	inf	sup	inf	sup	inf
16	+	+	+	+	+	+	+	+	+	+	+	+	f	f
15	+	+	+	+	f	+	+	+	f	f	+	+	+	+
14	+*	+*	+*	+*	+*	f*	f*	f*	+*	+*	+*	+*	+*	+*
13	+	+	+	+	+	+	+	+	+	+	+	+	+	+
12	+	+	f	+	+	+	+	+	+	+	+	+	e	e
11	f	+	+	f	e	+	+	+	e	e	+	+	+	+
10	+*	f*	+*	+*	+*	e*	e*	e*	+*	+*	f*	f*	+*	+*
9	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	+	+	e	+	+	+	+	+	+	+	+	+	+	+
7	e	+	+	e	+	+	+	+	+	+	+	+	+	+
6	+*	e*	+*	+*	+*	+*	+*	+*	+*	+*	e*	e*	+*	+*
5	+	+	+	+	+	+	+	+	+	+	+	+	+	+
4	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	+	+	+	+	+	+	+	+	+	+	+	+	m	m
2	+*	+*	+*	+*	+*	+*	m*	m*	m*	m*	+*	+*	+*	+*
1	+	+	m	+	+	+	+	+	+	+	+	+	+	+
0	m	m	+	m	m	m	+	+	+	+	m	m	+	+
-1	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table 3-3: Year classes from table 3-2 after classification of the teeth according to the relation between the time of eruption and start (discontinuation) of the fluoridation.

- m - coincidence of start of mineralization and start (discontinuation) of the fluoridation.
- e - coincidence of eruption and start (discontinuation) of the fluoridation.
- f - examination four years after the coincidence of the start (discontinuation) of the fluoridation and the eruption.
- + - other year classes to be examined.
- * - data not available

Interval between the time of eruption and the start (discontinuation) of the fluoridation			I1		I2		C		P1		P2		M1		M2	
start		discontinuation	sup	inf	sup	inf	sup	inf	sup	inf	sup	inf	sup	inf	sup	inf
	10			+									+	+		
	9		+	+		+							+	+		
	8		+	+*	+	+							+*	+*		
	7		+*	+	+	+*							+	+		
years	6	years	+	+	+*	+		+	+	+			+	+		
after	5	before	+	+	+	+	+	+	+	+	+	+	+	+		
eruption	4	eruption	f	f*	f	f	f	f*	f*	f*	f	f	f*	f*	f	f
	3		+*	+	+	+*	+*	+	+	+	+*	+*	+	+	+	+
	2		+	+	+*	+	+	+	+	+	+	+	+	+	+*	+*
	1		+	+	+	+	+	+	+	+	+	+	+	+	+	+
eruption	0	eruption	e	e*	e	e	e	e*	e*	e*	e	e	e*	e*	e	e
	1		+*	+	+	+*	+*	+	+	+	+*	+*	+	+	+	+
	2		+	+	+*	+	+	+	+	+	+	+	+	+	+*	+*
	3		+	+	+	+	+	+	+	+	+	+	+	+	+	+
years	4	years	+	+*	+	+	+	+*	+*	+*	+	m	+*	+*	+	+
before	5	after	+*	+	+	+*	+*	+	+	+	+*	+*	+	+	+	+
eruption	6	eruption	+	+	+*	+	+	+	+	+	+	+	m	m	+*	+*
	7		m	m	m	m	+	+	+	+	+	+	+	+	+	+
	8		+		+	+	+	+*	m	m	+	+			+	+
	9						+*	+			m*	m*			m	m
	10						+	m			+	+			m	m
	11						m	+							+	+

Fig. 3-12 shows a survey of clinical and radiographical examinations of the Tiel-Culemborg study between 1952 and 1989.

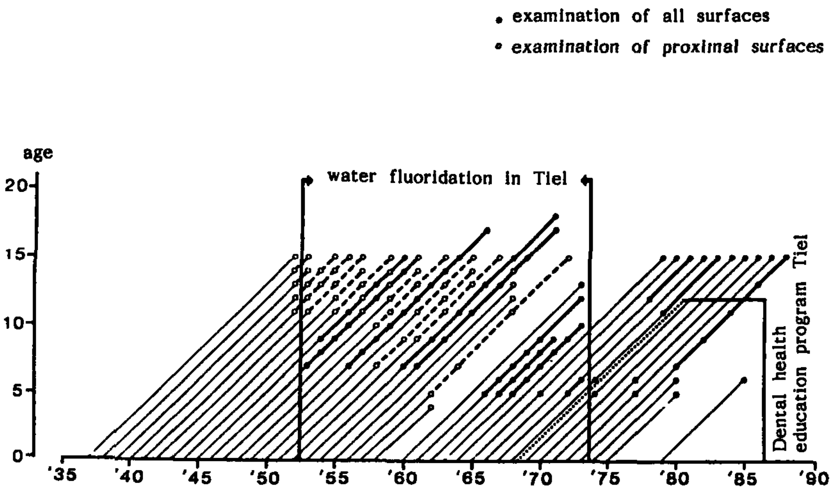


Fig. 3-12: Review of the clinical and radiographical examinations, the year of birth and the age at examination of the children participating to the Tiel - Culemborg study.

3.7.2 Study at start of the fluoridation

Combining the data from figure 3-12 with those in table 3-2 it appears that at the start of the fluoridation there are insufficient clinical data concerning pits, fissures and smooth surfaces to assess the pre- and posteruptive caries reducing effect according to the method described in the first part of this chapter. Only the DMF-S data of the proximal surfaces are sufficiently available at the ages of 11, 13 and 15 years.

In paragraph 3.6.1 the age of 15 years was found to be the minimum age which was required if all permanent teeth were included in the study. Since cross-sectional data of the proximal surfaces in 15-year-old children are sufficiently available, this age group will be selected for the study.

The DMF-S scores of the proximal surfaces in this radiographic study are sufficiently reliable, because a standardized scoring system was used (Backer Dirks et al., 1953). Lesion progression will hardly be disturbed by premature intervention by dentists and certainly not during the first two decades of this study. In the past fifties and sixties dentists in The Netherlands made few bite-wing radiographs to diagnose early proximal caries, so the first stages of proximal carious lesions were not interrupted by the placement of a filling as was probably frequently the case in occlusal surfaces. In the latter surfaces fillings often could have been made as a preventive measure, even if there was only a brown discoloration of the fissure (see par. 3.6.2).

The proximal surfaces of the lower incisors and lower cuspids and the distal surface of the upper cuspid show a very low caries experience. They were therefore omitted from the study, which was confined to the proximal surfaces of premolars, molars and upper incisors and the mesial surface of the upper cuspids, from which the caries scores for each surface separately at each examination year are present in the archives of the NIPG-TNO Caries Research Unit in Utrecht.

The mean age of the children at examination was 15 years and 4 months (± 3 months).

The children were examined in a dental car using mirror, probe and a small mouthlamp for the diagnosis of the fissures and pits, the smooth surfaces and the proximal surfaces of the lower front teeth.

For the diagnosis of the other proximal surfaces bite-wing radiographs were used.

As a result of the decrease of DMF-S, which occurred in The Netherlands in the past years (Kalsbeek, 1982), the decision was made that from the examination in 1986 on, no bite-wing radiographs were made of the upper front teeth of a child if with the mouth lamp no dentinal lesions could be observed in the proximal surfaces of the upper front teeth.

In each surface the following scores were given:

Sound (score 0)
Enamel caries (stage 1 and stage 2, scores I and II respectively)
Dentinal caries (small cavity and deep cavity, scores III and IV respectively)
Restauration (filling, score V, crown not due to a trauma, score K)
Missing (extraction due to caries, score X)

The criteria for the diagnosis of enamel and dentinal caries lesions were the same as those used by Backer Dirks and coworkers (Backer Dirks et al., 1953; Backer Dirks and Kwant, 1954; Backer Dirks et al. 1957).

For the present study exclusively the scores for dentinal caries were used.

In order to avoid a shift in the standards of scoring - a must for a study covering more than 30 years - the carefull descriptions of the diagnostic standards for the different stages of caries lesions have not been changed in the course of the study. Each new examiner was calibrated against an experienced examiner and against standard sets of radiographs. Each examiner was calibrated yearly by scoring a reference set of radiographs. The radiographs were scored "blindly" by several co-workers and most examinations were done in duplo. One of the co-workers participated in scoring the radiographs from the start of the study in 1952 until 1981.

In the period 1960 - 1973 clinical examinations were carried out in duplo. From 1979 on each fifth child was examined in duplo.

In each case that the scores of both examiners were different the mean was taken as the definite score.

In each examination year the D, M or F surfaces of the 15-year-old children were recorded for each surface separately. Fissures and pits of the upper molars received two scores, one for the mesio-occlusal and one for the disto-occlusal fissure and the fossa of Carabelli. The same sites of the lower molars received a separate score for the occlusal fissure and for the buccal pit. However, for the presentation in this study only one score per molar was taken, which was the highest caries score of both.

In order to meet the requirement of paragraph 3.4.3 concerning the length of the period at risk, teeth erupting at about the age of seven years (upper incisors and first molar) and examined at the age of 11 years (group A) should be compared with teeth erupting at about the age of 11 years (upper cuspid, premolars and second molar) and examined at 15 years (group B).

According to fig. 3-12 there are enough cross-sectional data of proximal surfaces available for children aged 11 (group A) and 15 years (group B).

This has been elucidated in table 3-4, where is presented in which examination year the DMF-S of proximal surfaces of the first molars and the upper incisors in group A (11-year-old children) as well as the DMF-S of proximal surfaces of premolars, second molars and upper cuspids in group B (15-year-old children) are available from the Tiel-Culemborg study.

If the DMF-S data are present '+' has been placed in the specific column. If no data are available although they ought to be for an optimal result '-' has been printed.

Table 3-4: Availability of Caries data of proximal surfaces in 11 years old children (for $I_{1sup.}$, $I_{2sup.}$ and M_1) and 15 years old children (for $C_{sup.}$, P_1, P_2 and M_2), in the Culemborg - Tiel study (p). (- = data not available).

Year of birth	57	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37
Age at start of fluoridation	-4	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Group A (age 11)	+	+	+	+	-	+	+	+	-	+	+	+	-	+	+	+	-	+	+
year of examination	68	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48
Group B (age 15)	+	+	+	+	-	+	+	+	-	+	+	+	-	+	+	+	-	+	+
year of examination	72	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52

Although between each series of three subsequent years no data were available from one year, the whole of the series in both groups seems to be sufficient to use the above mentioned method to assess the pre- and posteruptive caries reducing effect in proximal surfaces.

3.7.3 Study at discontinuation of fluoridation

Combination of the data from fig. 3-12 and table 3-3 shows that after the discontinuation of the water fluoridation on 24th december 1972 there is a lack of caries data for those children who were between 10 and 15 years of age at the discontinuation, because no examinations were carried out between 1973 and 1979. For children who were between zero and nine years old at the discontinuation data are present for all categories of tooth surfaces: clinical data of fissures, pits and smooth surfaces and radiographical data for proximal surfaces.

This has been summarized in table 3-5.

Table 3-5: The year of birth, the age at discontinuation of the water fluoridation, the years of examination and the availability of caries data of fissures, pits, smooth surfaces and proximal surfaces in 15-year-old children from Culemborg and Tiel.
- = no data available.
* = year classes to be examined in the future.

Year of birth	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
Age at discontinuation of fluoridation	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Year of examination	-	-	-	-	-	-	79	80	81	82	83	84	85	86	*	*

Table 3-6 shows to which extent caries data of the various teeth are available from the Culemborg - Tiel study after the discontinuation of the fluoridation, for the assessment of the pre-eruptive effect, initially with an additional effect of a decreasing posteruptive period and finally of a pre-eruptive period only. The data are classified according to the relation between the time of eruption and the discontinuation of the water fluoridation in Tiel.

Table 3-6: *Availability of caries data in year classes after the discontinuation of the water fluoridation from table 3-5.* **The teeth have been classified according to the relation between the time of eruption and the discontinuation of the fluoridation.**

- **m** - coincidence of start of mineralization and start (discontinuation) of the fluoridation.
- **e** - coincidence of eruption and start (discontinuation) of the fluoridation.
- **f** - examination four years after the coincidence of the start (discontinuation) of the fluoridation and the eruption.
- **+** - other year classes to be examined.
- ***** - data not available
- ****** - to be examined in 1987 and 1988

Interval between the time of eruption and the discontinuation of the fluoridation	I1 sup	I1 inf	I2 sup	I2 inf	C sup	C inf	P1 sup	P1 inf	P2 sup	P2 inf	M1 sup	M1 inf	M2 sup	M2 inf
discontinuation														
9		+*									+*	+*		
8	+*	+*									+*	+*		
7	+*	+*	+*	+*							+*	+*		
6	+*	+*	+*	+*							+*	+*		
5 years	+*	+*	+*	+*							+*	+*		
4 after	+*	+*	+*	+*	+*	+*	+*	+*	+*	+*	+*	+*		
3 eruption	+*	+	+*	+*	+*	+*	+*	+*	+*	+*	+	+	+*	+*
2	+	+	+*	+*	+*	+*	+*	+*	+*	+*	+	+	+*	+*
1	+	+	+	+	+*	+*	+*	+*	+*	+*	+	+	+*	+*
0 eruption	e	e	e	e	e*	e*	e*	e*	e*	e*	e	e	e*	e*
1	+	+	+	+	+*	+*	+*	+*	+*	+*	+	+	+*	+*
2	+	+	+	+	+	+	+	+	+	+	+	+	+*	+*
3	+	+	+	+	+	+	+	+	+	+	+	+	m	m
4 years	+	+	+	+	+	x	+	+	m	m	+	+	m	m
5 before	+	m**	+	+	+	+	+	+	+	+	+**	+**	+	+
6 eruption	m**	m**	+	m	+	+	m	m	+	+	m**	m**	+	+
7	m**		m**	m**	+	+			+	+	+	+	+	+
8					+	+			+	+			+	+
9					+	m**			m	m			m	m
10					m**	m**							m	m
11					m**									

It is clear that for none of the teeth a complete range of data is available. For the later erupting teeth there are insufficient data to study the decreasing posteruptive effect and even the full pre-eruptive effect can not be studied in these teeth since in the first examined year class of this series (15-year-old children in 1979) the water fluoridation was discontinued at the moment when these teeth had not yet erupted.

Only the data for the first upper incisors and for the first molars are sufficiently available to study the decreasing posteruptive effect, but for these teeth data for the whole pre-eruptive period still lack.

In order to study pre- and posteruptive effect at discontinuation of the fluoridation the teeth can be divided into two groups: the first containing the central upper incisors and the first molars (if desired together with the lateral upper incisors) and the second the upper cuspids, premolars and second molars. As at the start of the fluoridation the lower front teeth remain without consideration too.

The assessment of the pre- and posteruptive effect at discontinuation of the fluoridation will be discussed extensively in chapter 9.0.

3.8 STATISTICAL ANALYSIS AND PRESENTATION OF THE DATA

Analysis of the statistics of DMF-S data of the examinations in 1952 (only data for proximal surfaces available), 1968 and 1985 taught that the standard deviation in the individual DMF-S figures is proportional to the DMF-S itself. The proportional is about 0.6. For test and control groups of around 100 children this means that the deviation in a relative difference is about 10 per cent of that relative difference. As this error discussion is not only valid for the whole mouth DMF-S figures but also for partial DMF-S figures, this error estimate replaces an error estimate for each relative difference throughout this publication.

The DMF-S and the percentages have been rounded off to integer values. Differences between the published totals or percentages and those which could be calculated from the values of the data as these are published are due to round off errors.

3.9 OTHER CONDITIONS

An important parameter which has to be known is the median age of eruption of each tooth. These data will not necessarily be equal to the those published by Logan and Kronfeld (1933).

For the presentation in table 3-2 and 3-3 the median age of eruption has been rounded off to one year. However, if the median age of eruption is situated between the ages of two examinations adjacent to the coincidence of the median age at eruption the DMF index of teeth which erupted at the start of the fluoridation can be calculated more precisely using the following formula:

$$D1 = (1 + a1 - a2).D2 + (1 - a1 + a3).D3 \qquad \text{(Formula 3-2)}$$

D1 = DMF index at the age of 15 of surfaces which erupted at start of the water fluoridation. (To be calculated).

D2 = DMF index at the age of 15 of surfaces which erupted less than a year after the start of the water fluoridation.

D3 = DMF index at the age of 15 of surfaces which erupted less than year year before the start of the water fluoridation.

a1 = median age at eruption

a2 = age at start of the fluoridation of the children with DMF index D2.

a3 = age at start of the fluoridation of the children with DMF index D3.

An example will be given for a tooth erupting at the age of 6 1/4 year (a1). For this tooth the ages adjacent to the coincidence of eruption and start of the fluoridation are 7 (a2) and 6 (a3) years.

D2 and D3 are the DMF indices at the age of respectively 7 and 6 years. Formula 3-2 becomes then:

$$D1 = (1 + 6.25 - 7).D2 + (1 - 6.25 + 6).D3$$

Hence: $D1 = (0.25).D2 + (0.75).D3$

The median age of eruption of the teeth, calculated from hitherto unpublished data, gathered at Culemborg and Tiel in the period between 1955 and 1960 will be presented in chapter 5.0.

It is emphasized that the Culemborg - Tiel project also has to fulfil the epidemiological conditions presented in this chapter. The most important one being the comparability of test and control town throughout the study. This will be discussed in chapter 4.0.

The data for the proximal surfaces from the Culemborg - Tiel experiment are sufficiently available to study the effect of posteruptive and additionally pre-eruptive consumption of fluoridated water at the start of the water fluoridation. For the other categories of surfaces it is not possible to assess these effects directly.

At the discontinuation for none of the teeth sufficient data are available for the whole pre- and posteruptive period. In this part of the study the teeth have to be considered separately.

4.0 THE DENTAL, DEMOGRAPHIC AND SOCIAL SITUATION OF THE STUDY- AND CONTROLGROUP DURING THE STUDY PERIOD

4.1 INTRODUCTION

In a survey which embraces more than three decades it is necessary that study and control group are not only similar at the base-line examination but also that this degree of conformity remains during the course of the investigations for all conditions which could influence the dental caries except for the the addition of fluoride to the drinking water at a concentration of 1 mg/l.

The aim of this part of the study is to investigate the degree of similarity of a limited number of other factors than water fluoridation which may have influenced the dental health of study and control group during the course of the study and to rule out a possible effect of these factors

Before the start of the study the choice of Culemborg and Tiel out of several combinations of towns was based on an internal report by Groenman, which showed the similarity of the population of Tiel and Culemborg (Groenman 1951).

Nevertheless, at the the base-line examination in 1952, 15-year-old children from Tiel had a mean DMF of proximal surfaces of 5.6 per child, whereas in Culemborg this was 6.9 per child, which is 19% higher for Culemborg. One year later, after half a year of water fluoridation in Tiel, these indices were for 6.2 and 5.7 for Tiel and Culemborg, which is a 9% higher DMF index for Tiel (Kwant et al., 1972). The data for Culemborg in this paper in the same figure demonstrate the considerable variation from year to year, apart from the increase of the DMF index in the course of time.

Among others, variations in the following items could have influenced the dental health of the children examined:

A. social and economical status of the children (4.2)

B. dental care (4.3)

ad A.

Children of different social classes might have a different number of DMF-S (Koenig, 1978). If the composition of study and control group in an examination year differed with respect to the social classes, this could have affected the difference between DMF indices of both towns. Since in the first years of examination all children of one birthclass in both towns participated and since in later years they were randomly chosen it is sufficient to study the social and economical composition of the whole population in both towns.

ad B.

The MF portion of the DMF index is a result of dental treatment. The D portion might be affected by dental health education. It is important to observe the situation of the dental care in the test- and controltown during the study-period in order to see if they are comparable at start and if they will remain comparable.

Operative dental treatment will have a very limited or no influence at all on the DMF indices of proximal surfaces. However, occlusal fillings in the first molar which are often made in a very early stage of lesion formation as a means of caries prevention, can cause an iathrogenic increase of the DMF-S. The quality of the dental care is narrowly related to the availability of dentists for children of this age. After 1945 a school dental service was gradually instituted in the Netherlands. In 1949 this service started in Culemborg and in 1951 in Tiel.

The aim of this part of the study is to investigate if the demographic situation and the dental care in the two towns remained similar during the period of the study.

Three demographic factors will be studied in the paragraphs below:

1. Growth of the population
2. Professions and urbanisation
3. Income

4.2 DEMOGRAPHIC, SOCIAL AND ECONOMICAL STATUS OF THE POPULATION

4.2.1 Material and Methods

Data obtained from the Dutch Central Office for Statistics (CBS) in Voorburg were used for this study.

In order to compare the two towns the number of inhabitants during the study-period was recorded at yearly intervals and compared with the development of the total number of Dutch inhabitants in the same period.

The social and economical status of the population of the two towns has been compared using the data for the distribution of different professions as collected at the census of May 31th, 1960 and February 28th, 1971 being the only evaluations available which provide information for both towns. After 1971 no census has been carried out. Also data about the mean and the distribution of earnings are presented. These were available for 1946, 1958, 1960, 1963, 1965, 1969, 1974, 1976 and 1978. After the last year the data about earnings were not available anymore for each community apart, but only for the region as a whole. Also the mean earnings were compared with those of the total Dutch population in order to prove their conformity with the mean earnings of the Dutch population during the study-period.

In recent publications a positive correlation has been demonstrated between the level of schooling of the mothers and the dental health of their children (Tijmstra, 1980; Kalsbeek, 1985). Women aged 35 - 54 years, who did not receive schooling anymore and of no occupation, were classified according to the level of the schooling they received before. It can be assumed that almost all of them were housewives and that this age-range contains all mothers of 15-year-old children.

4.2.2 Results

1. Figure 4-1 shows the number of inhabitants of the two towns at december 31th of each year between 1952 and 1984, and the total number of inhabitants in the Netherlands.

The break at 1956/1957 and at 1977/1978 in the curves of the two towns (indicated by a vertical line between the bars) is caused by modification of the borders.

In 1956/1957 this caused an increase of 30 inhabitants for Culemborg and of 505 inhabitants for Tiel. In 1977/1978 the number of inhabitants in the two towns grew with 60 and 2,500 respectively, which was due to the same cause.

2. The distribution of the different professions is presented in table 4-1.

Table 4-2 presents the heads of a family between 35 and 59 years of age classified according to social and professional group and based on the tables of the census in 1960 and 1971 of the Dutch Central Office for Statistics. They are also classified to their social classes according to the classification by the Institute of Applied Sociology (ITS) in Nijmegen.

Table 4-1: Distribution of the different professions in Tiel and Culemborg. (Source: tables of the census in 1960 and 1971. Dutch Central Office for Statistics).

	CULEMBORG 1960 number				TIEL 1960 number				CULEMBORG 1971 number				TIEL 1971 number			
	M	V	M+V	%	M	V	M+V	%	M	V	M+V	%	M	V	M+V	%
Agriculture	266	29	295	6.6	244	18	262	3.9	125	5	130	2.2	120	15	135	1.6
Industry, handicraft and mining	1973	313	2286	51.0	2454	304	2758	41.5	1985	350	2335	39.7	2695	395	3090	37.8
Building-industry	288	6	294	6.6	467	6	473	7.1	465	15	480	8.1	765	40	805	9.9
Public Utilities	20	2	22	0.5	120	5	125	1.9	30	10	40	0.7	110	10	120	1.5
Trade, bank and insurance	398	155	553	12.4	804	372	1176	17.7	650	310	960	16.3	795	420	1215	14.9
Transport, storage and communication	180	17	197	4.4	390	21	411	6.2	275	35	310	5.3	340	35	375	4.6
Rendering service	420	387	807	18.0	746	663	1409	21.2	575	560	1115	18.9	830	920	1750	21.4
Unknown employement	21	1	22	0.5	35	-	35	0.5	365	154	519	8.8	460	215	675	8.3
Total	3566	910	4476	100.0	5260	1389	6649	100.0	4450	1439	5889	100.0	6115	2050	8165	100.0

Table 4-2: Classification of the heads of a family between 35 and 59 years of age according to their social and professional group and to their social classes (I, II and III for high, intermediate ad low respectively.

	social class	CULEMBORG 1960 number	%	TIEL 1960 number	%	CULEMBORG 1971 number	%	TIEL 1971 number	%
Farmers	II	80	4.81	84	3.30	60	2.92	45	1.60
Other managers with employees									
- in shops	I	19	1.14	50	1.96	30	1.46	85	3.01
- in industry, handicraft, mining, building-industry, and public utilities,									
with more than 10 employees	I	39	2.35	21	0.82	40	1.95	30	1.07
5 - 9 employees	I	23	1.38	19	0.75	)			
1 - 4 employees	I	48	2.89	76	2.98	)			
- in other trades	I	54	3.25	83	3.26	)			
Other managers without employees						) 165	8.03	255	9.06
- in shops	II	32	1.93	33	1.30	)			
- in industry etc.	II	24	1.44	39	1.53	)			
- in other trades	II	44	2.65	83	3.26	)			
Scientific free professions	I	9	0.54	29	1.14	5	0.24	20	0.71
Other free professions	I	1	0.06	5	0.20	included above			
Higher employees	I	58	3.49	100	3.93	145	7.06	190	6.75
Other employees									
- year salary Fl. 7,500	I	80	4.82	215	8.44	250	12.17	400	14.21
- year salary Fl. 5,500 - 7,449	II	127	7.65	273	10.71	195	9.49	310	11.01
- year salary Fl. 3,750 - 5,449	III	83	5.00	122	4.79	80	3.89	90	3.20
- year salary Fl. 3,750	III	16	0.96	15	0.59	5	0.24	10	0.36
Landworkmen	III	19	1.14	24	0.94	20	0.97	15	0.53
Other workmen									
- year salary Fl. 7,500	I	0	0	3	0.12	20	0.97	45	1.60
- year salary Fl. 5,500 - 7,449	II	51	3.07	65	2.55	285	13.87	375	13.32
- year salary Fl. 3,750 - 5,449	III	624	37.58	951	37.32	610	29.68	790	28.06
- year salary Fl. 3,750	III	209	12.58	217	8.52	45	2.19	15	0.53
Collaborating members of a family									
- in agriculture	III	1	0.06	1	0.04	-		-	
- in other trades	III	0	0	0		-		-	
Unemployed	III	20	1.20	40	1.57	120	5.84	140	4.97
Total group I (high)		331	20	601	23.5	553	27	897	32
Total group II (intermediate)		358	21.5	577	22.5	622	30	858	30.5
Total group III (low)		972	58.5	1,370	54	880	43	1,060	37.5
Total		1,661	100.00	2,548	100.00	2,055	100.00	2,815	100.00

The original tables for table 4-2 have been composed of age groups of five years, e.g. 35 - 39, 40 - 44 years and so on. The oldest age group in 1960 contains persons from 55 to 59 years old. If the latter had a 15-year-old child in 1960 than the age at birth of this child was 44. Although this is relatively old, this age group nevertheless has been included here because during the second world war not only many couples delayed an intended marriage, but also many married people did not have children until the war was ended in 1945. The mean age of the fathers of the children born in the first years after the end of the war was relatively older than those of the age groups which were born later.

Fig. 4-2 shows the development of the mean income per annum per earner and per inhabitant in both towns and in The Netherlands in Dutch guilders (without correction for inflation).

Since the enormous increase due to inflation makes a comparison between these three groups in this way difficult, the mean income per annum per earner and the mean income per inhabitant of both towns has been compared with the same data in The Netherlands fixing the value of the latter at 100 for each year in order to get percentages for Tiel and Culemborg. The graphics in fig. 4-3a and 4-3b show the result of this procedure for the values from fig. 4-2 for the mean income per annum per earner and per inhabitant.

The same procedure has been executed for these parameters fixing these values in each year at 100 in Culemborg in order to have percentages for both parameters in Tiel. The results are presented in fig. 4-3c.

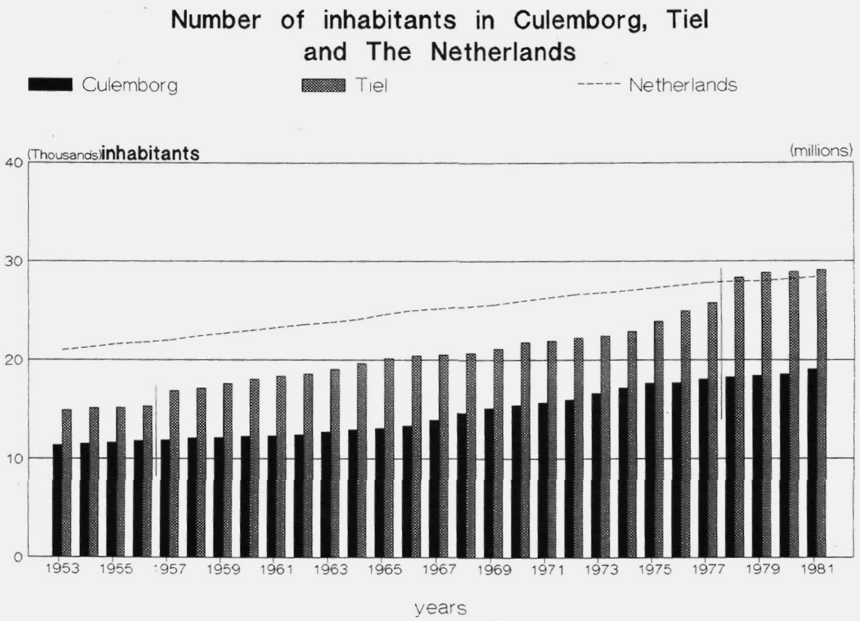


Fig. 4-1: The number of inhabitants in Culemborg, in Tiel and in The Netherlands between 1953 and 1980. (The left vertical ax serves for the numbers in Culemborg and Tiel and the right vertical ax for the numbers in The Netherlands).

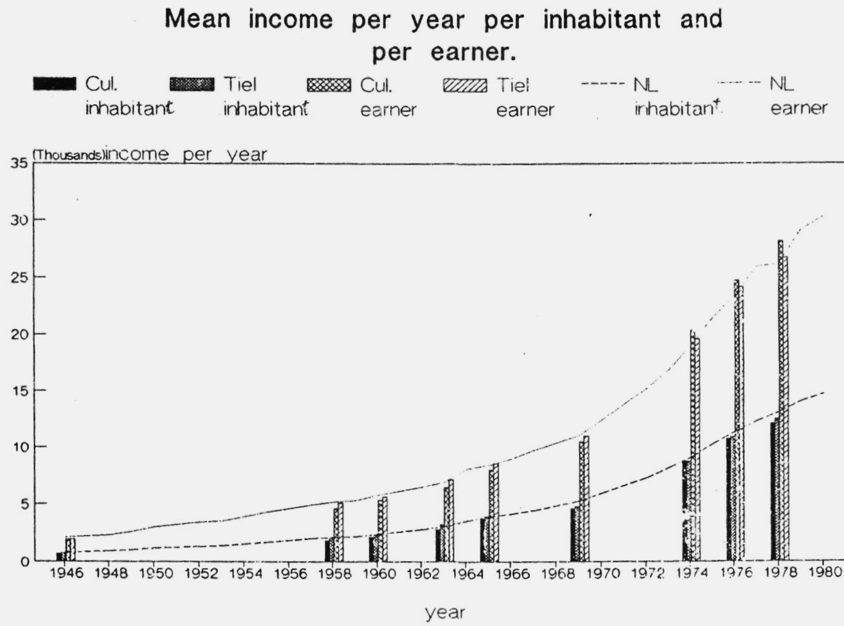


Fig. 4-2: The mean income per inhabitant and per earner in Culemborg, Tiel and The Netherlands between 1946 and 1979. The data are not corrected for inflation.

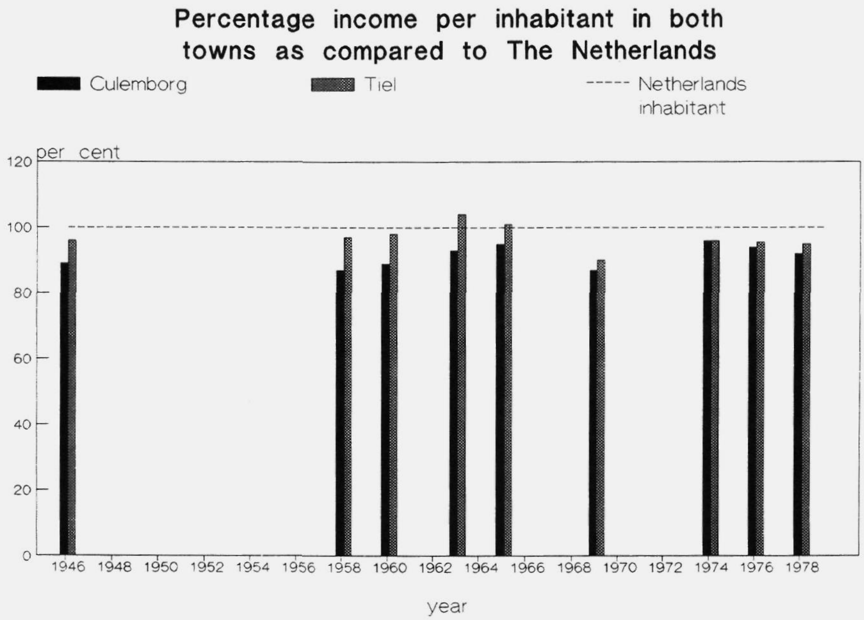


Fig. 4-3a: The mean income per earner in Culemborg and Tiel between 1946 and 1979 presented as a percentage of the mean income per earner in The Netherlands.

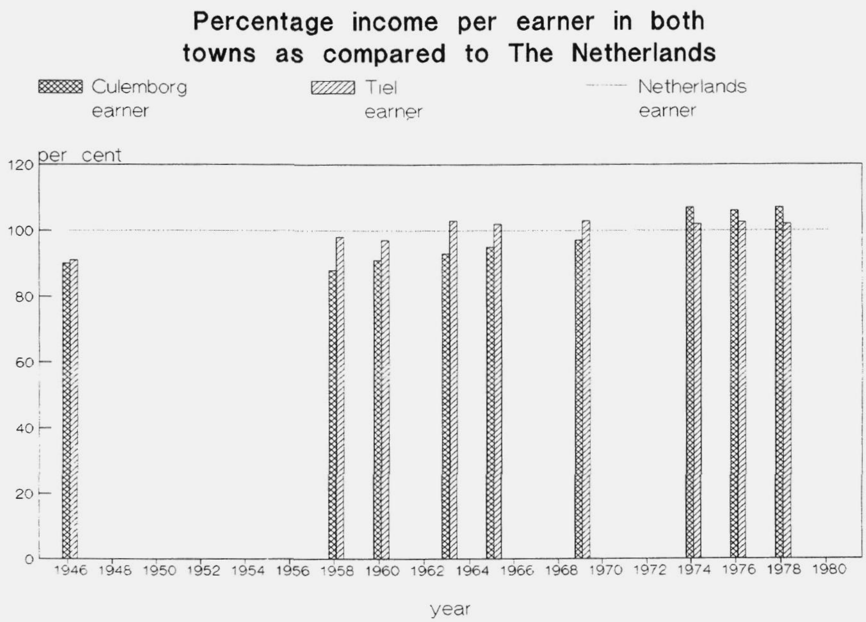


Fig. 4-3b: The mean income per inhabitant in Culemborg and Tiel between 1946 and 1979 presented as a percentage of the mean income per earner in The Netherlands.

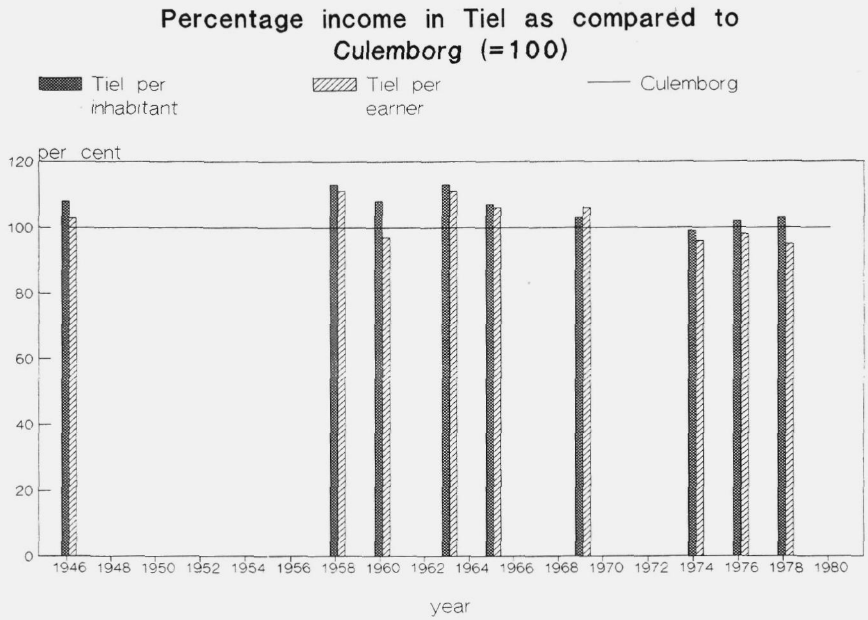


Fig. 4-3c: The mean income in Tiel per earner and per inhabitant between 1946 and 1979 presented as a percentage of the mean income in Culemborg.

The distribution of the mean year income per earner is presented in fig. 4-4 for three years, one before start, one during the study and the last one which could be obtained, respectively 1946 and 1958 (fig. 4-4a) and 1978 (fig. 4-4b). After 1978 these data were only available for regions and no more per community, which made it impossible to compare the two towns.

Table 4-3 shows for 1960 and 1971 the number of women aged 35 - 54 years from both towns, who did not receive schooling anymore and who did not have a profession. They are classified according the level of their schooling.

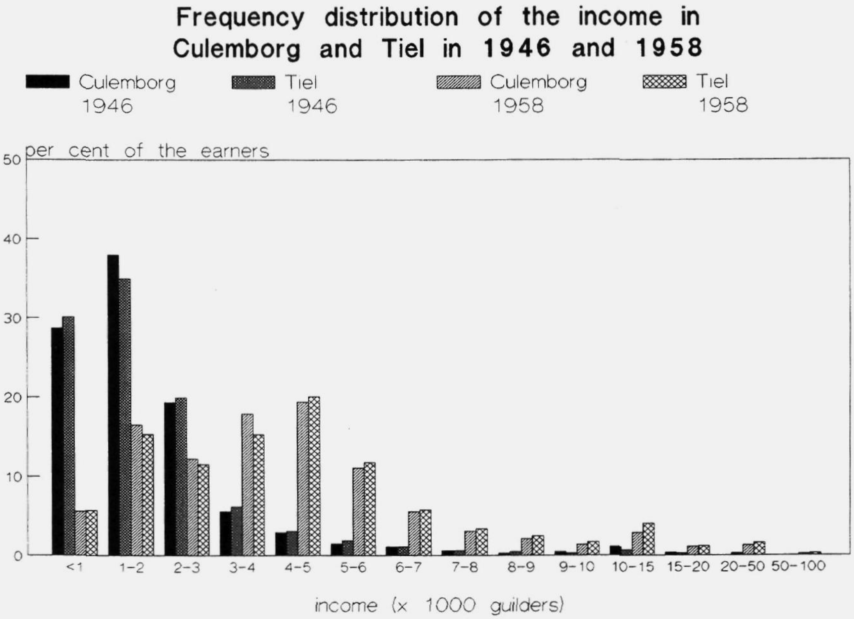


Fig. 4-4a: Frequency distribution of the income per earner in Culemborg and Tiel in 1946 and 1958.

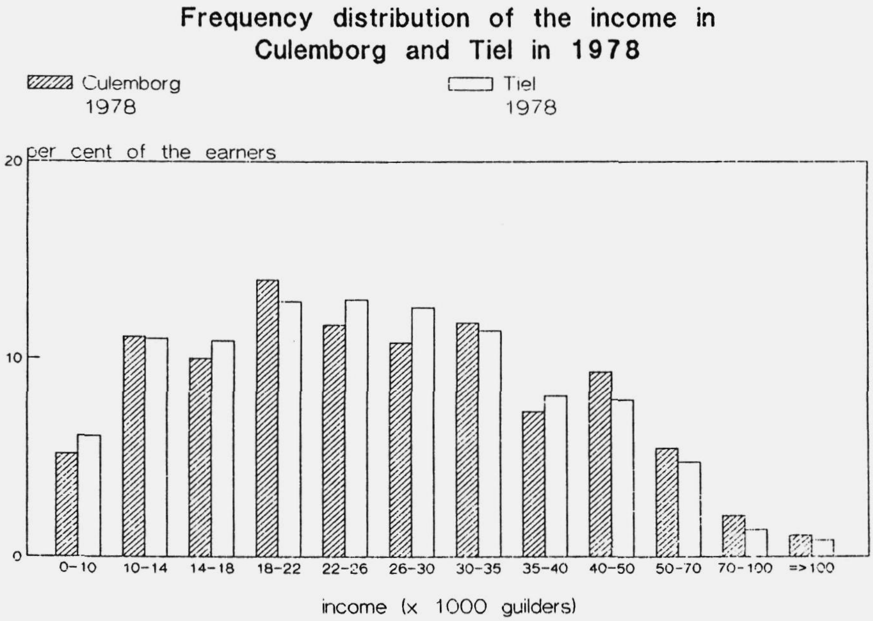


Fig. 4-4b: Frequency distribution of the income per earner in Culemborg and Tiel in 1978.

Table 4-3: Women aged 35 - 54 years from Culemborg and Tiel, who did not reçeive schooling anymore and who did not have a profession, classified according the level of the schooling they have received before.

	Primary school only (incl. unknown)		Secondary school lower level		Secondary school higher level and more		Total	
1960	number	%	number	%	number	%	number	%
Culemborg	1341	95.2	55	3.9	13	0.9	1409	100.0
Tiel	1834	92.3	123	6.2	29	1.5	1986	100.0
1971								
Culemborg	1065	74.0	275	19.1	100	6.9	1440	100.0
Tiel	1390	75.1	335	18.1	125	6.8	1850	100.0

Since the classification of the schooltypes according to their level is only roughly the same for the two census, the upper part of this table can not be compared with the lower part. Only comparison between the two towns in each year separately is valid.

Nevertheless in both towns an increase of the level of schooling can be observed in the period between the two census.

4.2.3 Discussion

The number of inhabitants in Tiel was greater than in Culemborg at the start of the study. The growth of the population in Tiel in the course of the study was, also relatively, greater than in Culemborg, but this is partly due to the two annexations where more persons were added to Tiel than to Culemborg. From the fact that apart from the two breaks the graphics do not diverge very much it can be concluded that the relative growth of the population in both towns is about equal in the period between 1953 and 1980. From the start of the study until 1985 both towns belonged to class C2 according to the classification of the Dutch Central Office of Statistics (CBS), i.e. division C: communities with a urban character; subdivision 2: small towns with a central part of 10,000 to 30,000 inhabitants.

As compared with the growth of the total Dutch population during the study-period both towns grew faster. This can be ascribed to the fact that during these years there was a general trend towards urbanisation of rural towns in The Netherlands at the cost of big cities where the population did not grow so fast or even diminished (yearly CBS publications, 1947 - 1985)

Neither, however had a marked function as dormitory-town or suburb, where the relatively high number of economically and socially better situated can cause a reduction of the mean DMF index of the total population (Tan, 1981) as compared with the mean of the country.

As can been seen from fig. 4-2, 4-3a and 4-3b the mean income per annum in both towns as compared to that in the Netherlands shows hardly any difference. It can be observed, however, that at start of the period the level of the mean income per earner in both towns was about 10% lower than the mean in the Netherlands but that in 1978 the level had risen above that. It must be kept in mind that at the start of the study both towns were situated in a rather secluded region, called the "Betuwe", which was bordered by two large rivers. This region had a low migration level. At the start of the study Tiel already had the function of a regional center.

This relative isolation has now drastically been changed by the construction of highways, a bridge and better communications by railways. It could, however, explain the relatively lower incomes as compared to the mean in The Netherlands at the start of the study.

The mean income per inhabitant in both towns remains under the level of the mean in The Netherlands except for 1962 and 1964 in Tiel. From this it can be concluded that in the course of this period in both towns more people had to live on one income. This can be due to the fact that the mean number of children per family in both towns was greater than that in The Netherlands.

Comparison of the same data from the two towns shows that generally the income per earner and per inhabitant in Tiel was somewhat higher than in Culemborg, but that from 1974 on the values are about the same in both towns. Probably due to smaller families in Tiel in 1976 and in 1978 the mean income per inhabitant is higher in this town although the mean income per earner is lower. The differences are, however, neglectable.

In order to give an impression of the distribution of the income per annum in the Netherlands it can be said that in 1976 this ranged from Fl. 17,760.- per earner in the community with the lowest mean income per annum to Fl. 49,019.- in the community with the highest. The mean income in the Netherlands over that year was Fl. 23,350.- whereas in Tiel and Culemborg this was respectively Fl. 24,126.- and Fl. 24,668.-. This is a neglectable difference.

The distributions of the income per annum as presented in figure 4-4 are comparable for Tiel and Culemborg in each of the three years, although they show a marked difference between these years, which was probably caused by inflation and by changing economical and social circumstances which generally took place in The Netherlands.

4.3 DENTAL CARE

4.3.1 Material and Methods

The data for Tiel and Culemborg have been obtained from the reports of the director of the school dental service published by the Dutch Association for Social Dentistry (Nederlandse Vereniging voor Sociale Tandheelkunde) and from the directory of the Dutch Dental Association which appeared nearly each year.

The reports of the school dental service were published for the first time in 1957 (schoolyear 1956/57) and from 1959 on (schoolyear 1958/59) yearly. Since no reports were available after 1966 only those until this year are presented here.

Culemborg belonged to the school dental service of the region of Geldermalsen which started in 1949 and Tiel to that of the region of Tiel, which started in 1951. The first year only children from the lowest grade of the primary school participated, in the second year children from the lowest two grade and so on. Six years after the start of the school dental service all age groups of primary school children could participate.

It was intended that each participating child should visit the school dentist semi-annually. If the second visit could not be completed the mean number of fillings was not published.

From 1963 to 1966 the percentages of non-participants were also published.

Apart from this the number of dentists established in the two towns was recorded for each year that it was available. It was also recorded if a dentist was working for the school dental service, in a private practice, or if he was doing other work.

4.3.2 Results:

The results concerning the school dental service are shown in table 4-4. This table presents the mean number of fillings per child per schoolyear in the region of Geldermalsen and the region of Tiel, the number of participating schools and the number and the percentage of children participating to the school dental service in the period 1956 to 1966. These data have been reported by the director of the school dental service in The Netherlands in the yearly reports of the Dutch Association for Social Dentistry.

Table 4-4: Data of the school dental service in the regions of Culemborg ad Tiel, 1956 - 1966. (Source: Yearly reports of the Dutch Association for Social Dentistry).

Schoolyear	number of schools Geldern.	number of schools Tiel	Mean number of fillings per child per schoolyear (in parentheses number of children in the two rounds) region Geldermalsen		region Tiel		percentage participants Geldermalsen	Tiel	The Netherlands
1956/57	72	37	1.50	(12,810)	*	*			
1958/59	74	39	1.72	(14.050)	1.50	(8,960)	*	*	*
1959/60	70	43	1.62	(14.380)	1.72**	(8,700)	*	*	*
1960/61	70	43	1.56	(13.270)	2.24	(9,480)	*	*	67
1961/62	71	43	1.87	(13,260)	1.91	(9,010)	*	*	66
1962/63	71	44	1.70	(13,030)	2.09	(8,970)	78	70	65
1963/64	72	45	1.80	(12,890)	2.29	(9,240)	70	69	63
1964/65	72	46	*	(12,530)	1.87	(9,100)	79	68	63
1965/66	72	44	*	(12,010)	1.68**	(8,430)	78	66	62

* not available

** estimation because the second round was not completed. Mean number of fillings in the town of Tiel 0.70. As is remarked in the report: due to the fluoridation of the drinking water!

*** Mean number of fillings in the fluoridated town of Tiel 0.57. In the other municipalities 2.42.

Table 4-5: The number of dentists in Culemborg and Tiel during the period 1952 - 1981 and their occupations.
S: school dentist; U: staff-member at a University; R: retired;
C: working in youth dental center in Tiel.
All other, own practice.

Year	number C	number T	Year	number C	number T	Year	number C	number T
52/53	2	5	62/63	2	6	72	4	8
	2S	1S		3S	-		-	1CU
	-	-		-	-		-	1R
54/55	3	4	63/64	1	6	75	4	8
	1S	1S		4S	-		-	1C
	-	-		-	-		-	1R
57	1	4	65	2	6	76	5	9
	2S	1S		2S	2S		-	1C
	-	-		-	-		-	1R
58	-	5	66	2	6	77	6	9
	3S	-		2S	1S		-	1C
	-	-		-	1U		-	1R
59	1	4	68	2	6	79	-	9
	3S	1S		2S	1S		-	1C
	-	-		-	-		-	1R
60/61	1	4	69/70	3	5	80	7	10
	3S	1S		2S	1S		-	1S
	-	-		-	-		-	1C
61/62	1	5	71	3	4	81	8	11
	3S	1S		-	-		-	1S
	-	-		-	-		-	1U

Table 4-5 shows the number of dentists in both towns and their professional occupations.

In the region of Geldermalsen the treatment occurred in 1956/57, partly in the schools, where a transportable dental unit was used and partly in a dental car. In later years the treatment was performed in a dental car only.

In the region of Tiel children were treated in the school during the whole study-period.

4.3.3 Discussion:

The operative dental treatment of the school dental service and of the dentists working in their own practice mainly affects the MF portion of the DMF index.

The data in table 4-4 present the number of fillings in succesive years in the two regions made by the school dental service, but no data are present about the number of the cavities which remained untreated and about the number of extractions.

The distribution of the number of fillings per child and per year among all school dental services was published in 1959 and 1966. This ranged from 0.5 to 3.25, with a mean per year ranging from 1.35 in 1956/57 to 1.74 in 1963/64. Although the mean number of fillings in Culemborg and Tiel is higher than the overall mean, this difference is not signifant according to the X^2 -test.

In the Tiel region not only the number of participating children is smaller than in the Geldermalsen area, but also the percentage, as far as these data are available. However, both percentages are above the national one.

The data from 1959/60 and 1965/66 show that the mean number of fillings per child in the town of Tiel is 60% and 65% lower respectively than that in the other communities of that region, which were not fluoridated.

Despite the reduction in the town of Tiel, the mean number of fillings per year in the region of Tiel is higher in most years than in the Geldermalsen area. There are several possible causes for this difference. The criteria for making a filling could be different, e.g. more or less preventive fillings. The caries score could be higher in Tiel. The third possibility is that the smaller participation in the school dental service is caused by the higher number of private dentists in Tiel, who attracted in the first place the higher social levels.

However, within the total range of data from all school dental services in The Netherlands this difference is neglectable.

Combining the results from table 4-5 and fig. 4-1 it can be deducted that between 1952 and 1981 in both towns the number of dentists in a private practice increases relatively more than the number of residents. Nevertheless, until 1970 the number of dentists living and working in Culemborg is much smaller than in Tiel, even if the difference in number of residents between the two towns is taken into account. As has been stated above, Tiel more than Culemborg, has a function as a regional center, so that dentists established in Tiel also treated people from the surrounding villages which makes the difference in dentist/population ratio between both towns smaller.

Such a difference of the dentist/population ratio can only affect the degree of treatment of those children who did not attend the school dental service but the private dentist.

It is possible that in Tiel the availability of more dentists working in their own practice contributed to the lower percentage of children who participated to the school dental service.

Unfortunately it is not known whether those children who did not participate in the school dental service (about 30%) attended the dentist or not. As a result a possible difference in degree of treatment at most could concern 30% of the children, but probably this percentage will be lower. The final effect is thus very limited.

A factor involved with the dental health of the children which is not yet discussed above is the dental awareness of parents and children. A difference of this parameter could have been caused by a difference in dental health education, particularly during the period that in Tiel the center for dental care for the youth was active.

About the period 1952 - 1972 no information is available.

Using questionnaires of 15-year-old children, examined between 1979 and 1984, Groeneveld et al. (1987) showed that during this period the use of fluoride tablets increased from 8% to 10% in Culemborg and from 6% to 12% in Tiel. The use of fluoride toothpaste increased from about 70% in 1979 to 94% in 1984 in both towns. In 1979 22% of the children in Culemborg and 31% of them in Tiel had received topical fluoride treatments, whereas in 1984 these percentages had risen to 71% and 82% respectively. The small differences between the two towns were however not significant.

From the results in this chapter it can be assumed that during the study-period both control and experimental town underwent considerable influences from general changes in social and demographic circumstances and dental care. Nevertheless the groups within one examination year remain comparable with each other during the study-period because these changes are of about the same magnitude in both towns. This means that not only the difference of the DMF index between Culemborg and Tiel occurring after the start of the fluoridation can thus be attributed to the addition of fluoride in the drinking water of Tiel, but also that if the water in Tiel would not have been fluoridated the DMF index in this town would have been similar to that in Culemborg.

The fact that unpublished longitudinal caries data of 7 - 11-year-old children from Culemborg and Tiel, born in 1973 (thus after the discontinuation of fluoridation), show that the DMF index in Tiel and Culemborg are comparable is an important indication for the value of Culemborg as control town in this study (unpublished data, NIPG-TNO Caries Research Unit, Utrecht, The Netherlands).

5.0 TIME OF ERUPTION OF PERMANENT TEETH IN CHILDREN FROM TIEL AND CULEMBORG

5.1 INTRODUCTION

As has been explained in chapter 3.0 the relation between the moment of eruption of a tooth and the start or discontinuation of the addition of fluoride to the drinking water is essential to discriminate between the effect of pre- and posteruptive use of fluorides for that particular tooth.

Also knowledge about the time of matrix-formation, mineralization and pre-eruptive maturation is important in order to determine in which stages pre-eruptive consumption is effective.

Theoretically for an assessment of the effect of fluoride pre- and posteruptively it is necessary to know the time of eruption of each tooth of each individual child. But this is not realistic because of the high frequency of examination that should be necessary. So in clinical studies an approximation can be made by using the mean age at which the different developmental stages occur and the median age of eruption of each category of teeth. The median age of eruption of a category of teeth (e.g. M1 or I1, etc.) is the age at which 50% of this category of teeth had erupted.

5.1.1 Aim of the study

The aim of this substudy is to assess the median age of eruption of each tooth type, - in the case they are different for Culemborg and Tiel separately, - using unpublished data from the Culemborg - Tiel study which are available in the archives of the NIPG-TNO Caries Research Unit in Utrecht. The results will also be compared with those from other publications, especially those from The Netherlands

Since, for the developmental period, neither data of the children from Culemborg and Tiel nor from the Netherlands are available, those already published elsewhere have to be used for this study.

5.1.2 Review of literature

One of the first studies dealing with the time of development and eruption of teeth was published by Peirce (1887) and followed by Legros and Magitot (1893), Black (1908) and Brady (1924).

In 1933 Logan and Kronfeld (1933) published an exhaustive study about the development of human jaws and teeth using serial sections of jaws and reviewing the results of some of the other authors mentioned above. Table 5-1 shows the time of beginning of calcification of permanent teeth as found by Logan and Kronfeld (1933) and slightly modified by Schour.

Table 5-1: Time of beginning of the calcification of permanent teeth. (Compiled from Logan and Kronfeld, 1933, slightly modified by Schour).

Tooth	Upper jaw	Lower jaw
M3	7 - 9 years	7 - 9 years
M2	2 1/2 - 3 years	2 1/2 - 3 years
M1	at birth	at birth
P2	1 - 2 1/4 years	2 1/4 - 2 1/2 years
P1	1 1/2 - 1 3/4 years	1 3/4 - 2 years
C	4 - 5 months	4 - 5 months
I2	10 - 12 months	3 - 4 months
I1	3 - 4 months	3 - 4 months

Table 5-2: Median age of eruption of teeth in Dutch boys and girls in years and month (8 years 10 months is written as 8.10). In parentheses the first quarter in months. (Reported by Bisseling et al., 1916 and compiled from Grewel, 1935; Schilstra, 1961 and de Boer, 1970).

GREWEL		I1	I2	C	P1	P2	M1	M2
boys	upper teeth	7.7 (.8)	8.10 (.8)	11.11 (.12)	11.0 (.14)	11.10 (.13)	<6.6	12.8
	lower teeth	6.9	8.0 (.8)	11.1 (.11)	11.4 (.13)	12.2	<6.6	12.2 (.12)
girls	upper teeth	7.3 (.8)	8.4 (.9)	11.2 (.11)	10.6 (.12)	11.4 (.13)	<6.6	12.3 (.11)
	lower teeth	<6.6	7.8 (.8)	10.2 (.10)	10.3 (.12)	11.8 (.14)	<6?	11.9 (.11)
SCHILSTRA		**I1**	**I2**	**C**	**P1**	**P2**	**M1**	**M2**
boys	upper teeth	7.4	8.5	11.6	10.0	10.10	6.5	12.3
	lower teeth	6.4	7.6	10.6	10.10	12.1	6.2	11.11
girls	upper teeth	6.11	8.0	11.2	9.7	10.7	6.2	11.11
	lower teeth	6.1	7.1	9.8	10.2	11.5	5.10	11.9
DE BOER		**I1**	**I2**	**C**	**P1**	**P2**	**M1**	**M2**
		s d	s d				s d	
boys	upper teeth	6.11 7.0	7.11 8.0	-	-	-	<6.0 6.2	-
	lower teeth	<6.0 <6.0	7.2 7.1	-	-	-	<6.0 <6.0	-
girls	upper teeth	6.7 6.7	7.5 7.6	-	-	-	<6.0 <6.0	-
	lower teeth	<6.0 <6.0	6.8 6.8	-	-	-	<6.0 <6.0	-

The eruption time of permanent teeth has been studied in the U.K. by Stones et al. (1951), Clements and Davies-Thomas (1953) and Parfitt (1954). In the U.S.A. a study was carried out by Carlos and Gittelsohn (1965).

In the Netherlands the time of eruption of permanent teeth was studied by Bisseling et al. (1916), Grewel (1935), Schilstra (1961) and de Boer (1970). The latter published the results of a longitudinal study, whereas the other authors used a cross-sectional study design. Grewel published a table with median values and quarters of the eruption time in Dutch children calculated by the author from the data published by Bisseling et al. (1916). The results showed that generally teeth erupted about a half year earlier in girls than in boys. Data from these three studies are summarized in table 5-2.

In 1960 Schilstra examined 4593 children who were between 5 and 15 years of age and who lived on three isles in the north of the Dutch province of 'Zeeland'. He recorded for each child which permanent teeth were present in the mouth and presented cumulative frequency curves of each permanent tooth separately for boys and girls apart. He observed that in boys teeth erupted between three and seven months later than in girls (Schilstra, 1961).

De Boer (1970) studied different aspects of the dental development in children who were between five and eleven years old. She examined longitudinally 441 children from Meppel using plaster casts. The age range of the study-group only permitted to study the eruption data of the permanent incisors and the permanent first molar. She observed among other things that the earlier eruption of these teeth in girls than in boys was significant.

5.2 MATERIAL AND METHODS

Because the number of studies concerning the eruption time of the teeth is limited, this material will be published in extenso.

For this substudy a cross-sectional design was selected, in order to assess the median eruption time in a large group of different children for each age group.

A tooth was counted as being erupted if the whole incisal or occlusal surface was visible, whereas it was counted as being in eruption if only a part of the incisal edge or only one or more cuspids were visible.

Since the enamel of teeth in eruption is detached from the internal environment and already in direct contact with the oral cavity, bacterial plaque or mouth fluid and hence could experience a topical effect of water fluoridation, teeth from the latter group are also counted as being erupted in this study.

In children aged 7 to 17 years (age at last birthday), each tooth was recorded as erupted, in eruption or not erupted separately for Culemborg and Tiel. A second, much smaller group of children was studied between four and seven years of age at the last birthday. The children were examined in 1957, 1958, 1959 and 1960.

Each year class was divided into two age groups except the four to seven years old children, because there were insufficient children in this group. The division into half year age groups was as follows:

1. Children whose last birthday had occurred maximally half a year before the examination. These children had a mean age of x years and 3 months (± 3 months).

2. Children whose last birthday had occurred more than half a year but less than a year before the examination. These

children had a mean age of x years and 9 months (± 3 months).

Each half year age group of children from both towns was divided into two subgroups according to sex.

Since differences between right and left side of each jaw were small and at random distributed, the data of corresponding teeth of the two sides were counted together. Because the differences between corresponding teeth in upper and lower jaw are significant the data from upper and lower teeth were counted separately.

In the group of kindergarten children (between 4 and 7 years old) the percentages of erupted first molars and lower first incisors were also counted. Since these data were not available for boys and girls separately they are presented as one mean value.

5.3 RESULTS

The results for 7 - 16-year-old children as they were collected in the archives of the NIPG-TNO Caries Research Unit in Utrecht are presented in tables 5-3, 5-4, 5-5 and 5-6 for Culemborg and Tiel and for boys and girls separately.

Those for kindergarten children with a mean age of about five years are shown in table 5-7. From children with a mean age of 5 1/2 years in 1959 only the percentages for the upper and lower first molars together could be retraced. There are no data at all for six-year-old children.

Figures 5-1 - 5-4 are based on tables 5-3 - 5-6. They all represent the cumulative frequency distribution for the teeth of children with a mean age between 7 1/4 and 15 3/4 years inclusive.

Table 5-3: The percentage of erupted teeth including teeth in eruption. Boys from Culemborg, age between seven and 16 years.

age (years)	year of examination	number of children	s/i	percentage teeth erupted (including teeth in eruption) superior M2	M1	P2	P1	C	I2	I1	inferior M2	M1	P2	P1	C	I2	I1
7 1/4	1960	33	s	-	92.4	-	3.0	-	15.2	81.8							
			i								-	95.5	-	3.0	1.5	75.8	98.5
7 3/4	1960	42	s	-	100.0	1.2	6.0	-	40.5	85.7							
			i								-	100.0	1.2	1.2	2.4	75.0	97.6
8 1/4	1957	27	s	-	96.3	-	1.9	-	44.4	77.8							
			i								-	96.3	1.9	-	1.9	79.6	94.4
8 3/4	1957	30	s	-	100.0	5.0	15.0	-	58.3	86.7							
			i								-	100.0	6.7	6.7	-	95.0	93.3
9 1/4	1958	27	s	-	100.0	5.6	14.8	1.9	74.1	96.3							
			i								-	96.3	3.7	9.3	9.3	94.4	100.0
9 3/4	1958	29	s	-	100.0	22.4	39.7	-	81.0	100.0							
			i								-	100.0	12.1	24.1	20.7	96.6	93.1
10 1/4	1959	26	s	3.8	100.0	9.6	32.8	15.4	88.4	100.0							
			i								1.9	100.0	11.5	30.8	27.0	98.0	100.0
10 3/4	1959	29	s	10.3	100.0	32.8	55.2	24.1	94.8	100.0							
			i								19.0	100.0	27.6	48.3	51.8	96.6	93.2
11 1/4	1959	28	s	25.0	100.0	51.8	68.0	35.7	100.0	100.0							
			i								26.8	100.0	39.3	59.0	78.6	98.2	100.0
11 3/4	1959	33	s	28.8	100.0	65.2	82.0	66.6	100.0	100.0							
			i								51.6	100.0	57.6	77.3	88.0	98.5	100.0
12 1/4	1959	29	s	39.7	100.0	81.0	86.2	79.3	96.6	100.0							
			i								63.8	100.0	58.6	87.9	94.8	100.0	100.0
12 3/4	1959	32	s	64.0	100.0	84.4	95.4	78.2	97.0	100.0							
			i								81.3	100.0	70.4	86.0	100.0	100.0	100.0
13 1/4	1959	32	s	85.9	100.0	95.3	100.0	92.2	96.9	100.0							
			i								90.6	100.0	76.6	92.2	100.0	100.0	100.0
13 3/4	1959	28	s	87.5	100.0	78.6	91.1	100.0	100.0	100.0							
			i								89.3	100.0	78.6	91.1	100.0	100.0	100.0
14 1/4	1959	16	s	90.6	100.0	100.0	100.0	93.8	100.0	100.0							
			i								100.0	100.0	93.8	96.9	100.0	100.0	100.0
14 3/4	1959	34	s	95.6	100.0	95.6	98.5	95.6	94.1	100.0							
			i								97.1	100.0	95.6	100.0	100.0	100.0	100.0
15 1/4	1959	22	s	100.0	100.0	100.0	100.0	100.0	100.0	100.0							
			i								100.0	100.0	95.4	100.0	100.0	100.0	100.0
15 3/4	1959	28	s	100.0	100.0	96.5	98.2	94.6	100.0	100.0							
			i								98.2	100.0	98.2	100.0	100.0	100.0	100.0

Table 5-4: The percentage of erupted teeth including teeth in eruption. Girls from Culemborg, age between seven and 16 years.

age (years)	year of exa-mination	number of children	s/i	percentage teeth erupted (including teeth in eruption) superior M2	M1	P2	P1	C	I2	I1	inferior M2	M1	P2	P1	C	I2	I1
7 1/4	1960	36	s	-	75.0	-	2.8	2.8	40.3	86.1							
			i								-	98.6	-	-	5.6	84.7	97.2
7 3/4	1960	35	s	-	100.0	-	8.6	-	48.6	91.4							
			i								2.9	100.0	-	1.4	2.9	91.4	98.6
8 1/4	1957	24	s	-	95.8	-	6.3	-	54.2	87.5							
			i								-	95.8	2.1	8.3	12.5	83.3	100.0
8 3/4	1957	33	s	-	100.0	4.5	15.2	1.5	75.8	100.0							
			i								-	100.0	4.5	10.6	12.1	95.5	100.0
9 1/4	1957	23	s	-	100.0	10.9	19.6	4.3	78.3	89.1							
			i								-	100.0	8.7	23.9	34.8	93.5	100.0
9 3/4	1957	32	s	-	100.0	23.4	50.0	12.5	95.3	100.0							
			i								4.7	100.0	12.5	25.0	53.1	100.0	100.0
10 1/4	1959	22	s	-	100.0	25.0	45.4	20.4	91.0	100.0							
			i								22.7	100.0	31.8	50.0	66.0	97.6	100.0
10 3/4	1959	32	s	7.8	100.0	56.3	67.2	39.0	95.4	100.0							
			i								28.1	100.0	36.0	59.4	90.7	100.0	100.0
11 1/4	1959	30	s	28.3	100.0	66.6	83.4	73.4	96.4	100.0							
			i								53.4	100.0	55.0	75.0	100.0	100.0	100.0
11 3/4	1959	28	s	34.0	100.0	66.0	91.0	73.2	100.0	100.0							
			i								71.4	100.0	66.0	85.7	98.2	100.0	100.0
12 1/4	1959	30	s	58.3	100.0	80.0	90.0	83.3	100.0	100.0							
			i								85.0	100.0	70.0	90.0	100.0	100.0	100.0
12 3/4	1959	30	s	80.0	100.0	90.0	93.3	94.3	95.0	98.3							
			i								93.3	100.0	80.0	96.7	100.0	100.0	100.0
13 1/4	1959	16	s	78.1	100.0	84.4	93.8	84.4	93.8	100.0							
			i								84.4	100.0	87.5	93.8	96.9	100.0	100.0
13 3/4	1959	43	s	93.0	100.0	95.3	100.0	94.2	100.0	100.0							
			i								93.0	100.0	88.4	97.7	100.0	100.0	100.0
14 1/4	1959	26	s	88.5	100.0	96.2	94.2	94.2	100.0	100.0							
			i								100.0	100.0	96.2	100.0	98.1	100.0	100.0
14 3/4	1959	25	s	100.0	100.0	90.0	92.0	96.0	100.0	100.0							
			i								100.0	100.0	92.0	98.0	100.0	100.0	100.0
15 1/4	1959	21	s	100.0	100.0	92.8	95.2	100.0	97.6	100.0							
			i								100.0	100.0	90.5	97.6	100.0	100.0	100.0
15 3/4	1959	31	s	100.0	100.0	92.0	96.6	98.4	95.2	100.0							
			i								100.0	100.0	96.6	100.0	100.0	100.0	100.0

Table: 5-5: The percentage of erupted teeth including teeth in eruption. Boys from Tiel, age between seven and 16 years.

age (years)	year of examination	number of children	s/i	percentage teeth erupted (including teeth in eruption) superior M2	M1	P2	P1	C	I2	I1	inferior M2	M1	P2	P1	C	I2	I1
7 1/4	1960	33	s	-	89.4	-	-	-	27.3	75.8							
			i								-	90.9	-	-	-	87.9	97.0
7 3/4	1960	42	s	-	97.6	1.2	3.6	-	31.0	31.0							
			i								-	95.2	-	-	-	83.3	94.0
8 1/4	1957	32	s	-	100.0	4.7	9.4	-	51.6	87.5							
			i								-	100.0	6.3	4.7	-	85.9	98.4
8 3/4	1957	29	s	-	100.0	3.4	10.3	-	58.6	96.6							
			i								-	100.0	6.9	8.6	3.4	94.8	100.0
9 1/4	1957	32	s	-	98.4	17.2	25.0	1.6	85.9	90.6							
			i								-	100.0	12.5	15.6	12.5	100.0	100.0
9 3/4	1957	25	s	-	98.0	12.0	34.0	10.0	90.0	100.0							
			i								4.0	100.0	16.0	30.0	22.0	96.0	100.0
10 1/4	1959	32	s	1.5	100.0	37.5	54.7	7.8	100.0	97.0							
			i								6.3	100.0	33.0	43.8	42.2	100.0	100.0
10 3/4	1959	27	s	7.4	100.0	42.2	59.2	20.4	96.3	100.0							
			i								26.0	100.0	27.8	55.6	55.6	100.0	100.0
11 1/4	1959	25	s	16.0	100.0	64.0	84.0	42.0	100.0	100.0							
			i								38.0	100.0	58.0	70.0	70.0	100.0	100.0
11 3/4	1959	34	s	42.6	100.0	66.0	99.2	57.4	100.0	100.0							
			i								63.2	100.0	61.8	78.0	89.6	100.0	100.0
12 1/4	1959	30	s	48.3	100.0	85.0	91.7	65.0	100.0	100.0							
			i								58.3	100.0	75.0	91.7	93.3	100.0	100.0
12 3/4	1959	30	s	70.0	100.0	85.0	88.6	81.6	98.4	100.0							
			i								78.4	100.0	83.3	95.0	98.4	100.0	100.0
13 1/4	1959	20	s	77.5	100.0	90.0	92.5	95.0	97.5	100.0							
			i								85.0	100.0	75.0	97.5	100.0	100.0	100.0
13 3/4	1959	35	s	85.7	100.0	92.9	98.6	97.1	100.0	100.0							
			i								94.3	100.0	91.4	98.6	100.0	100.0	100.0
14 1/4	1959	22	s	90.9	100.0	88.9	100.0	100.0	100.0	100.0							
			i								93.2	100.0	88.9	100.0	100.0	100.0	100.0
14 3/4	1959	27	s	98.1	100.0	96.3	100.0	100.0	94.4	100.0							
			i								96.3	100.0	88.9	100.0	100.0	100.0	100.0
15 1/4	1959	22	s	100.0	100.0	97.7	100.0	100.0	100.0	100.0							
			i								100.0	100.0	100.0	100.0	100.0	100.0	100.0
15 3/4	1959	31	s	96.8	100.0	96.8	96.8	95.2	98.4	100.0							
			i								98.4	100.0	95.2	100.0	96.8	100.0	100.0

Table 5-6: The percentage of erupted teeth including teeth in eruption. Girls from Tiel, age between seven and 16 years.

age (years)	year of examination	number of children	s/i	percentage teeth erupted (including teeth in eruption)													
				superior							inferior						
			i	M2	M1	P2	P1	C	I2	I1	M2	M1	P2	P1	C	I2	I1
7 1/4	1960	35	s	-	94.3	-	1.4	1.4	34.3	78.6							
			i								-	95.7	-	1.4	-	65.7	100.0
7 3/4	1960	41	s	-	95.1	-	3.7	1.2	70.7	93.9							
			i								2.4	97.6	-	6.1	8.5	96.3	98.8
8 1/4	1957	37	s	-	97.3	-	8.1	1.4	60.8	90.5							
			i								-	100.0	2.7	6.8	5.4	85.1	97.3
8 3/4	1957	19	s	-	100.0	7.9	28.9	5.3	81.6	100.0							
			i								-	100.0	7.9	21.1	10.5	100.0	100.0
9 1/4	1958	37	s	-	98.6	13.5	27.0	6.8	68.9	100.0							
			i								-	100.0	12.2	25.7	29.7	100.0	100.0
9 3/4	1958	19	s	5.3	100.0	36.8	42.1	7.9	94.7	100.0							
			i								10.5	100.0	28.9	39.5	36.8	97.4	100.0
10 1/4	1959	38	s	6.6	98.6	29.0	43.4	29.0	94.7	100.0							
			i								14.5	100.0	37.0	55.3	67.1	100.0	100.0
10 3/4	1959	20	s	25.0	100.0	65.0	72.5	25.0	100.0	100.0							
			i								25.0	100.0	50.0	67.5	90.0	97.5	100.0
11 1/4	1959	27	s	27.8	100.0	70.4	83.4	70.4	100.0	100.0							
			i								40.8	100.0	59.3	77.8	89.0	98.2	100.0
11 3/4	1959	33	s	54.5	100.0	71.2	89.4	75.6	100.0	100.0							
			i								62.0	100.0	72.7	92.5	100.0	100.0	100.0
12 1/4	1959	29	s	55.2	100.0	72.4	98.3	93.1	96.6	100.0							
			i								84.5	100.0	77.6	89.7	96.6	100.0	100.0
12 3/4	1959	31	s	71.0	100.0	87.1	100.0	90.3	95.2	100.0							
			i								91.9	100.0	83.9	100.0	100.0	98.4	98.4
13 1/4	1959	27	s	75.9	100.0	85.2	94.4	92.6	98.1	100.0							
			i								90.7	100.0	87.0	96.3	94.4	100.0	100.0
13 3/4	1959	28	s	96.4	100.0	100.0	98.2	98.2	100.0	100.0							
			i								96.4	100.0	96.4	100.0	100.0	98.2	100.0
14 1/4	1959	24	s	100.0	100.0	97.9	95.8	100.0	95.8	100.0							
			i								91.7	100.0	93.8	100.0	100.0	100.0	100.0
14 3/4	1959	33	s	100.0	100.0	100.0	100.0	98.5	98.5	100.0							
			i								98.5	100.0	95.5	100.0	100.0	100.0	98.5
15 1/4	1959	18	s	100.0	100.0	100.0	100.0	97.2	100.0	100.0							
			i								97.2	100.0	94.5	100.0	100.0	100.0	100.0
15 3/4	1959	30	s	96.6	100.0	93.4	100.0	95.0	100.0	100.0							
			i								95.0	100.0	98.4	100.0	100.0	100.0	100.0

Table 5-7: The percentage of erupted teeth including teeth in eruption. Kindergarten children from Culemborg and Tiel, age between four and seven years.

age	year of examination	number of children examined	s / i	percentage teeth erupted			
				M1	I1	M1	I1
Culemborg							
4 yr 11 months	1959	72	s	5.6	-		
			i			8.3	2.8
5 yr 6 months	1959	?	s+i	25.0	-		
Tiel							
5 yr 1 month	1959	89	s	15.7	-		
			i			14.6	9.0
5 yr 6 months	1959	?	s+i	10.0	-		

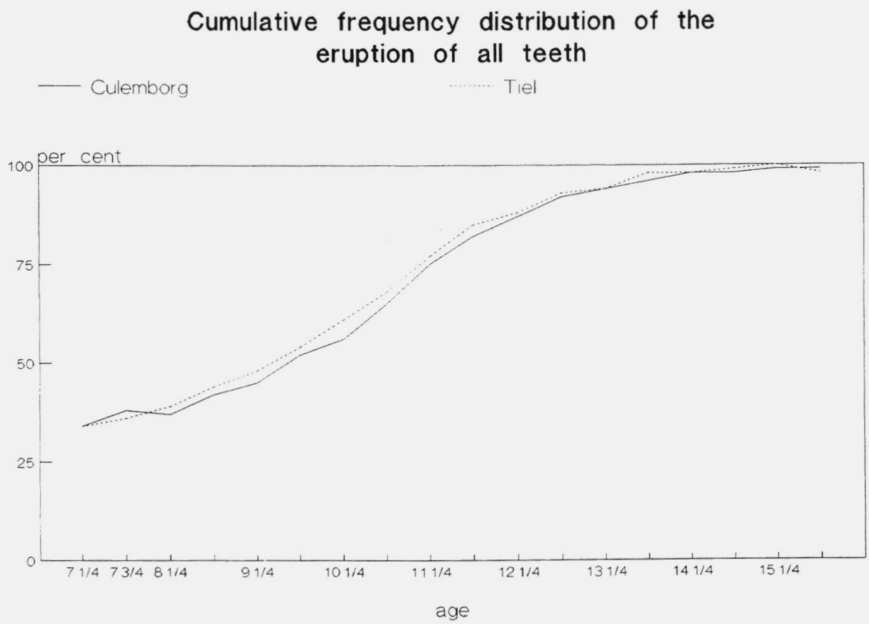


Fig. 5-1: Cumulative frequency distribution of the eruption of all permanent teeth in boys and girls together for Culemborg and Tiel separately.

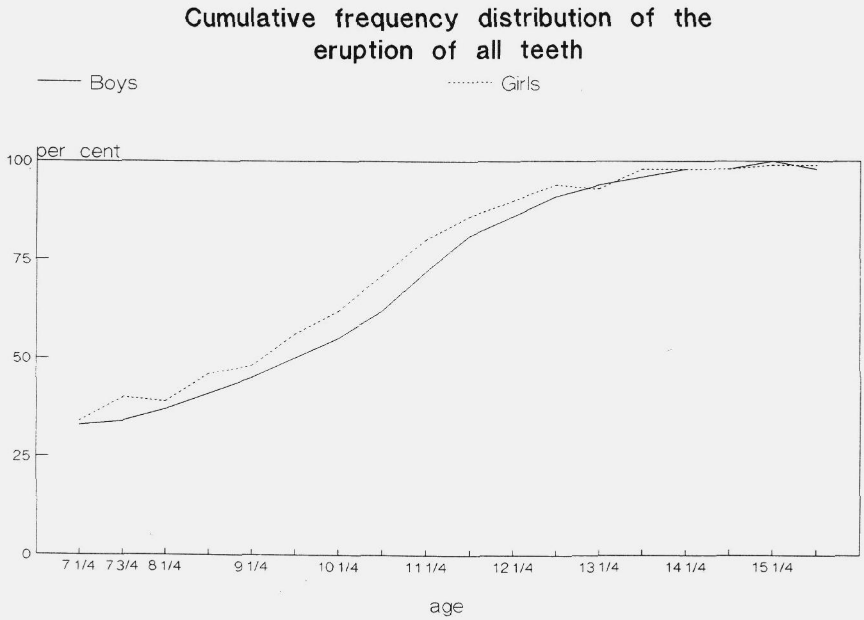


Fig. 5-2: Cumulative frequency distribution of the eruption of all permanent teeth in Culemborg and Tiel together for boys and girls separately.

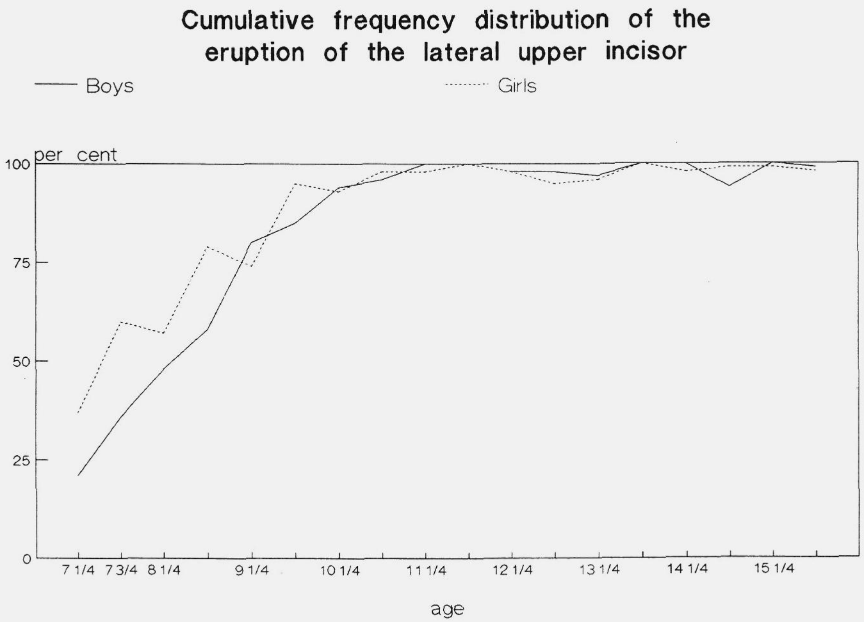


Fig. 5-3a: Cumulative frequency distribution of the eruption of the upper lateral incisor in Culemborg and Tiel together for boys and girls separately.

Cumulative frequency distribution of the eruption of the upper canine

—— Boys ········ Girls

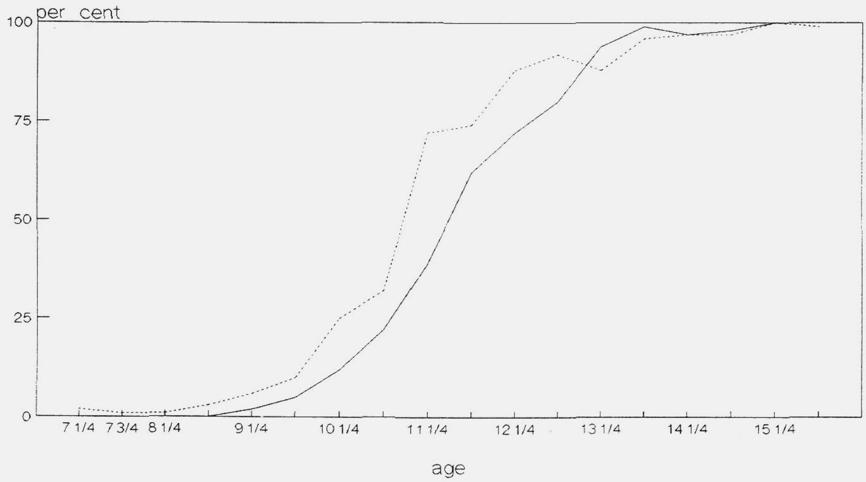


Fig. 5-3b: Cumulative frequency distribution of the eruption of the upper canine in Culemborg and Tiel together for boys and girls separately.

Cumulative frequency distribution of the eruption of the upper first premolar

—— Boys ········ Girls

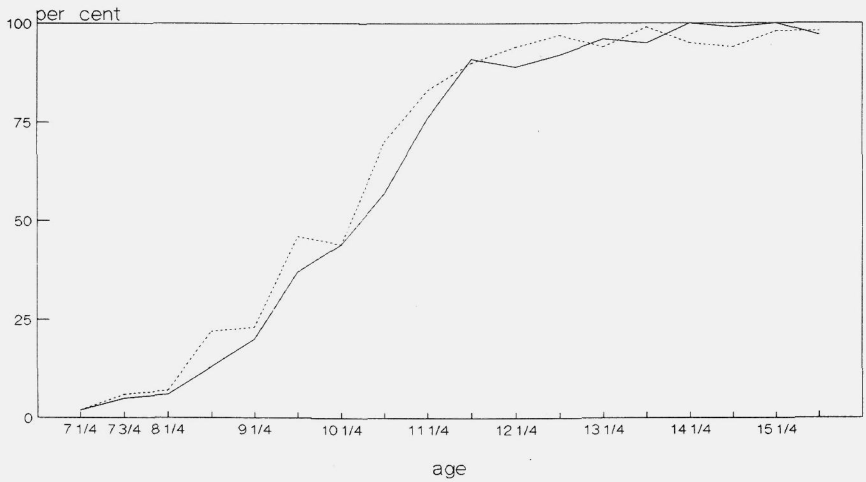


Fig. 5-3c: Cumulative frequency distribution of the eruption of the upper first premolar in Culemborg and Tiel together for boys and girls separately.

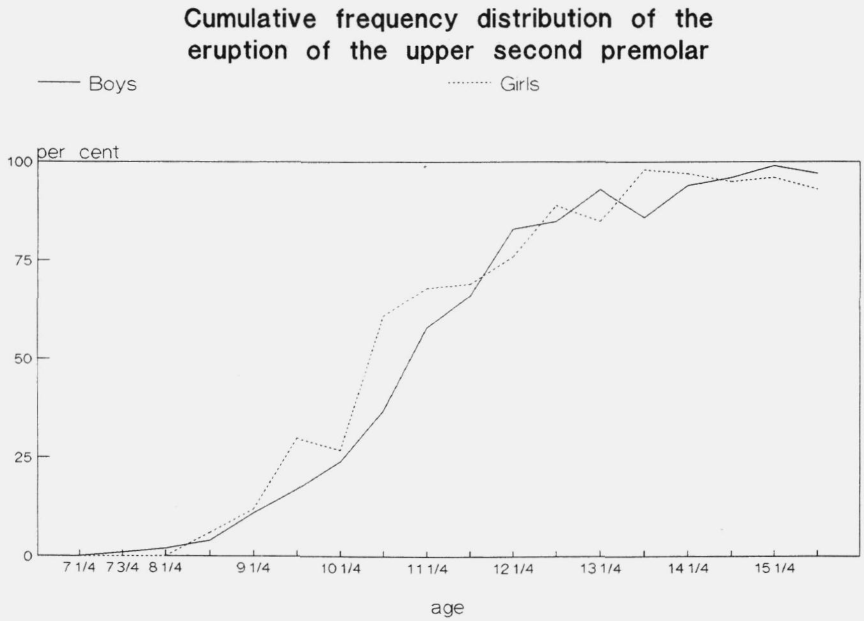


Fig. 5-3d: Cumulative frequency distribution of the eruption of the upper second premolar in Culemborg and Tiel together for boys and girls separately.

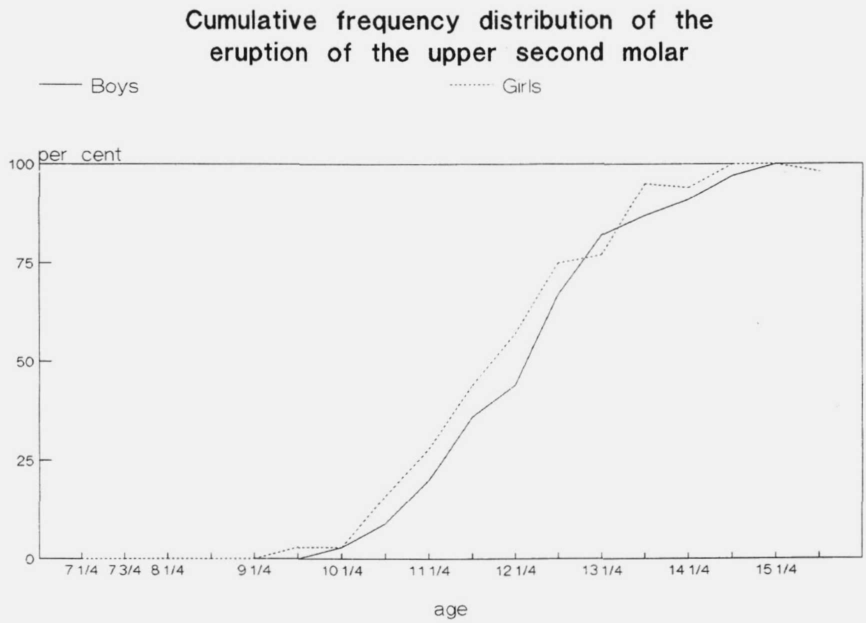


Fig. 5-3e: Cumulative frequency distribution of the eruption of the upper second molar in Culemborg and Tiel together for boys and girls separately.

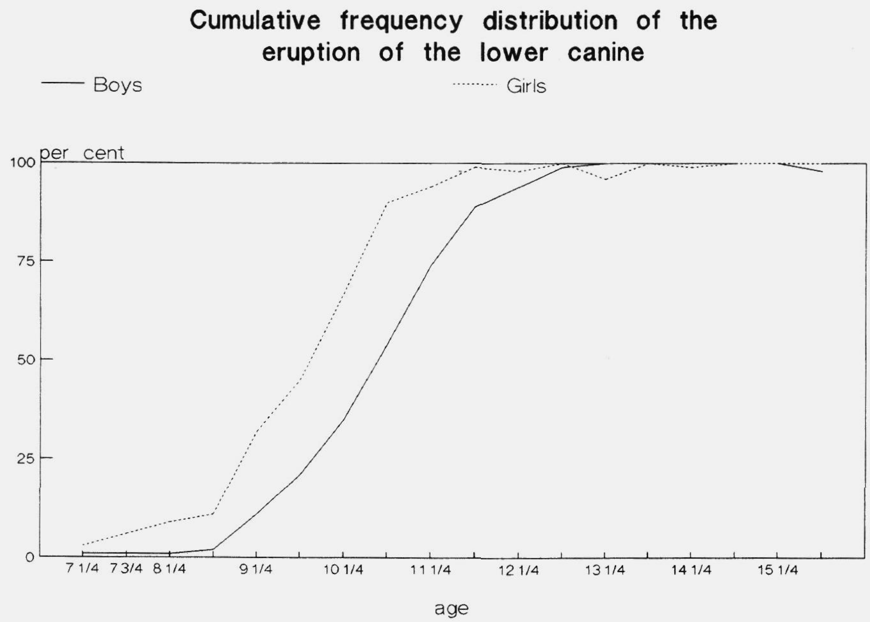


Fig. 5-4a: Cumulative frequency distribution of the eruption of the lower canine in Culemborg and Tiel together for boys and girls separately.

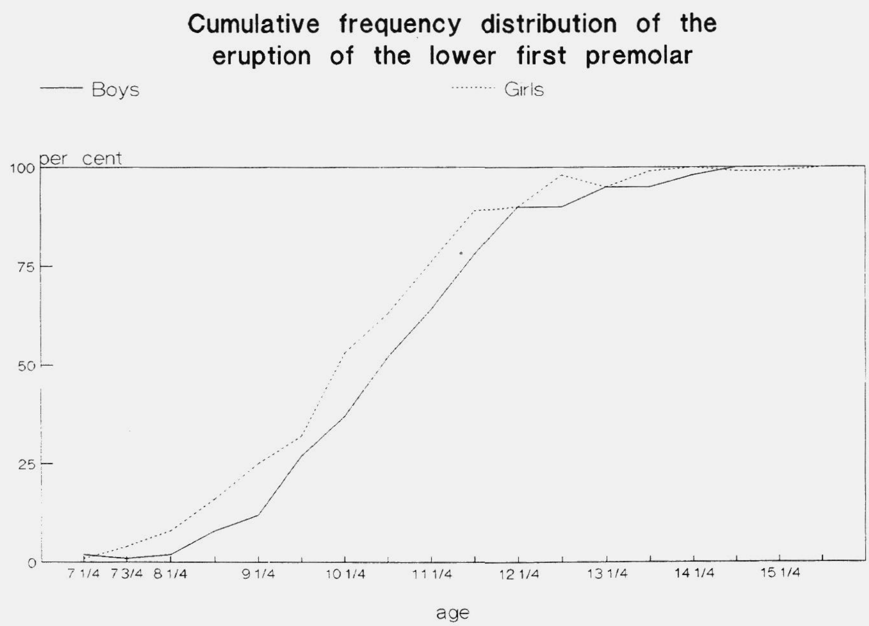


Fig. 5-4b: Cumulative frequency distribution of the eruption of the lower first premolar in Culemborg and Tiel together for boys and girls separately.

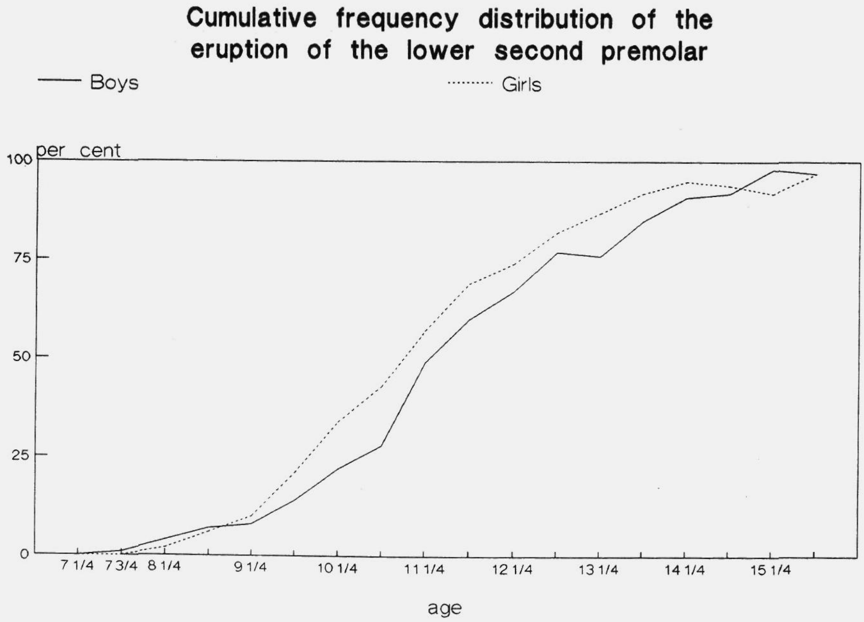


Fig. 5-4c: Cumulative frequency distribution of the eruption of the lower second premolar in Culemborg and Tiel together for boys and girls separately.

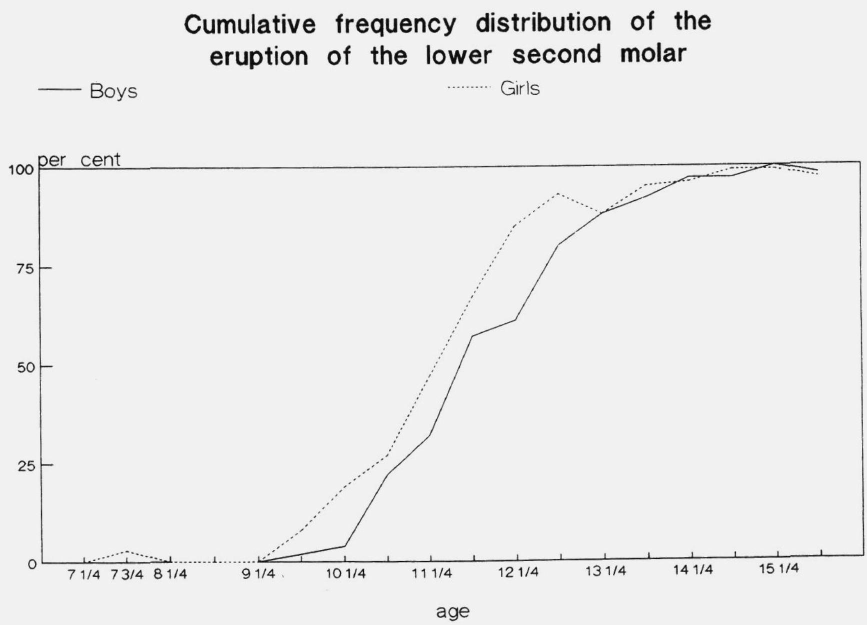


Fig. 5-4d: Cumulative frequency distribution of the eruption of the lower second molar in Culemborg and Tiel together for boys and girls separately.

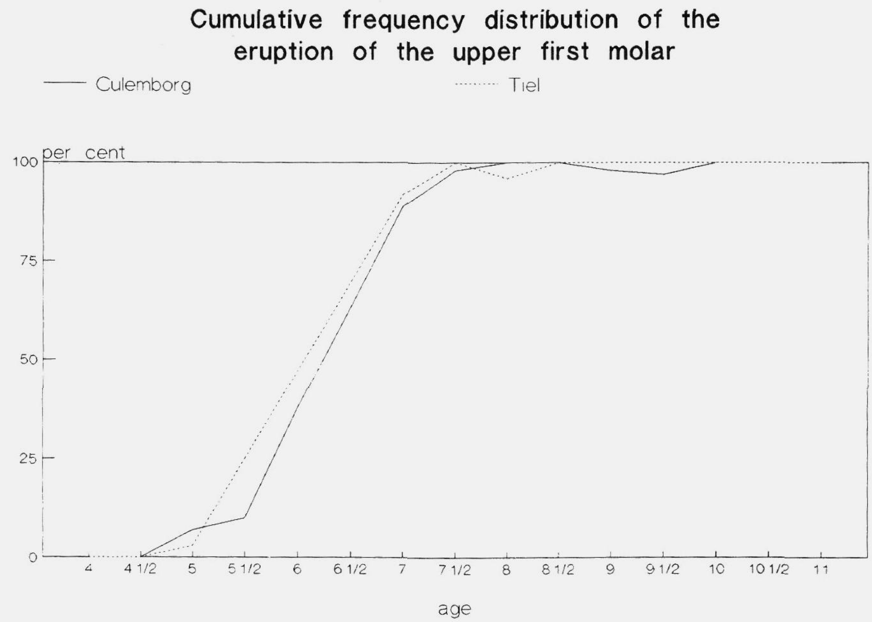


Fig. 5-5a: Cumulative frequency distribution of the eruption of permanent upper first molars in boys and girls together for Culemborg and Tiel separately.

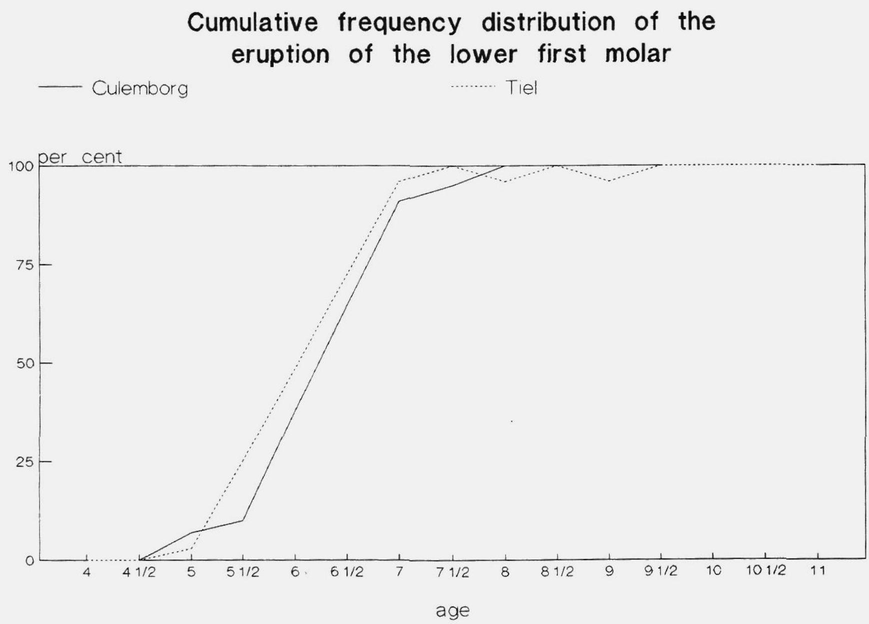


Fig. 5-5b: Cumulative frequency distribution of the eruption of permanent lower first molars in boys and girls together for Culemborg and Tiel separately.

The age in months at which 50% of the teeth has been erupted was calculated from the curves based on these tables and is presented for each tooth and each group apart in table 5-8.

Table 5-8: Age in years at which 50% of the teeth has been erupted (median age of eruption). Figures have been rounded off to 1/8 year. Teeth which are underlined will further be used in this study.

	CULEMBORG			TIEL			Culemborg + Tiel			
teeth	boys	girls	boys + girls 2	boys	girls	boys + girls 2	boys	girls	boys + girls	sup + inf
I1sup	*	*	*	*	*	*	*	*	*	*
I1inf	*	*	*	*	*	*	*	*	*	*
I2sup	8 1/4	7 1/2	7 7/8	8 1/4	7 1/2	7 7/8	8 1/4	7 1/2	7 7/8	7 7/8**
I2inf	*	*	*	*	*	*	*	*	*	*
Csup	11 1/2	11	11 1/4	11 1/2	11	11 1/4	11 1/2	11	11 1/4	11 1/4**
Cinf	10 3/4	9 3/4	10 1/4	10 1/2	10	10 1/4	10 5/8	9 7/8	10 1/4	10 3/4***
P1sup	10 1/2	10	10 1/4	10	10 1/2	10 1/4	10 1/4	10 1/4	10 1/4	10 3/8
P1inf	10 3/4	10 1/4	10 1/2	10 1/2	10	10 1/4	10 5/8	10 1/8	10 3/8	
P2sup	11 1/4	10 1/2	10 7/8	11	10 1/2	10 3/4	11 1/8	10 1/2	10 3/4	11
P2inf	11 1/2	11	11 1/4	11	10 3/4	10 7/8	11 1/4	10 7/8	11	
M1sup	*	*	(6 1/4)	*	*	(6 1/2)	*	*	6 3/8	6 3/8
M1inf	*	*	(6 1/4)	*	*	(6 1/2)	*	*	6 3/8	
M2sup	12 1/2	12	12 1/4	12 1/4	11 1/2	11 7/8	12 3/8	12	12 1/4	11 7/8
M2inf	11 3/4	11 1/4	11 1/2	11 3/4	11 1/2	11 5/8	11 3/4	11 3/8	11 1/2	

* - data not available.
** - sup. alone.
*** - sup. + inf.

Figure 5-1 shows the cumulative frequency distribution for all teeth of boys and girls together, for Culemborg and Tiel separately.

Figure 5-2 for all teeth of boys both from Culemborg and Tiel and for girls from both towns together.

Figures 5-3a - 5-3e show the frequency distribution of the eruption for the upper teeth of boys and girls separately for Culemborg and Tiel together.

Figures 5-4a - 5-4d present the same for the lower teeth of boys and girls separately, both towns taken together.

For the other teeth (upper first incisor and first molar, lower incisors and first molar) the tables do not contain the median value. For the first molars, however, it was possible to draw a rough cumulative frequency-curve for boys and girls together, if the data from table 5-7 were combined with the other ones. Figures 5-5a and 5-5b represent the cumulative frequency curves for the upper and the lower first molar respectively for boys and girls together and for Culemborg and Tiel separately.

The age in months at which 50% of the teeth had erupted was calculated from the curves based on these tables and is presented for each tooth separately in table 5-8.

5.4 DISCUSSION

5.4.1 Comparison between Culemborg and Tiel

The tables 5-3 - 5-6 and figure 5-1 show that in Tiel the eruption is between three and six months earlier than in Culemborg. The earlier eruption in Tiel is also observed for boys and girls apart.

According to the sign test the earlier eruption of teeth in Tiel is significant, which will be relevant for the remark in par. 5.4.1 that this is contrary to what would be expected. It is, however, not relevant for the study of the pre- and posteruptive effect of water fluoridation, due to its small size in comparison to the interval of at least one year for the caries examinations in the cross-sectional study.

That permanent teeth in a fluoridated town erupt earlier is contrary to that what would be expected: since less temporary teeth are extracted, because of carious lesions with pulp involvment in the fluoridated region, the permanent successors would eventually erupt later.

It has as well been postulated that a higher fluoride intake, resulting in a denser bone and a reduced solubility, could result in a later eruption.

From a review of the literature about the relation between water fluoridation and the time of eruption by Kuenzel (1976) it appears that in studies by Ast et al. (1956) (in Newburgh - Kingston) and Lovius and Goose (1969) (in Anglesey) a later eruption was reported in the fluoridated area.

Houwink (1963) (in Tiel - Culemborg) and Carlos and Gittelsohn (1965) (in Newburgh - Kingston) did not observe that eruption was accelerated or retarded by fluoridation.

Kuenzel (1971) (in Karl-Marx-Stadt - Plauen) observed an earlier eruption in both study and control group eight years after the base-line examination.

A consequence of an earlier eruption time in the fluoridated town could be that a possible posteruptive effect of fluoridated water will exert its action earlier, whereas a possible pre-eruptive action has a shorter duration.

Another consequence is that in children of the same age the period at risk, compared to that in a non-fluoridated town, is longer. This might result in the earlier formation of carious lesions (3 - 6 months) in the fluoride town. Especially shortly after eruption and for lesions that are formed soon after eruption (fissure lesions) a lower percentage of caries reduction could be the result.

The same applies to the caries experience in boys and girls. Here only the fissures show a 3-6 months retarded caries curve (cf. Kwant et al., 1972). For the proximal surfaces there is no difference in caries between boys and girls (Backer Dirks, 1961)

However, the data in this study are limited to find a possible effect of water fluoridation on the eruption time of permanent teeth. The reason is that older age groups in Tiel also started to consume fluoridated water at an elder age, thus in a later stage of tooth and jaw development. This means that a possible influence of fluoridation on tooth eruption should decrease in older age groups. Children between the age of seven and eight years who were examined in 1960, had consumed fluoridated water (nearly) from birth. If an influence of water fluoridation on the time of eruption should be present this could be observed best in these year classes which contained data of permanent teeth erupting at about the age of seven years, such as the first molars and first incisors.

On the other hand, the three months earlier eruption in Tiel can be observed in all age groups, irrespective of the stage of tooth development at the start of the fluoridation. Moreover, Houwink (1963) observed a similar difference between children from Culemborg and Tiel examined in 1952, thus before the start of the water fluoridation. This observation en our data lead to the conclusion that water fluoridation had no influence on the eruption pattern in Tiel.

As to be expected the variation within each of the four groups (boys or girls separately from Tiel or Culemborg apart) between different age classes is rather large (see Tables 5-3 - 5-6). This is due to three facts:

- the time of eruption is very variable, as also demonstrated in other studies.
- the number of children in each half year group was small.
- the cross-sectional design of the study.

The four curves constructed using these data made this variation visible, but they showed also that all curves were more or less similar. Therefore the curves for boys and girls separately for the two towns apart have not been published in the study.

If two groups are taken together - regardless if that are boys and girls per town or both towns together per sex (see par. 5.4.2) - the curve will partly be smoothed, but the cross-sectional design of the study causes still a non smooth curve.

5.4.2 Comparison between boys and girls

If the data from Tiel and Culemborg were added for boys and girls apart, two curves were created for each tooth. These curves were smoother than for each town apart. Figure 5-2, presenting the data classified according to this procedure for all teeth together, shows that generally in girls teeth erupt half a year earlier than in boys, the curve for the former being shifted to the left with respect to the latter. Here also the earlier eruption in girls is significant according to the sign test.

The difference also exists in separate teeth. However, it varies from tooth to tooth as is shown in figures 5-3a/e for upper teeth and 5-4a/e for lower teeth. Whereas the Cinf. shows a difference of nine months there is hardly any difference between the curves for the upper second molar and for the upper first premolar.

5.4.3 Comparison with other studies

The earlier eruption of teeth in girls is in accordance with all data from other authors, e.g. the findings of Carlos and

Gittelsohn (1965) and the Dutch studies by Grewel (1935), Schilstra (1961) and de Boer (1970). The latter showed in a longitudinal study that the earlier eruption of comparable teeth in girls was statistically significant.

It is of course especially interesting to check if the eruption patterns and the median eruption time of this study agree with those of the two other Dutch studies concerning the eruption time, to wit by Schilstra (1961) and De Boer (1970).

The first study is not only contemporary, but it has also the same design and criteria. Unfortunately the author presented his data with yearly intervals so that an exact comparison is not possible.

Comparison of the data in the present study from both towns together with that of Schilstra shows that most of the cumulative frequency curves from both studies are comparable. In most teeth the mean age at eruption does not show a difference of more than three months. The following teeth from the Culemborg -Tiel study, however, showed a greater difference:

- the lateral upper incisor in girls, which erupted six months earlier,
- the upper second premolar in girls, which erupted nearly eight months later,
- the lower second premolar, which erupted ten months earlier in boys and six months earlier in girls.

De Boer (1970) used for her longitudinal study plaster models which were made with a half year interval. This author, however, presented as the time of eruption the mean of the period between the last diagnosis "unerupted" and the first diagnosis "erupted" of a tooth. She stated that this might be the cause that her median eruption time is somewhat earlier than those found by Schilstra. However, the values presented by De Boer are probably those which approximate best the real time of eruption. Besides, the fact that the curves are very smooth is the result of the longitudinal design of her stüdy. Since the study by De Boer only concerns the central and lateral incisors and the first molars, comparison with other teeth from our study is not possible.

The data can also be compared with those presented in Table I and II of the paper by Parfitt (1954) concerning school children from London.

Parfitt's study has the same design as the one presented here, but the children were examined at quarterly intervals so that in his study still more precise curves could be constructed.

In the paper by Parfitt can be seen that generally the median age of eruption of teeth in boys tends to be later than in the Culemborg - Tiel study, namely for the upper second premolar, the lower cuspid, the premolars and the lower second molar. The median age of eruption in girls is about the same as in the Culemborg-Tiel study except for the upper first premolar which erupts earlier, and the upper lateral incisor and lower second premolar which both erupt later.

5.4.4 Addition of lacking data and combination of data

For the median age of eruption for the teeth which are lacking or could not be calculated precisely in our study (i.e. the upper central incisor and the first molars), those by Schilstra presented in Table 5-2 are used.

As was pointed out above, the median age of eruption, representing the age at which 50% of the teeth has erupted, has to be known in order to assess the contribution of pre- and posteruptive consumption of fluoridated water to caries reduction.

The median age of eruption is about half a year later for boys than for girls from the same town and is also different for upper and lower teeth. Nevertheless for this study dealing with the effect of the use of fluoridated water pre- and posteruptively the median eruption time of boys and girls together was used. For the premolar - molar group the mean for upper and lower teeth is used as the median time of eruption. Because the caries experience in the surfaces of each tooth apart showed considerable variations between the different year groups due to random variation, the caries data of upper and lower teeth were added in order to obtain groups containing enough surfaces. The median eruption times of the teeth in the groups composed by boys and girls as well as upper and lower teeth together have been presented in the last column of Table 5-8. For the upper central incisor and the first molar the mean was taken from the additional data obtained from Schilstra taking boys and girls and, in the first molar, upper and lower molars together. The following values were calculated for the median eruption time:

- upper central incisor 7 years 2 months
- first molar 6 years 2 months

If for the DMF index of a year class a weighted average of boys and girls is used the contribution of both sexes is equal, so that the median time of eruption of the total group is the mean of the median times of eruption of boys and girls apart. This is also the case for the upper and lower teeth because their number is the same.

Since the age of eruption in each group is also equally distributed, it is justified that, - if the mean is taken of the median ages at eruption for boys and girls separately, and for upper and lower premòlars or molars, - the result of the assessment of the pre- and posteruptive effect will not be affected as long as the DMF index of each surface in control and study group is also assessed for the same, comparable groups.

With respect to the period of fluoride use pre- and posteruptively, groups with an earlier and later median age of eruption (girls or boys; lower or upper teeth) form a compensation for each other, the more so as the spread in the eruption time of teeth of the same type within one of the four groups can cover some years and the differences between the median eruption times of the groups are small in comparison to the minimally yearly interval between the examinations of the Culemborg - Tiel study.

The conclusions of this study can be summarized as follows:

- In Tiel teeth erupt about three months earlier than in Culemborg regardless of the use of fluoridated water. This means a three months longer caries at risk period. Especially for the occlusal fissure of the molars this may lead to underestimating the fluoride effect.

- Except for the first upper premolar in Tiel, where the curves show practically the same course, comparable teeth erupt about six months earlier in girls than in boys. This earlier eruption in girls is a well known phenomenon reported by other authors.

- The data are comparable with other contemporary eruption studies elsewhere in The Netherlands, so the median eruption age found in our study can be used for the assessment of the effect of the use of fluoridated water pre- and posteruptively.

- There is no evidence that in this study the use of fluoridated water has influenced the time of eruption.

6.0 THE EFFECT OF POSTERUPTIVE AND PRE-AND POSTERUPTIVE USE OF FLUORIDATED WATER ON DENTINAL CARIES LESIONS IN PROXIMAL SURFACES

6.1 INTRODUCTION

As has been pointed out in chapter 3.0 the start of an artificial water fluoridation experiment is particularly suited to discriminate between the effect of posteruptive use of fluoridated water only and of its combined pre- and posteruptive use at different stages during the development and after eruption of the teeth on caries experience. The reasons why different types of surfaces have to be considered separately, have been explained in the same chapter. The aim of this study is to assess the effect of the use of fluoridated water during an increasing period posteruptively and during an increasing additional preeruptive period, while the posteruptive use continues until the moment of examination on dental caries in proximal surfaces.

This chapter describes four studies, i.e.:

- a cross-sectional study yearly consisting of the 15-year-old children,
- standardization of these data at the tooth level with respect to the use of fluoridated water pre- and posteruptively,
- standardization of the data with respect to the caries experience of each surface,
- standardization of the period between eruption and examination.

In the sections Material and Methods, Results and Discussion the last two digits of the numbering of the parallel paragraphs is the same.

6.2 MATERIAL AND METHODS

6.2.1 General

The scores of the dentinal lesions, obtained from standardized bite-wing radiographs from the Culemborg - Tiel water fluoridation study, were used exclusively.

The method of taking the radiographs and the method of scoring dental caries in proximal surfaces from these radiographs have been described by Backer Dirks and co-workers (Backer Dirks et al., 1953; Backer Dirks and Kwant, 1954) and an outline can be found in par. 3.7.2.

In the front region three radiographs were made: two lateral and one central. In the molar region four bite-wings were available: on each side two, of which one was placed half the width of a premolar more mesially than the other. This was done in order to prevent overlap from adjacent surfaces and to obtain a clear view of all surfaces including the distal surface of the second molar and the distal surface of the canine.

Radiographical data from proximal surfaces of the following teeth were present in each year of examination.

a. on radiographs of the front teeth: upper central incisors, upper lateral incisors and the mesial surface of the upper canines;
b. on radiographs of the premolar - molar region: premolars and molars and the distal surface of the canines.

Of the lower front teeth no radiographs were made systematically during the study because the number of proximal lesions was too low to justifiy the necessary three radiographs. The distal surface of the canines had an extremely low caries level as well. Therefore these surfaces have been omitted from the study.

The radiographs were independendly scored by two carefully trained persons.

A dentinal lesion was described as a dark zone in the dentin at the dentinal-enamel junction.

Each year class contained a different number of children and the number of boys and girls was not the same in most of the groups. In order to obtain comparable caries data, all DMF figures were calculated as a weighted mean of boys and girls. For those years of which no data were available the mean was taken from the preceding and the succeeding examination years.

6.2.1.1 Cross-sectional study

Caries data concerning the proximal surfaces of 15 year classes examined between 1952 and 1973 of children with a mean age of 15 1/4 years were recorded in each year of examination and for each surface separately. These data (table 6-1) were used for further calculations.

6.2.1.2 Standardization with respect to the use of fluoridated water pre- and posteruptively

The data of the cross-sectional study were now arranged at the tooth level in such a way that the median time of eruption of each tooth category (cf. table 4-8) coincided with the start of the water fluoridation in Tiel. All important aspects of this method have been described extensively in paragraph 3.6.2. The outline of the method is summarized below. Also the corrections applied to the data of the Culemborg - Tiel experiment will be discussed.

The limitation for table 6-2 at the bottom (= maximal period between formation and eruption) is formed by the duration of the formation and mineralization pre-eruptively, which ranges between at least six to seven years for the first molar and nine years for the upper canine. The shorter of the two intervals is the limiting factor. (See also table 3-3 and table 6-1).

If the data of each class (= each row) containing surfaces with the same interval between the median time of eruption and the start of the use of fluoridated water, are counted together, the totals represent the number of proximal DMF-surfaces in 12 imaginary groups of 15-year-old children from Culemborg and Tiel whose teeth erupted all at the same time. Besides, for each group in Tiel fluoridation started for all teeth at about the same stage of tooth development, from seven years before eruption until four years after eruption. The data from Culemborg are from the same teeth in the same years of examination.

6.2.1.3 Standardization with respect to the caries experience of each surface.

A disadvantage of the way of calculation as presented in paragraph 6.2.1.2 is, that surfaces with a high caries experience (DMF) have far more influence on the total DMF count than surfaces with a low caries experience. In order to obtain a mean reduction which is independent of the level of caries experience in different teeth, the percentages less DMF-S in Tiel compared to Culemborg of each surface apart and in each year class are classified in the same way as described for the surfaces in the preceding two paragraphs (6.2.1.1/.2).

The mean of these percentages less DMF-S is calculated. This is the mean of the percentages reduction in dental caries in these proximal surfaces in case water fluoridation started from four years after eruption until seven years before eruption.

On the other hand the method of calculation using the mean of the individual percentages reduction of each surface apart has the disadvantage that in surfaces with an extremely low caries frequency - e.g. the mesial surface of the upper canine and the distal surface of the second molar (<5% of the surfaces affected), - small differences in number of affected surfaces may result in large variations in the reduction expressed as a percentage. Therefore the data of these two surfaces have been omitted from this calculation.

6.2.1.4 Standardization of the period between eruption and examination of the various teeth.

The intervals between eruption and examination at the age of 15 years are different for the various teeth: 3 1/2 years for the second molar, 4 years for the upper canine, 4 1/4 years for the second premolar, 5 years for the first premolar, 7 1/2 years for the lateral upper incisor, 8 years for the central upper incisor and 9 years for the first molar.

In order to investigate if this difference in caries at risk period has an influence on the relative contribution of posteruptive use only, and/or combined pre- and posteruptive use of fluoride, DMF-S scores of proximal surfaces of teeth, which erupt about the age of seven years, were recorded at age 11 1/4. At this age these surfaces were for four to five years at risk for caries, and thus more comparable with the premolars and second molars at age 15 1/4.. Morever, the caries data were available in the same frequency as for 15-year-old children. This procedure has been described extensively in Chapter 3.0, sections 3.5 and 3.6. An outline of it follows here. Surfaces selected for this part of the study are:

- the proximal surfaces of the central upper incisors,
- the mesial surface of the lateral upper incisors,
- the mesial surface of the first molars.

The distal surfaces of the first molars and the lateral incisors were not used, because these surfaces must be considered as free smooth surfaces until the eruption of the adjacent teeth, the second molar and the upper canine respectively.

The thus obtained data and the percentages reductions of dentinal lesions were classified in the same way as those in 15-year-old children described in paragraphs 6.2.1.1 to 6.2.1.4

They were compared with the proximal DMF-S index from the same surfaces of these children examined four years later at the age of 15 years.

The DMF-S indices of these surfaces at the age of 11 (group A) were also compared with the DMF-S indices of the proximal surfaces in 15-year-old children, which had also been at risk of caries during 4 - 5 years. This group (group B) contains data of the mesial surfaces of the upper canines and the proximal surfaces of the premolars and of the second molars. The latter have been selected, because they erupt at about the age of 11.

To compare these groups the percentage of attacked surfaces was used as the unit of measurement.

6.3 RESULTS

6.3.1 General

In tables 6-1 (children, aged 15) and 6-4 (children, aged 11) the data are reported for Culemborg and Tiel separately. In each year class the DMF indices are presented for each surface separately per 100 children as a weighted mean of boys and girls. Since each year group consists of other children it may be expected that the variation in the DMF indices in the different year classes will be considerable.

6.3.1.1 Cross-sectional study

In tables 6-1a and 6-1b the number of children with a mean age of 15 1/4 years, the DMF-S index of each surface separately and the age of the children in each group at the start of the water fluoridation in Tiel are presented for each year of examination for both towns. For the years that no examination was carried out the data have been placed in brackets. These data are the mean of those in the two adjacent years of examination. The DMF indices of the teeth in Tiel which erupted around the start of the fluoridation have been printed in bold type. If the lapse of time between the median age of eruption and one of the two adjacent groups exceeded six weeks (= 1/8 of a year) both figures have been printed in bold. The DMF figures of teeth which started to calcificy at the start of the fluoridation, are underlined.

Table 6-1c is identical to table 6-1b, but with indications for the relation in the various surfaces between the start of the fluoridation and the median time of eruption. The upper line (-----) indicates teeth erupting four years before the start of the fluoridation, the drawn line (-----) teeth erupting at the start of the fluoridation and the lower line (·····) indicates teeth erupting seven years after the start of the fluoridation. Where these lines cross the numbers the data itself could be used. Where the line runs in between the numbers the data to be used are interpolated. The number of years that a column must be shifted upwards is indicated at the bottom of the table.

Figure 6-1 shows the total DMF score of the proximal surfaces per 100 children at the age of 15 years in each year of examination and figure 6-2 presents the percentage less proximal DMF surfaces in Tiel as computed from the data in table 6-1. Figure 6-2 also shows the mean of the percentages less DMF (Data of the mesial surface of the upper canines and the distal surface of the second molars are excluded). In the last case the relative contribution of the reduction in each surface apart to the total result is equal, irrespective of the level of caries experience in that surface.

6.3.1.2 Standardization with respect to the use of fluoridated water pre- and posteruptively.

Whereas in table 6-1 and fig. 6-1 and 6-2 the data are classified according to the age of the children at the start of the water fluoridation in Tiel, in table 6-2 and 6-3 and in fig. 6-3 and 6-4 the data are classified according to the pre- or posteruptive age of the individual teeth at the start of the water fluoridation. The result is that each row in table 6-2 and 6-3 gives no longer the data of a group of children, but of surfaces with the same pre- or posteruptive age in relation to the start of the water fluoridation.

Figure 6-3 shows the total scores of proximal surfaces in Culemborg and Tiel which had the same age at the start of the water fluoridation in Tiel (table 6-2). Figure 6-4 shows the percentage less caries in Tiel with respect to Culemborg.

6.3.1.3 Standardization with respect to the caries experience of each surface.

Figure 6-4 shows besides the percentage less DMF of the total of the proximal surfaces used in this study, and the mean of the percentages less DMF-S (table 6-2). As in figure 6-2 the contribution of the redüction in each type of surface is equal now, irrespective of the relative level of the caries frequency in the various surfaces in the control group Culemborg.

6.3.1.4 Standardization of the period between eruption and examination.

In order to obtain a more comparable condition e.g., a caries at risk period of 4 - 5 years for the earlier erupting teeth as well as for the later erupting teeth, the DMF indices of the proximal surfaces of the central upper incisor and the mesial surface of the first molars and the lateral upper incisor are presented for both towns in children aged 11 years (table 6-4). The DMF indices in Tiel of the teeth which erupted around the start of the fluoridation have been printed in bold type. If the lapse of time between the median age of eruption and one of the two adjacent groups exceeded six weeks (= 1/8 of a year) both figures have been printed in bold. The DMF figures of teeth which started to calcificy at the start of the fluoridation, are underlined.

The percentage reduction in DMF of comparable surfaces in children from Tiel with respect to those from Culemborg can be found in the last column of the same table.

Figure 6-5 shows the DMF curves for the 11 years age groups from both towns, using data from table 6-4 and of the same surfaces and the same birth classes at the age of 15 years, compiled from table 6-1.

Figure 6-6 shows the number of DMF of the same surfaces as in the preceding paragraph in 11-year-old children (group A) and in 15-year-old children, the DMF-S curves of proximal surfaces in teeth which erupt at the age of about 11 years (premolars, second molars and the mesial surface of the upper canines) (group B). Both groups of surfaces have been classified according to the relation between the median age of eruption of each tooth and the start of the fluoridation in Tiel. (Data from table 6-5a, 6-5b, 6-2a and 6-2b).

Figure 6-7 shows the percentage less proximal DMF-S of the selected proximal surfaces of incisors and first molar at age 11 and of the same surfaces at age 15. The surfaces are classified according to the relation between the median age of eruption and the start of the water fluoridation in Tiel. (Data at age 11 from table 6-5, data at age 15 from table 6-2).

Fig. 6-8 shows the percentage less proximal DMF-S of the selected proximal surfaces of incisors and first molar in 11-year-old children (the same as in figure 6-7) and, at the age of 15 years, the percentage less DMF in the proximal surfaces of the premolars, the second molar and the mesial surface of the upper canine together, classified in the same way.

Figure 6-9 shows the percentage reduction (table 6-5b, last column) and the mean of the percentages reduction of the separate teeth as presented in the last column of table 6-6.

Table 6-1: Proximal DMF surfaces per 100 15-year-old children from Culemborg (6-1a) and Tiel (6-1b and 6-1c) examined between 1952 and 1973 and the percentage less DMF-S in Tiel (6-1b, last column). Weighted average from boys and girls. For further explanation see text.

			I1sup		I2sup		Csup	P1		P2		M1		M2		TOTAL
			mes	dis	mes	dis	mes	mes	dis	mes	dis	mes	dis	mes	dis	
median age of eruption (in years)			7 1/4		7 3/4		11 1/4	10 1/4		11		6 1/4		10 3/4		
year of birth	age at start F/H2O in Tiel	number of boys+girls	superior					superior + inferior								
Table 6-1a: CULEMBORG - proximal DMF surfaces per 100 children (weighted mean of boys and girls) at age 15																
1937	15 3/4	86	53	53	59	28	11	20	50	65	92	165	177	29	20	822
1938	14 3/4	108	49	35	39	13	10	26	58	49	97	150	150	18	9	704
1939	(13 3/4)		(52)	(50)	(40)	(23)	(8)	(26)	(62)	(66)	(96)	(173)	(164)	(27)	(15)	(801)
1940	12 3/4	96	55	64	42	32	6	27	65	83	95	196	178	35	20	898
1941	11 3/4	81	56	53	51	24	8	25	68	67	103	217	178	50	27	928
1942	10 3/4	102	57	59	54	29	9	30	81	78	106	235	188	47	28	1000
1943	(9 3/4)		(53)	(56)	(49)	(31)	(14)	(29)	(73)	(78)	(109)	(213)	(191)	(50)	(27)	(973)
1944	8 3/4	102	49	53	44	34	20	28	64	77	113	192	194	52	26	947
1945	7 3/4	100	53	54	62	27	9	32	73	77	109	195	197	65	33	989
1946	6 3/4	125	52	70	67	39	19	33	68	83	110	200	197	60	36	1032
1947	(5 3/4)		(61)	(73)	(68)	(40)	(18)	(34)	(74)	(80)	(116)	(203)	(198)	(63)	(31)	(1057)
1948	4 3/4	111	71	76	69	41	17	36	79	77	121	205	198	67	26	1082
1949	3 3/4	107	44	58	36	24	8	34	61	73	94	214	181	71	35	933
1950	2 3/4	116	64	64	64	23	8	33	74	86	122	187	180	55	25	985
1951	(1 3/4)		(63)	(70)	(70)	(30)	(18)	(41)	(74)	(84)	(112)	(202)	(199)	(70)	(27)	(1060)
1952	0 3/4	114	63	76	76	37	28	48	74	82	103	217	217	85	29	1135
1953	- 1/4	126	56	79	77	46	25	47	88	86	109	188	195	80	43	1118
1954	-1 1/4	135	57	72	75	52	20	63	96	94	133	222	200	84	53	1221
1955	(-2 1/4)															
1956	(-3 1/4)															
1957	-4 1/4	131	50	85	70	40	19	51	92	90	115	205	181	74	29	1101

Table 6-1b: TIEL - proximal DMF-S per 100 children (weighted mean of boys and girls) at age 15.

year of birth	age at start F/H20 in Tiel	number of boys+girls	superior I1sup nes	I1sup dis	I2sup nes	I2sup dis	Csup nes	superior + inferior PI nes	PI dis	P2 nes	P2 dis	M1 nes	M1 dis	M2 nes	M2 dis	TOTAL	percentage reduction of TOTAL DMF-S
1937	15 3/4	98	36	34	41	16	5	18	49	43	81	164	153	21	8	669	19
1938	14 3/4	107	39	48	38	13	5	19	59	61	86	167	161	25	12	736	-5
1939	(13 3/4)		(47)	(55)	(43)	(16)	(5)	(23)	(62)	(66)	(83)	(190)	(169)	(28)	(15)	(802)	0
1940	12 3/4	103	55	61	47	20	6	26	66	70	79	212	177	30	19	868	3
1941	11 3/4	105	53	57	46	32	9	23	64	64	100	217	192	36	21	914	1
1942	10 3/4	82	50	45	47	10	4	18	45	43	56	178	156	20	13	685	31
1943	(9 3/4)		(39)	(46)	(46)	(12)	(5)	(15)	(51)	(49)	(78)	(203)	(173)	(30)	(20)	(766)	21
1944	8 3/4	101	28	47	46	13	6	11	57	55	99	229	191	39	26	847	11
1945	7 3/4	100	30	45	40	17	8	12	49	50	74	177	129	26	13	671	32
1946	6 3/4	124	41	42	29	14	5	17	47	45	68	172	145	22	11	657	36
1947	(5 3/4)		(34)	(38)	(29)	(12)	5	(14)	(39)	(37)	(69)	(161)	(133)	(22)	(7)	(599)	43
1948	4 3/4	114	27	34	29	9	6	11	30	29	70	149	121	22	3	540	50
1949	3 3/4	109	11	26	16	7	6	17	23	22	36	113	88	5	9	379	59
1950	2 3/4	116	25	21	21	4	4	11	30	27	60	117	75	10	5	409	58
1951	(1 3/4)		(25)	(25)	(22)	(8)	(6)	(13)	(27)	(27)	(53)	(93)	(63)	(11)	(5)	(377)	64
1952	0 3/4	114	25	28	23	11	7	14	25	28	45	70	52	11	5	345	70
1953	- 1/4	138	25	18	22	9	4	18	17	17	37	64	55	14	6	307	73
1954	-1 1/4	147	18	19	18	6	2	12	32	25	58	73	52	18	3	336	72
1955	(-2 1/4)																
1956	(-3 1/4)																
1957	-4 1/4	142	13	17	19	4	2	13	21	27	57	67	32	11	4	287	74

Table 6-1c: TIEL - proximal DMF-S per 100 children (weighted mean of boys and girls) at age 15. Data identical to Table 6-1b. Indications added for surfaces erupting:

------ - four years after
——— - at the start of the fluoridation
.... - seven years before

year of birth	age at start F/H20 in Tiel	number of boys+girls	superior					superior + inferior							
			I1sup		I2sup		Csup	P1		P2		M1		M2	
			mes	dis	mes	dis	mes	mes	dis	mes	dis	mes	dis	mes	dis
1937	15 3/4	98	36	34	41	16	5	18	49	43	81	164	153	21	8
1938	14 3/4	107	39	48	38	13	5	19	59	61	86	167	161	25	12
1939	(13 3/4)		(47)	(55)	(43)	(16)	(5)	(23)	(62)	(66)	(83)	(190)	(169)	(28)	(15)
1940	12 3/4	103	55	61	47	20	6	26	66	70	79	212	177	30	19
1941	11 3/4	105	53	57	46	32	9	23	64	64	100	217	192	36	21
1942	10 3/4	82	50	45	47	10	4	18	45	43	56	178	156	20	13
1943	(9 3/4)		(39)	(46)	(46)	(12)	(5)	(15)	(51)	(49)	(78)	(203)	(173)	(30)	(20)
1944	8 3/4	101	28	47	46	13	6	11	57	55	99	229	191	39	26
1945	7 3/4	100	30	45	40	17	8	12	49	50	74	177	129	26	13
1946	6 3/4	124	41	42	29	14	5	17	47	45	68	172	145	22	11
1947	(5 3/4)		(34)	(38)	(29)	(12)	5	(14)	(39)	(37)	(69)	(161)	(133)	(22)	(7)
1948	4 3/4	114	27	34	29	9	6	11	30	29	70	149	121	22	3
1949	3 3/4	109	11	26	16	7	6	17	23	22	36	113	88	5	9
1950	2 3/4	116	25	21	21	4	4	11	30	27	60	117	75	10	5
1951	(1 3/4)		(25)	(25)	(22)	(8)	(6)	(13)	(27)	(27)	(53)	(93)	(63)	(11)	(5)
1952	0 3/4	114	25	28	23	11	7	14	25	28	45	70	52	11	5
1953	- 1/4	138	25	18	22	9	4	18	17	17	37	64	55	14	6
1954	-1 1/4	147	18	19	18	6	2	12	32	25	58	73	52	18	3
1955	(-2 1/4)														
1956	(-3 1/4)														
1957	-4 1/4	142	13	17	19	4	2	13	21	27	57	67	32	11	4
number of years that column must be shifted upwards			4.5	4.5	4.0	4.0	0.5	1.5	1.5	0.75	0.75	5.5	5.5	0	0

Table 6-2: Proximal DMF surfaces per 100 15-year-old children from Culemborg (6-2a) and Tiel (6-2b) examined in 1952 - 1969. Data are classified according to the period of post- and additional pre-eruptive consumption of fluoridated water (1.0 mg F^-/l) for each kind of tooth and two tooth surfaces separately.

Table 6-2a: CULEMBORG - proximal DMF-S per 100 children (weighted mean of boys and girls) at age 15

period between eruption and start of fluoridation in Tiel	I1sup		I2sup		Csup	P1		P2		M1		M2		
	mes	dis	mes	dis	mes	mes	dis	mes	dis	mes	dis	mes	dis	TOTAL
start F/H2O 4 years after	57	56	51	24	10	26	60	53	96	224	189	29	20	897
3	55	57	54	29	9	26	62	62	97	203	193	18	9	874
2	51	54	49	32	7	26	65	79	95	193	196	27	15	892
1	51	53	44	34	7	25	68	71	101	198	197	35	20	904
0 eruption	53	62	62	27	8	30	81	76	105	201	197	50	27	976
1 year before	56	71	67	39	11	29	73	78	108	204	198	47	28	1009
2	66	74	68	40	17	28	64	77	112	209	190	49	27	1023
3	57	67	69	41	14	32	73	77	110	200	181	52	26	998
4	54	61	36	24	14	33	68	82	109	195	189	65	33	965
5	63	67	64	23	19	35	74	81	114	210	208	60	36	1054
6	59	73	70	30	17	36	79	78	120	203	206	63	31	1062
7	57	77	76	37	12	33	68	74	101	205	197	67	26	1032

Table 6-2b: TIEL - proximal DMF-S per 100 children (weighted mean of boys and girls) at age 15

period between eruption and start of fluoridation in Tiel	I1sup		I2sup		Csup	P1		P2		M1		M2			per cent
	mes	dis	mes	dis	mes	mes	dis	mes	dis	mes	dis	mes	dis	TOTAL	reduction
start F/H2O 4 years after	51	51	46	32	5	21	61	57	85	191	165	21	8	795	10
3	44	46	47	10	5	25	64	65	84	217	182	25	12	826	7
2	34	47	46	12	6	25	65	69	80	203	160	28	15	789	12
1	29	46	46	13	7	20	55	66	95	175	137	30	19	738	18
0 eruption	36	44	40	17	6	16	48	48	67	166	139	36	21	685	30
1 year before	38	40	29	14	4	12	54	47	72	155	127	20	13	624	38
2	31	36	29	11	5	11	53	54	93	131	105	30	20	609	40
3	19	30	29	9	7	14	48	51	80	115	82	39	26	549	45
4	18	23	16	7	7	15	43	46	69	105	69	26	13	458	53
5	25	22	21	4	5	12	34	39	69	82	58	22	11	405	62
6	25	26	22	7	6	14	26	31	70	67	54	22	7	378	64
7	25	23	23	11	6	14	27	24	44	69	54	22	3	344	67

Table 6-3: The percentage less proximal DMF surfaces in 15-year-old children from Tiel compared with children from Culemborg examined in the same year (see Table 6-2). The start of the period ranged from 7 years before eruption until 4 years after eruption.

PERCENTAGE REDUCTION of DMF surfaces in Tiel with respect to Culemborg

period between eruption and start of fluoridation in Tiel	I1sup		I2sup		Csup	P1		P2		M1		M2		Mean of the percentages in the separate surfaces
	mes	dis	mes	dis	mes	mes	dis	mes	dis	mes	dis	mes	dis	
start F/H2O 4 years after	11	9	10	-33	50	19	-2	-8	11	15	13	28	60	14
3	20	19	13	66	44	4	-3	-5	13	-7	6	-39	-33	8
2	33	13	6	62	14	4	0	13	16	-5	18	-4	0	13
1	43	13	-5	62	0	20	19	7	6	12	30	14	5	17
0 eruption	32	29	35	37	25	47	41	37	36	17	29	28	22	32
1 year before	32	44	57	64	64	59	26	40	33	24	36	57	54	45
2 eruption	53	51	57	72	71	61	17	30	17	37	45	39	26	44
3	67	55	58	78	50	56	34	34	27	42	55	25	0	45
4	67	62	56	71	50	55	37	44	37	46	63	60	61	54
5	60	67	67	83	74	66	54	52	39	61	72	63	69	64
6	58	64	69	77	65	61	67	60	42	67	74	65	77	65
7	56	70	70	70	50	58	60	68	56	66	73	67	88	66

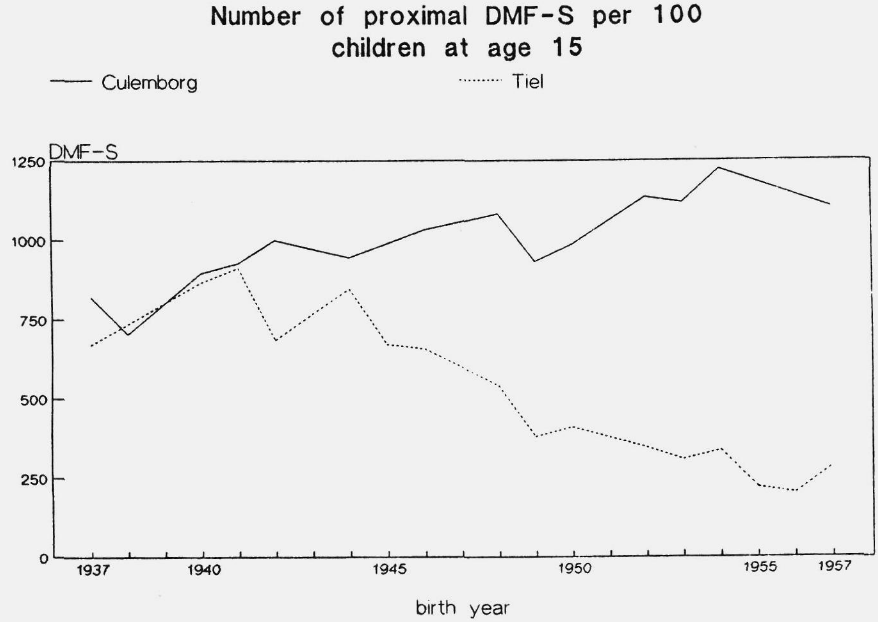


Fig. 6-1. Total proximal DMF surfaces in the premolar - molar region and in the upper anterior teeth per 100 children from Culemborg and Tiel at the age of 15 years. Children are born between 1937 and 1958.

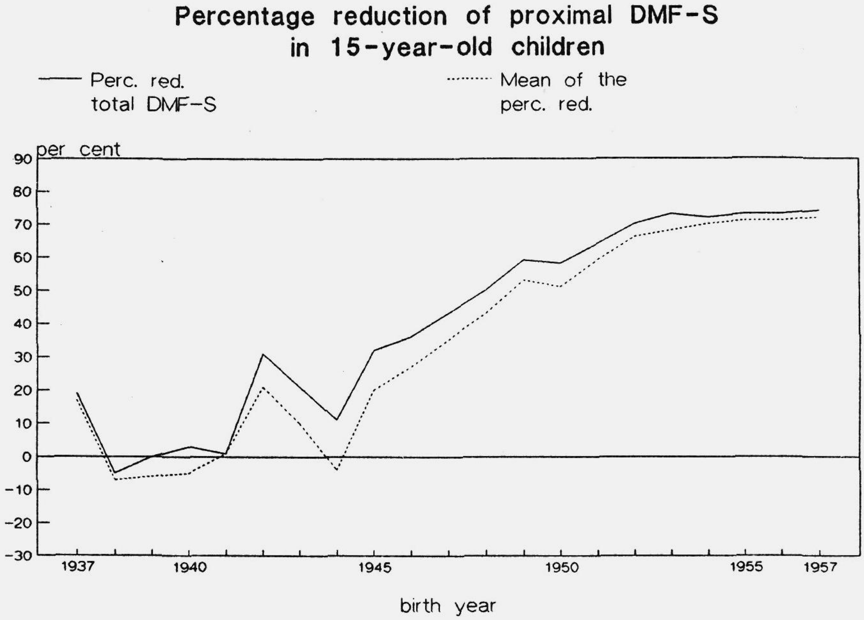


Fig. 6-2. Percentage less proximal DMF-S in Tiel and the mean of the percentages less DMF-S in the proximal surfaces; same groups as in Fig. 6-1.

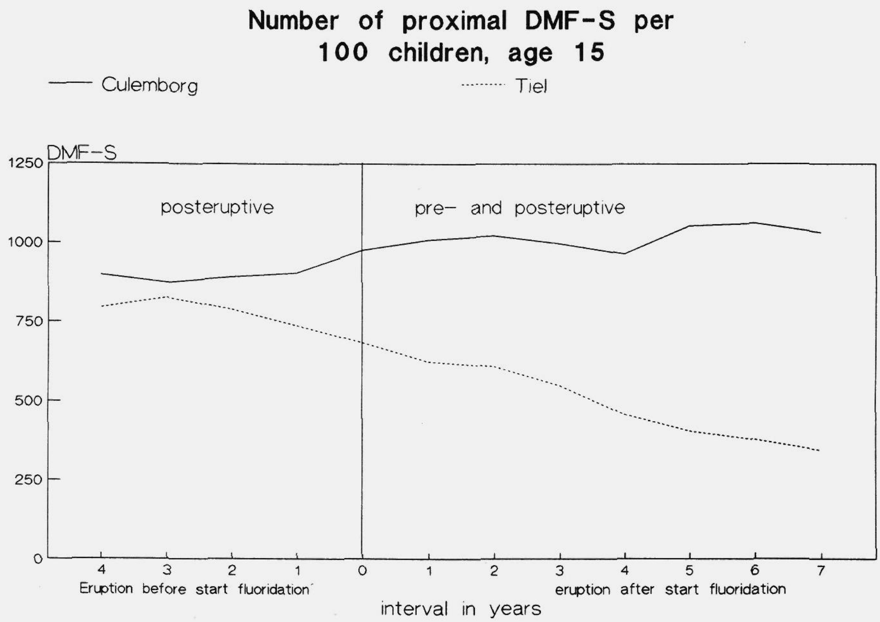


Fig. 6-3. Proximal DMF surfaces classified according to the relation between the median time of eruption and the start of the water fluoridation in Tiel. 15-year-old children from Culemborg and Tiel. The zero line indicates for all surfaces the coincidence of the median time of eruption and the start of the water fluoridation in Tiel.

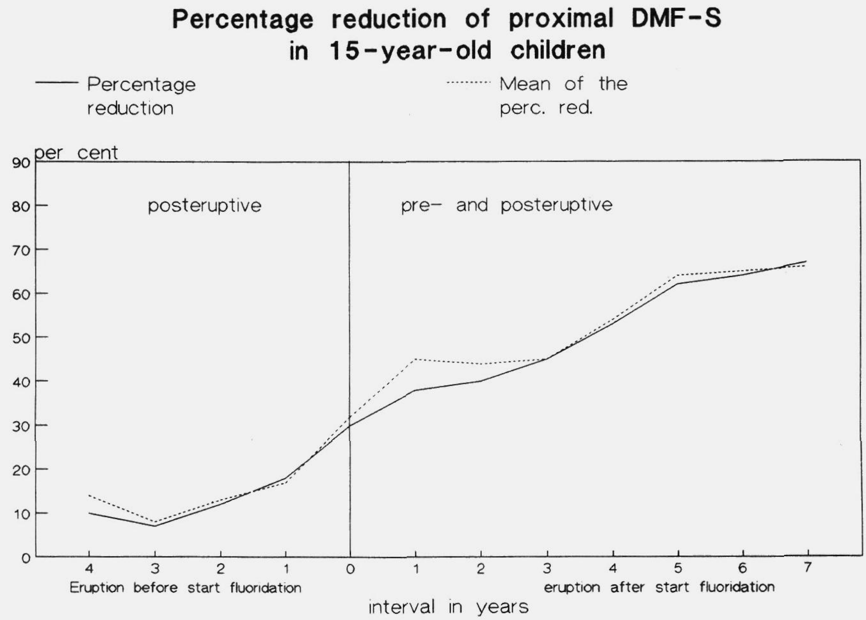


Fig. 6-4. Percentage less proximal DMF-S in Tiel and the mean of the percentages less DMF-S in the proximal surfaces; same groups as in Fig. 6-3.

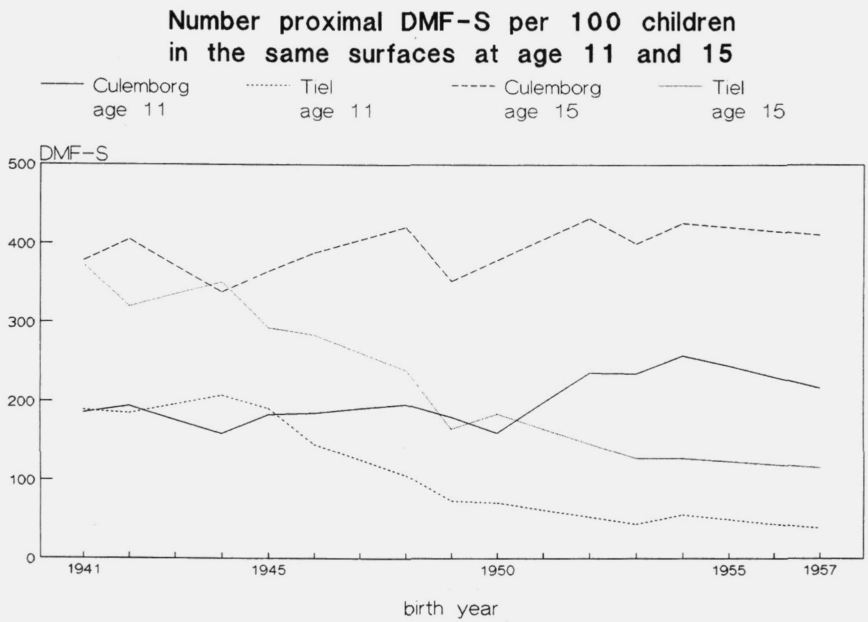


Fig. 6-5. Total number of proximal DMF-S per 100 children in the I_{1} sup., the I_{2} sup. mes. and the M_{1} mes. in children from Culemborg and Tiel born between 1941 and 1958, at the age of 11 years and at the age of 15 years.

Table 6-4: Proximal DMF surfaces per 100 11-year-old children (weighted mean of boys and girls) born between 1941 and 1957, in teeth erupting at about the age of seven years in Culemborg (6-4a) and Tiel (6-4b) and the percentage less DMF-S in Tiel (6-4b, last column).

Table 6-4a: CULEMBORG - proximal DMF-S per 100 children (weighted mean of boys and girls) at age 11

Year of birth	Age at start F/H2O	I1sup. mes.	I1sup. dist.	I2sup. mes.	M1. mes.	Total
1941		28	22	26	110	186
1942		7	24	25	138	194
1943		(14)	(25)	(25)	(113)	(176)
1944		20	26	25	88	159
1945		30	32	30	91	183
1946		20	36	28	101	185
1947		(23)	(33)	(32)	(102)	(191)
1948		26	30	37	103	196
1949		24	22	24	109	180
1950		26	26	27	81	160
1951		(28)	(33)	(35)	(100)	(198)
1952		31	40	43	122	236
1953		24	40	46	124	235
1954		33	48	47	131	258
1955		(29)	(48)	(47)	(120)	(245)
1956		(26)	(48)	(48)	(109)	(231)
1957		23	48	48	98	217

Table 6-4b: TIEL - proximal DMF-S per 100 children (weighted mean of boys and girls) at age 11

Year of birth	Age at start F/H2O	I1sup. mes.	I1sup. dist.	I2sup. mes.	M1. mes.	Total	Percentage reduction
1941	11 3/4	13	22	21	133	189	-2
1942	10 3/4	22	19	21	122	185	5
1943	9 3/4	(21)	(24)	(24)	(127)	(196)	-11
1944	8 3/4	19	29	27	132	207	-30
1945	7 3/4	18	26	28	118	191	-4
1946	6 3/4	21	22	11	92	145	21
1947	5 3/4	(16)	(19)	(14)	(77)	(126)	34
1948	4 /34	12	16	16	63	106	46
1949	3 3/4	4	7	7	54	73	59
1950	2 3/4	11	6	5	49	71	56
1951	1 3/4	(9)	(7)	(5)	(40)	(62)	67
1952	3/4	7	9	5	31	53	77
1953	- 1/4	3	2	3	35	44	81
1954	- 1 1/4	7	5	7	37	56	78
1955	- 2 1/4	(5)	(5)	(7)	(34)	(50)	80
1956	- 3 1/4	(3)	(5)	(6)	(30)	(44)	81
1957	- 4 1/4	2	5	5	27	39	82

Table 6-5: Proximal DMF surfaces per 100 11-year-old children from Culemborg (6-5a) and Tiel (6-5b), of teeth erupting at about the age of seven years. The data are classified according to the period of posteruptive and additional pre-eruptive use of fluoridated water (1.0 mg F^-/l) for each kind of tooth separately.

Table 6-5a: CULEMBORG - proximal DMF-S per 100 children (weighted mean of boys and girls) at age 11

time between eruption and start F/H2O in Tiel		I1sup. mes.	I1sup. dist.	I2sup. mes.	M1. mes.	Total
+4	years	18	23	26	125	192
+3	after	10	25	25	100	160
+2		17	25	25	89	157
+1		25	29	25	96	176
ERUPTION		25	34	30	102	190
-1	year	21	35	28	103	187
-2	before	24	32	32	106	195
-3		25	26	37	95	184
-4		25	24	24	91	165
-5		27	30	27	112	195
-6		30	36	35	123	224
-7		28	40	43	127	238

Table 6-5b: TIEL - proximal DMF-S per 100 children (weighted mean of boys and girls) at age 11

time between eruption and start F/H2O in Tiel		I1sup. mes.	I1sup. dist.	I2sup. mes.	M1. mes.	Total	Percentage reduction in Tiel
start F/H2O							
+4	years	18	21	21	125	184	4
+3	after	22	21	21	129	194	-21
+2		20	26	24	125	195	-25
+1		19	28	27	105	179	-2
ERUPTION		20	24	28	84	156	18
-1	year	18	20	11	70	120	36
-2	before	14	17	14	58	103	47
-3		8	12	16	52	87	53
-4		8	7	7	45	66	60
-5		10	7	5	36	58	70
-6		8	8	5	33	55	75
-7		5	6	5	36	53	78

Table 6-6: Percentage caries reduction in the surfaces of the groups from Table 6-5 and the mean of the percentages reduction.

Time between eruption and start F/H2O in Tiel	I1sup. mes.	I1sup. dist.	I2sup. mes.	M1. mes.	Mean of the percentages in the separate surfaces
+4 years	0	11	20	0	8
+3 after	-109	13	15	-29	-28
+2	-20	-3	4	-40	-15
+1	25	5	-8	-9	3
ERUPTION	22	29	5	17	18
-1 year	13	42	60	32	37
-2 before	42	45	58	45	48
-3	68	56	57	46	56
-4	70	73	70	51	65
-5	63	78	80	68	72
-6	72	77	85	73	77
-7	81	86	88	71	81

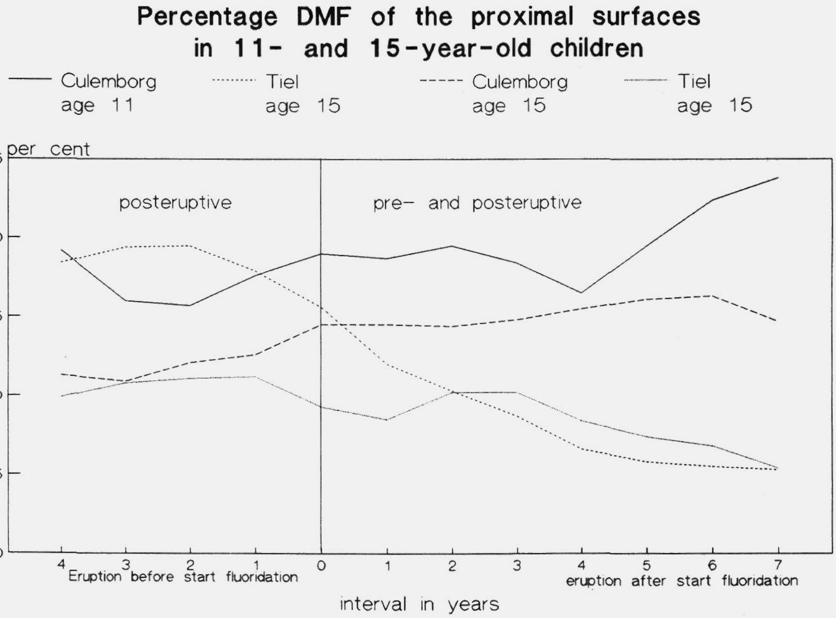


Fig. 6-6. Percentage proximal DMF-S at the age of 11 years in the $I_{1sup.}$, the $I_{2sup.}$ mes. and the M_1 mes. and the percentage proximal DMF-S at the age of 15 years in the premolars, the M_2 and the $C_{sup.}$ mes. together. Children from Culemborg and Tiel.
Surfaces are classified according to the relation between the median time of eruption and the start of the water fluoridation.

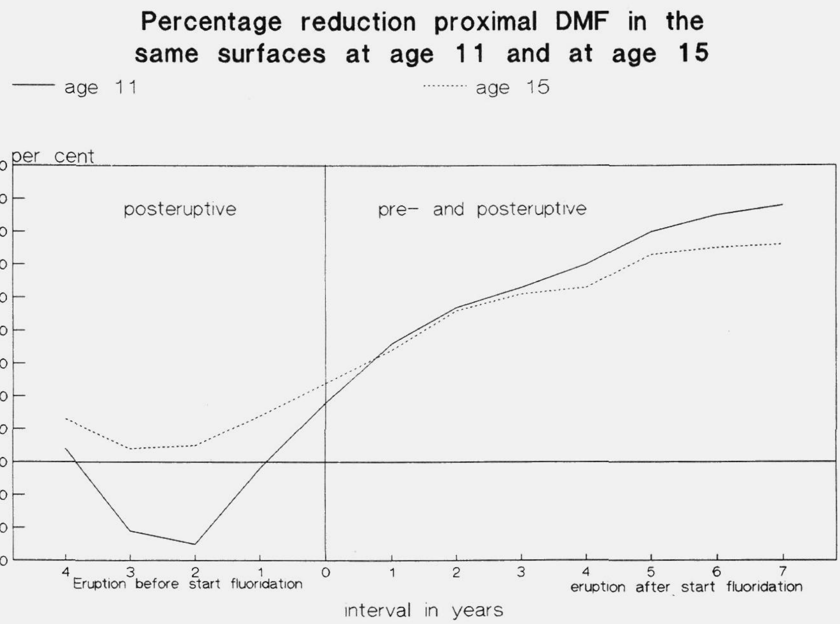


Fig. 6-7. Per cent less proximal DMF-S in Tiel of the $I_{1sup.}$, the $I_{2sup.}$ mes. and the M_1 mes. at the age of 11 years and at the age of 15 years in children born between 1941 and 1958.
Surfaces are classified according to the relation between the median time of eruption and the start of the water fluoridation.

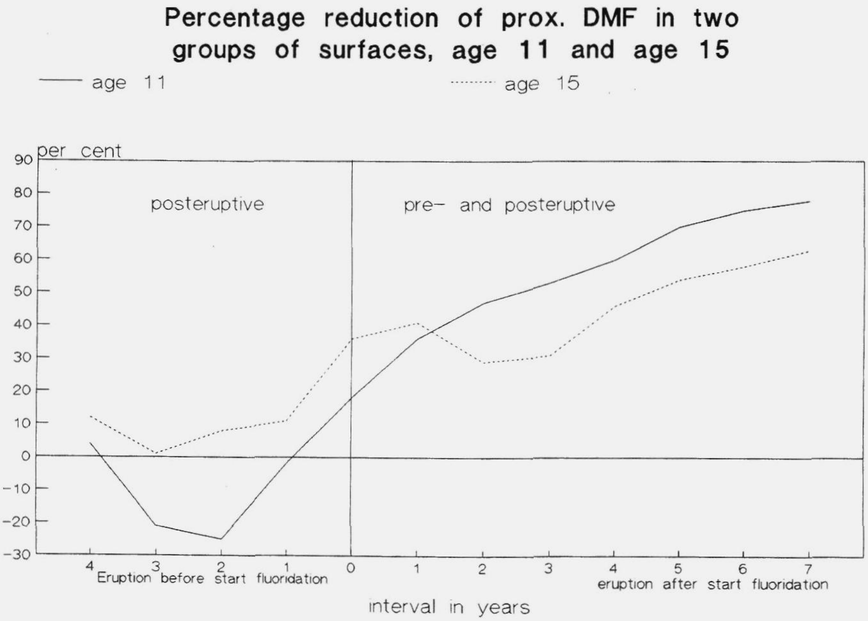


Fig. 6-8. Percentage less proximal DMF-S in Tiel in the $I_{1sup.}$, the $I_{2sup.}$ mes. and the M_1 mes. at the age of 11 years and the percentage less proximal DMF-S in the premolars, the M_2 and the $C_{sup.}$ mes. at the age of 15 years.
Surfaces are classified according to the relation between the median time of eruption and the start of the water fluoridation.

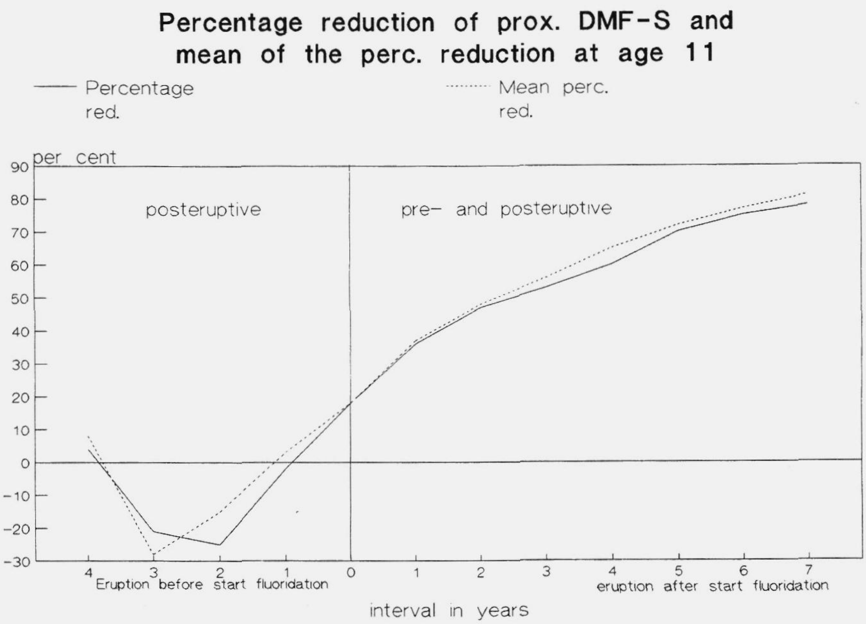


Fig. 6-9. Mean of the percentages less proximal DMF-S in 11-year-old children from Tiel in the $I_{1sup.}$, the $I_{2sup.}$ mes. and the M_1 mes. and the percentage less of the total DMF-S in the same surfaces.
Surfaces are classified according to the relation between the median time of eruption and the start of the water fluoridation.

6.4 DISCUSSION

6.4.1 General observations

The data in tables 6-1 and 6-4 and the curves of figures 6-1, 6-3, 6-5, 6-6 show that between the DMF indices in the same category of surfaces in successive years of examination a considerable difference can be observed in both control and study group. Two factors could have introduced a systematical error:

- 1. a difference in quality of the radiographs in various years,
- 2. a difference in the scoring between the various years of examination.

It is very unlikely that the last mentioned cause is the source of the difference, not only because the examiners were calibrated regularly using testseries of radiographs, but also because all radiographs were scored by two trained and regulary calibrated examiners. In case of disagreement the mean of the scores was used. Moreover, longitudinal data of several birth classes, as published by Kwant et al. (1972), show that within one birth class, examined longitudinally from the age of seven for eight years, the caries increment progresses smoothly.

All radiographs were developed according to a standardized and controlled procedure using new developer for each series of radiographs. However, it can not fully be excluded that variations of the development procedure, such as variations in temperature of the developer and/or the quality of the emulsion, might perhaps have contributed to these differences.

The difference between the data of the examination years in control and test group does not seem to be systematic neither for both age groups nor for the examination years. This can be attributed to random variation of the groups. The main cause for this variation in the data seems to be the variation in the randomly selected groups. This variation is situated within the standard error of the mean.

6.4.1.1 Cross-sectional study

Table 6-1 shows the continuous increase of the DMF-S index in Culemborg for all proximal DMF surfaces upto the examination in 1969. The overall increase of proximal DMF-S as observed in figure 6-1 amounts to about 50%. The total decrease in Tiel is about 60%.

In this kind of intervention study of a very long duration (more than 30 years) the need for a control group - not being a retrospective control group - is that, caused by factors other than the factor to be studied, the variables can decrease or increase. A control group is then indispensable as guard against false positive or false negative conclusions.

The Culemborg - Tiel study demonstrates this again. The continuous increase in caries experience in Culemborg in the first 15 years and the steep decrease in caries experience in Culemborg in the last 14 years of the study are of course disturbing. However, these marked changes in caries experience are not an isolated phenomenon, but a nationwide observation, which is also observed in other countries (Glass, 1982).

Moreover, the size of the effect of water fluoridation as recorded in Tiel is not much different from the results in the U.S.A. and New Zealand (Backer Dirks, 1967).

Table 6-1 also shows that in Tiel the DMF index of surfaces with an initially low caries level, e.g. the mesial surface of the first premolar, or the distal surface of the second molar, remains approximately equal during the study period, whereas that of surfaces with an initially high caries level, e. g. the mesial surface of the first molar and the mesial surface of the upper central incisor, shows a considerable decrease. In the surfaces with a low DMF index the percentage reduction of the DMF score caused by the water fluoridation is expressed by an increase in Culemborg, whereas the DMF-S in Tiel remain stable. However, in the surfaces with a high DMF index it can be observed that the caries reduction is mainly expressed by a decrease of the DMF-S in Tiel, whereas in Culemborg it remains stable or shows a small increase

If in this study, for the surfaces with a low caries prevalence, only a retrospective control group from Tiel should have been used, hardly any or no reduction at all would have been observed. This phenomenon shows that the use of an independant control group has a great importance for an objective assessment of the cause of the reduction of dental caries which is as exact as possible, especially in studies with a longer duration than two or three years.

The percentage reduction in total DMF-S in children who started the use of fluoridated water in Tiel at the age of 0 - 2 years (calcification of the first molar) is partly expressed by an increase of the DMF-S in Culemborg and partly by a decrease in Tiel, as can be observed in figure 6-1.

The use of the percentage reduction only, as presented in figure 6-2, is not sufficient to show the changing indices of study and control group separately.

This means that the still increasing difference between the DMF-S in Culemborg and Tiel during that period should be considered as a really reduced caries experience caused by fluoride. The data in Culemborg show what the situation in Tiel would have been without water fluoridation. For the study over a long period of the effect of fluoridated water on dental caries experience a control group from an other town is thus necessary.

The curve in figure 6-2 which pictures the mean of the individual percentages less proximal DMF of the various surfaces (dotted line) is situated above the one which pictures the percentage less of the total proximal DMF-S (drawn line) for children born in the period 1942 - 1952 who were 11 and one year of age respectively at the start of the water fluoridation. This can be explained by the fact that surfaces with a lower DMF-S show a greater reduction than surfaces with a higher DMF-S. The first molar and upper central incisor, which have both a relatively high DMF index have less influence on the mean percentage reduction than on the percentage reduction of the total DMF-S. On the other hand, teeth erupting at a higher age, which are in an earlier stage of development at the start of the fluoridation and which also have a shorter period between eruption and examination (premolars and second molar) have more influence on the mean of the percentages reduction of the individual teeth. Only at the moment that the maximal reduction is attained in all teeth (children born after 1951) both curves are situated at the same level.

Despite the variation in the level of caries experience between different surfaces of this category, no difference could be observed between the percentage reduction which maximally can be obtained with fluoridated water in the total DMF-S and the mean of the percentages in these surfaces.

With respect to the effect of post- and combined pre- and posteruptive use of fluoridated water fig. 6-2 shows that if consumption starts before the age of six years (children born in 1947), - thus before the eruption of the first permanent teeth, - the percentage reduction increases from about 40 to 70. This means that for proximal dentinal lesions an additional effect of pre-eruptive use to posteruptive use only is present.

6.4.1.2 Standardization with respect to the use of fluoridated water pre- and posteruptively.

The same features as in figures 6-1 and 6-2 can be observed in figures 6-3 and 6-4, but now according to the period of posteruptive and combined pre- and posteruptive consumption of fluoridated water. Here too a continuous increase of DMF-S in Culemborg can be observed in the period that in Tiel water fluoridation started during the pre-eruptive phase of the teeth, whereas the DMF-S in Tiel decreases constantly if fluoridated water has been used from before the third year posteruptively.

From figure 6-4 it can be concluded that teeth erupting at the start of the water fluoridation, and thus from then on in direct contact with fluoridated water (= maximal posteruptive effect) demonstrate a reduction in dentinal caries lesions of about 30%. Besides this topical effect fluoride is also in contact with the tooth via the internal route during the posteruptive phase (see Introduction).

The maximal effect is only attained if fluoridated water has also been consumed during the whole pre-eruptive period (seven years pre-eruptively). The effect is then nearly doubled: 65% less DMF-S in Tiel than in Culemborg. If, however, consumption begins at about four years after eruption, only a small reduction is observed. The curve for Tiel in figure 6-3 attains almost its minimum at about seven years before the coincidence of eruption and the start of the water fluoridation. This is for most teeth at the start of the crystallization period.

6.4.1.3 Standardization with respect to the caries experience of each surface

The difference between the method of calculation of an overall average in fig. 6-4 and the other curve in the same figure is, that the latter is independent of the different levels of caries experience of the various surfaces. In the former the tooth sites with a high prevalence of caries, - i.e. the proximal surfaces of the first molar and the distal surface of the second premolar, - form more than half of the total number of DMF-S in both towns and hence are determine the result in each year group to a great extent. In figure 6-4 a possible influence caused by a difference of caries frequency between the various surfaces within a year group is equilibrated. Since the courses of the two curves in figure 6-4 are generally not very different from each other, it can be concluded that in an overall measurement the diversity of caries experience in different proximal surfaces hardly influences the relative contribution of posteruptive and combined pre- and posteruptive use of fluoridated water. However, it must be kept in mind that surfaces with an extremely low caries prevalence were excluded from this count, because the small random variation of the number of DMF-S in these surfaces would have a disproportionate influence on the mean of the percentages reduction.

Unfortunately this variation of DMF-S in surfaces with a low caries prevalence between different years of examination is too large to draw any definite conclusion for each of these surfaces separately. Adding the caries scores of some of these surfaces, i.c. the mesial surface of the upper canine, the proximal surfaces of the premolars and the distal surface of the second molar (see table 6-3), and calculating the reduction in the same way as was done for the whole table 6-3, reveals that these surfaces show a result comparable to the total group.

The same procedure in the 11-year-old group showed that also in this group there was no difference between the percentage less DMF of proximal surfaces and the mean of the percentages of the surfaces apart after classification according to the relation between the median time of eruption and the start of the water fluoridation (fig. 6-9).

Although the difference of the level of caries experience within an age group hardly seems to influence the reduction, it must be kept in mind that the period at risk of the various surfaces is quite different. For the assessment of the relation between caries experience and the percentage reduction at different stages of tooth development, surfaces with a comparable period at risk, but with different levels of caries experience must be used.

6.4.1.4 Standardization of the period between eruption and examination

In the cross-sectional study the maximal percentage reduction of proximal DMF-S in the upper incisors and the mesial surface of the first molar is 80 at the age of 11 years (table 6-4) and 72 at the age of 15 years (calculated from table 6-1). This is a decrease of 8%.

About the decreasing difference with increasing age in persons consuming fluoridated water during their entire lives the literature is contradictory. Backer Dirks (1967) reported that in the Hastings study a decrease of overall reduction from about 75% at the age of 7 to about 50% at the age of 15 could be observed, but he noticed that only the 7 - 10 years age groups had received fluoridated water from birth. In the same publication he showed that the reduction of caries in the proximal surfaces of the first molar, calculated from the Culemborg - Tiel study was rather stable between 7 and 15 years of age. The study by Kwant et al. (1974) shows, however, that the reduction of DMF-S in the total number of proximal surfaces decreased from 84% at the age of 11 years via 72% at the age of 15 years to 58% at the age of 18 years.

The difference between the percentages at the age of 11 years and the age of 15 years is smaller in the present study than in the study by Kwant et al. (1974), probably because only a part of all surfaces have been used. Nevertheless it confirms the statement by Kwant that there is some decrease of the effect with increasing age.

After classification of the data of the 11-year-old children in relation to the median time of eruption and the start of the water fluoridation in Tiel the following observations can be made:

Figure 6-7 reveals that the maximal percentage reduction of proximal DMF surfaces of the upper incisors and the first molar (mesial surface) was higher at the age of 11 years than the reduction of the same surfaces in the 15-year-old group, classified in the same way. However, figure 6-7 also shows that at the coincidence of the moment of eruption and the start of the water fluoridation, the percentage caries reduction in the youngest age group (18%) was lower than in the same surfaces of the 15-year-old group (26%). Due to this phenomenon and to the higher maximal percentage reduction of the 11-year-old group, the curve over the total period of 12 years is steeper for this age group. Hence, it can be observed that there is a smaller maximal percentage caries reduction in the 15-year-old group. A relatively greater part of this smaller reduction is caused by the posteruptive use of fluoride: the 15-year-old group shows a greater effect of posteruptive use only in the same surfaces than the 11-year-old children.

A condition for an optimal reduction of caries increment by the posteruptive consumption of fluoridated water seems to be that its consumption starts immediately after eruption. If it is consumed pre-eruptively as well, the reduction increases significantly, ranging from approximately three times as much at the age of 11 years to approximately one time as much at the age of 15 years.

Comparison between the number of and the reduction of DMF surfaces in groups A (see par. 6.2.1.4) (teeth erupting at age seven and examined at age 11) and groups B (teeth erupting at age 11 and examined at age 15), showed that in the tooth surfaces of the study and control group which had erupted four years before the start of the water fluoridation about 70% more DMF-S were observed in group A if the number of surfaces at risk was the same in both groups (fig. 6-6).

The dip in the curve of control group A for surfaces which erupted four years after the start of the fluoridation and the two adjacent points (fig. 6-6) has been caused by a relatively low value for the DMF-S in the mesial surface of the first molar observed in birth class 1950 (table 6-4a). Apart from these three points the others fit in the range rather well.

The study groups of group A and group B had, apart from a comparable 'at risk' period, also the same period of posteruptive and additionally pre-eruptive use of fluoridated water (see fig. 6-6 and 6-8). The maximal percentage reduction was 75% in group A and 65% in group B (fig. 6-8). However, the relative effect of posteruptive use of fluoridated water was smaller in group A: 18% instead of 38% in group B (fig. 6-7). The high value of the latter is perhaps partly caused by at random variation. However, even if this curve is smoothed by connection of the value at two years before and the value at 2 years after the start of the fluoridation there is still an indication that within a category of surfaces there is an inverse relationship between the relative effect of posteruptive fluoride use and the level of caries experience, provided that the 'at risk' period is identical.

6.5 CONCLUSIONS

The results of this part of the study show that:

- the use of fluoridated water from birth on causes a mean caries reduction in the proximal surfaces of about 70% at the age of 15 years (cf. fig. 6-2). Except for surfaces with an extremely low caries experience, this percentage seems to be hardly dependent on the difference in the level of the caries experience between the various surfaces in an age group (cf. table 6-1a and 6-1b).

- the use of fluoridated water during the posteruptive period only, causes a caries reduction which is 45% of the maximal reduction in proximal surfaces at the age of 15 years. This maximal reduction is obtained if the consumption extends during the whole pre- and posteruptive period (fig. 6-4).

- comparison of the DMF-S in the same surfaces at the age of 11 years and at the age of 15 years reveals that, whereas in the younger age group the maximal caries reduction is about 10% more, the relative contribution of the consumption of fluoridated water used posteruptively to the reduction of dental caries is only approximately 1/4 of the maximal reduction, whereas in the 15 years age-group this is approximately 1/3 of the maximal reduction (fig. 6-7).

This result indicates that this shift, in combination with the small decrease of the maximal reduction between the age of 11 and the age of 15, could be the consequence of the gradual decrease of the effect of pre-eruptive use of fluoridated water in favour of the effect due to posteruptive use.

- using the percentage attacked surfaces as the unit of measurement and, for all surfaces in the study group an equal period for the use of fluoridated water, comparison of the number of proximal DMF-S and of the percentages reduction shows that proximal surfaces from group A (upper incisors and first molar mesial; see par. 6.2.1.4) had a higher DMF-S in the control group than proximal surfaces from group B (upper canine mesial, premolars and second molar) (fig. 6-6). However, group A experienced a relatively smaller effect of the posteruptive use of fluoridated water than group B (fig. 6-8). This suggests an inverse relationship between the level of caries experience and the relative effect of posteruptive use of fluoridated water within one category of surfaces with the same period at risk.

7.0 THE EFFECT OF POSTERUPTIVE AND PRE- AND POSTERUPTIVE USE OF FLUORIDATED WATER ON CARIES IN BUCCAL SMOOTH SURFACES.

7.1 INTRODUCTION

The buccal smooth surface lesions can also be named gingival (enamel) lesions, in contrast to the cervical lesions. They are also called free smooth surfaces in contrast to the proximal surfaces which are also smooth.

From figure 3-12, it appears that in the 21 years period of examination 1952 - 1972 for the toothsites which were examined clinically, i.c. smooth surfaces and fissures and pits, insufficient data are available to calculate the pre- and posteruptive effect in the same way as for the proximal surfaces. Clinical data of 15-year-old children are only available for children born in 1945, 1949, 1953, 1954 and 1957, aged 8, 4, 0, -1 and -4 years respectively at the start of the water fluoridation in Tiel.

7.2 MATERIAL AND METHODS

7.2.1 Cross-sectional data

The study consists of two sections:

In the first the DMF-S (dentinal lesions) of all bucco-gingival surfaces per 100 15-year-old children were compiled from the study by Kwant et al. (1972).

In the second section, for each category of teeth the DMF-S of the bucco-gingival surfaces were compiled from the original records. Upper and lower teeth of the same type were taken together, because their formation and the eruption take place at about the same time. Bucco-gingival surfaces which showed a discontinuity of the enamel surface due to caries which was longer than 1/2 mm and/or deeper than 1/4 mm were scored as being decayed. Since the caries frequency was rather low - (the highest being about 100 DF-surfaces per 100 children in the 400 second molars of children from Culemborg) - surfaces lost by extraction were not counted as being decayed. The chance that a bucco-gingival surface will be decayed was maximally 25%, but in most cases much smaller. This is different from the method used by Kwant et al. (1972), where extracted teeth received the same caries score as at the last one before the extraction at later examinations. The data in table 7-2 are thus not corrected for extractions. As a result the value of the DMF index of surfaces with a relatively high caries frequency will in fact be somewhat higher, because the chance that a decayed or filled surface has been extracted will be proportionally correlated to the number of DMF-surfaces.

7.2.2 Standardization with respect to the use of fluoridated water pre- and posteruptively

In both towns the data of the separate teeth were put in two sections. The first contained those teeth which erupted at the age of 6 - 8 years and the second those teeth which erupted at the age of 10 - 12 years. Hereafter, from these sections, groups of teeth were composed which had a similar relation between the time of eruption and the start of the fluoridation in Tiel.

In this way six groups were created: In Tiel the first group contained teeth which had erupted on average 1 1/2 years before the start of the fluoridation; only data for the first molar were available for this group. The second group contained teeth which erupted about 2 - 4 years after the start of the fluoridation. The third group contained teeth which had received fluoride from the start of their calcification on. In the fourth, fifth and sixth group fluoride was present during matrix formation a well. In the last group data were only available for premolars and second molars. The groups in Culemborg contained toothsurfaces examined in the same year as in Tiel.

7.3 RESULTS

The results are presented in tables 7-1, 7-2 and 7-3. All tables show the DMF of bucco-gingival surfaces in 15-year-old children from Culemborg and Tiel and the percentage reduction in Tiel.

Table 7-1 shows the DMF-S as compiled from the study by Kwant et al. (1972).

Table 7-2 shows cross-sectional data of the DF-S per tooth (thus without the extractions) as compiled from the original records.

In table 7-3 the data of table 7-2 are classified as much as possible according to the stage of development at the start of the water fluoridation in Tiel as described above.

For figure 7-1 the data from table 7-2, classified as in table 7-3, for the first and second molar have been used. About 70% of the cavities in the buccal smooth surfaces is present in these two teeth. The figure shows the reduction of DF-S in Tiel expressed as a percentage of the maximal reduction in buccal smooth surfaces of the first and second molar. The teeth are classified according to the relation between the time of eruption and the start of the water fluoridation in Tiel.

Table 7-1: DMF of bucco-gingival surfaces per 100 15-year-old children from Tiel and Culemborg born in 1945, 1949, 1953 and 1954, the mean age at start of the water fluoridation in Tiel and the percentage reduction in Tiel
(data from Kwant et al. 1972).

Year of birth	1945		1949		1953		1954	
	C	T	C	T	C	T	C	T
age at start F/H2O	7 3/4 yr		3 3/4 yr		-1/4 yr		-1 1/4 yr	
DMF-S	181	62	240	58	279	42	293	42
Percentage reduction	66		76		85		86	

Table 7-2: The decayed and filled bucco-gingival surfaces of 15-years old children from Culemborg and Tiel and the percentage reduction in Tiel in five different birth years.

		DMF per 100 children (weighted average of boys and girls)								
	number boys / girls	I1sup	I2sup	Csup	P1s+i	P2s+i	M1s+i	M2s+i	TOTAL	
		superior			superior + inferior					
CULEMBORG										
1945	50 / 50	4	15	13	11	6	44	65	157	
1949	53 / 54	8	10	19	9	9	69	98	222	
1953	68 / 58	17	22	19	11	6	67	85	226	
1954	65 / 70	7	16	22	18	9	70	102	245	
1957	72 / 59	8	13	8	6	7	55	63	160	
TIEL										
1945	44 / 56	2	1	4	4	1	28	18	58	
1949	56 / 53	3	2	1	1	1	26	20	53	
1953	68 / 70	1	3	2	2	1	15	13	38	
1954	73 / 74	1	6	0	2	2	15	11	39	
1957	73 / 70	4	4	1	2	4	10	10	35	
PERCENTAGE REDUCTION IN TIEL										Mean % red.
1945		42	94	70	61	75	36	73	63	65
1949		64	83	93	90	90	63	80	76	80
1953		96	88	87	80	76	77	85	83	84
1954		82	62	98	89	74	78	89	84	82
1957		50	70	87	67	43	82	84	78	69

TABLE 7-3 The relation between the DF of bucco-gingival surfaces in 15-year-old children from Culemborg and Tiel and the time of eruption and the start of the water fluoridation in Tiel.

number of years between eruption and start of the water fluoridation	I1sup,I2sup,M1			Csup,P1,P2,M2			TOTAL		
	CUL.	TIEL	%RED.	CUL.	TIEL	%RED.	CUL.	TIEL	%RED. of the TOTAL DMF-S
Eruption -									
1-2 years before	62	31	50	--	--	--	62*	31*	50*
2-3 years after	87	30	65	95	27	71	182	57	69
6-7 years after	105	19	82	135	23	83	240	42	83
7 (10-12)*** yrs after	93	23	76	121	19	84	214	42	80
10 (11-13)*** yrs after	76	18	76	152	16	89	228	34	85
(4-16) years after	--	--	--	84	17	79	84**	17**	79**

- the start of the water fluoridation

-- no data available
* data of first molar only
** data of upper canine, premolars and second molar only
*** figures in parentheses concern premolars and second molar

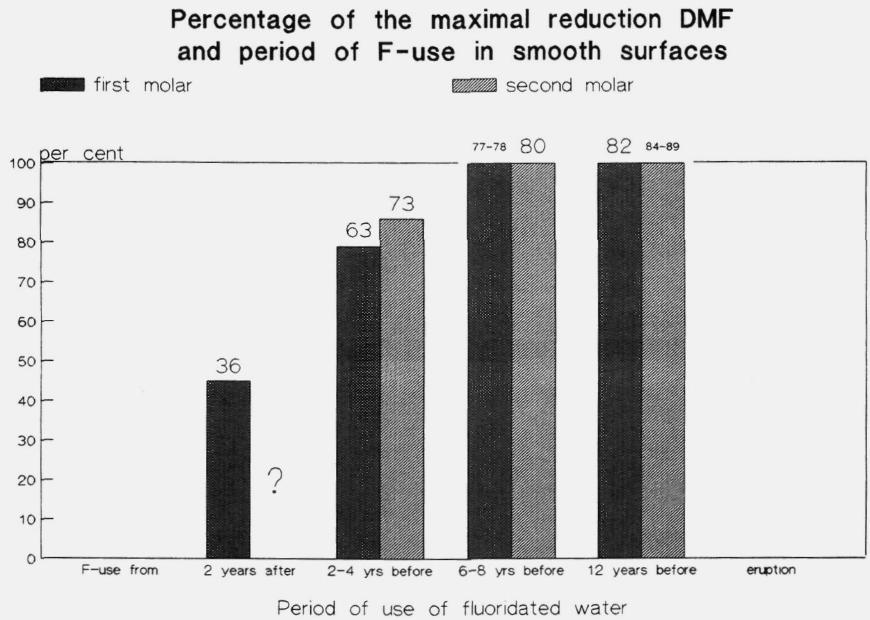


Fig. 7-1: The percentage less DMF-S in buccal smooth surfaces of 15-year-old children from Tiel, expressed as a percentage of the maximal reduction. The surfaces are classified according to the relation between the time of eruption and the start of the water fluoridation. On top of the staves the real percentage reduction DMF-S.

7.4 DISCUSSION

7.4.1 Cross-sectional data

The differences between the totals in Culemborg and Tiel of tables 7-1 and 7-2 are due to the fact that in table 7-1 extracted teeth were scored according to the last examination, whereas in table 7-2 extracted teeth were omitted from the study. Comparison of the percentage reduction in these tables shows a somewhat higher percentage reduction if extractons were included.

This is caused by the higher number of extractions in Culemborg than in Tiel, resulting as well in a higher loss of cavities in Culemborg. However, the differences are small.

The results in table 7-1 show that, if the consumption of fluoridated water starts at the age of about 8 years (group born in 1945), a caries reduction of 66% is present at the age of 15 years. This reduction increases upto 85% if the fluoridation starts at birth (groups born in 1953 and 1954).

Kwant's conclusion that water fluoridation has posteruptively an important effect on the prevention of this type of caries lesions is confirmed by the percentages reduction in table 7-2.

7.4.2 Standardization with respect to the use of fluoridated water pre- and posteruptively

Table 7-3 shows the caries reducing effect of posteruptive and combined pre- and posteruptive consumption of fluoridated water in more detail. The lack of data unfortunately does not allow a more precise calculation as was the case for the proximal surfaces. The DMF-S of the first and second molar respectively are dominating each in its own group.

The data of table 7-3 indicate that for the buccal smooth surfaces consumption of fluoridated water posteruptively alone causes a caries reducing effect between 50 and 65%. By extra consumption during the pre-eruptive period the reduction increases upto 80 - 85% depending on the kind of tooth.

Figure 7-1 shows the reduction in caries experience expressed as a percentage of the maximal reduction in first and second molar separately. The effect of posteruptive use alone, starting two years after eruption, is in the first molar about 45% of the maximal reduction.

The reduction in caries experience in the first molar increases with 2 - 3 years additional pre-eruptive use to about 80%, in the second molar this reduction is 85% if use of fluoridated water starts four year before eruption. Unfortunately for the second molar data lack for the effect of posteruptive use alone.

7.5 CONCLUSION

This substudy confirms the statement by Kwant et al. (1972) and Groeneveld (1986) about the great caries reducing effect on smooth surfaces of the availability of fluoridated water posteruptively. However, classificatied according to the stage of development at the start of the fluoridation, its contribution seems to be somewhat smaller than reported by these authors.

The range of data for the percentage reduction in the first molar as presented in table 7-2 show that, if in this tooth the start of the consumption of fluoridated water shifts from 2 years after to two years before eruption, the reduction increases from 36 to 63 %. This means that in this tooth the extra pre-eruptive consumption of fluoridated water causes an important extra reduction of carious lesions in this category of surface.

Unfortunately data for more detailed information of other teeth are not available.

8.0 THE EFFECT OF POSTERUPTIVE AND PRE- AND POSTERUPTIVE USE OF FLUORIDATED WATER ON CARIES IN FISSURES AND PITS

8.1 INTRODUCTION

The aim of this part of the study is to assess the reduction in caries experience in fissures and pits of posteruptive and combined pre- and posteruptive consumption of fluoridated water in 15-year-old children using the clinical data and the bite-wing radiographs available from the Culemborg - Tiel study. Just as for the smooth surfaces relevant clinical data are only available for five birth classes. After a rough assessment of the pre- and posteruptive effect, based on these clinical data, a more detailed picture will be given based on the use of bite-wing radiographs which are available for the same birth classes as for the proximal surfaces.

8.2 MATERIAL AND METHODS

8.2.1 Clinical data already available from the Culemborg - Tiel study

Clinical data of fissures and pits of 15-year-old children were available for children born in 1945, 1949, 1953, 1954 and 1957.

For this study only the data of dentinal lesions in the premolars and molars were used. The data were compiled from the original records. Data from upper and lower teeth of the same type were taken together, although Backer Dirks (1961) and Barr et al. (1957) demonstrated that the DMF index of the occlusal surface in the lower first premolar is half of that in the upper first premolar. Apart from this tooth, however, the DMF index for the premolar - molar region is comparable for the upper and the lower jaw. Of the scores of the mesio- and disto-occlusal fissure and the palatinal pit in the upper molar the highest caries score of the three was used. For the lower molar the same was done for the occlusal fissure and the buccal pit.

The data of both towns were then divided into two groups: the first containing those of the first molars (median age of eruption 6 1/4 years), the second those of the first and second premolar and the second molars (median age of eruption 10 1/4, 11 and 11 3/4 years).

In the same way as has been done for the smooth surfaces both groups were classified as much as possible according to the stage of development at the start of the water fluoridation in Tiel. The same six groups were created as described in paragraph 7.2.2.

The method using bite-wing radiographs whic was described in par. 8.1.2, has been developed in order to obtain data for the occlusal surfaces of the first six examination years (1952 - 1959) and also at smaller intervals than the clinical data which are only available in 1960, 1964, 1968, 1969 and 1972.

8.2.2a Scoring dental caries and fillings in occlusal surfaces from bite-wing radiographs and comparison with clinical diagnosis

Besides the clinical data, which were available from the original records, also bite-wing radiographs of 15-year-old children, born between 1937 and 1958 were used for this study.

In order to study the validity of the method, clinical DMF scores in fissures and pits of 15-year-old children from Culemborg born in 1953, were compared with those from bite-wing radiographs. The criteria and the scores used for the clinical examinations were according to the method by Backer Dirks and co-workers (Backer Dirks et al., 1957).

The description of the scores used for the bite-wing radiographs is:

Clinical score	Radiographical score
0 - sound I - small enamel lesion II - large enamel lesion	0 - no caries: surfaces which did not show a radiolucency in the dentin.
III - small cavity: discontinuity in the enamel surface =<2.5 mm.	1 - small cavity: a small radiolucency at dentino-enamel junction not extending beyond half the distance between the dentino-enamel junction and the pulp.
IV - large cavity: discontinuity in the enamel >2.5 mm.	2 - large cavity: radiolucency extending beyond half the distance between dentino-enamel junction and the pulp.
V - (eventually followed by index I-IV) filled surface.	3 - filled surface: surface with a filling, regardless if also a cavity was present at the border of this filling or elsewhere in the same surface.
X - extraction because of caries.	x - missing surface: extracted teeth. This score was used from the clinical records for the examination of the proximal surfaces.
WR - root: extraction indicated.	w - root: extraction indicated.

The radiographical data of the 15-year-old children from Culemborg born in 1953 were compared with the clinical data per child and for the toothsites under discussion.

8.2.2b Comparison of the MF index with the clinical DMF index in occlusal surfaces of the premolars and molars

Because the caries diagnoses showed insufficient similarity (see par. 8.3.2a) it was decided that only the MF scores would be used in the following sections.

The numbers of MF surfaces per 100 children (weighted average of boys and girls) scored on the bite-wing radiographs of five birth classes (children born in 1945, 1949, 1953, 1954 and 1957), aged 8, 4, 0, -1 and -4 years respectively at the start of the water fluoridation were compared with the number of DMF surfaces obtained from the five clinical examinations mentioned.

Comparison between clinical and radiographical data made it possible to observe a difference between the two towns with respect to the D-fractions which are mostly not visible on the radiographs and to observe if these fractions were different in the various years of examination.

8.2.3 Cross-sectional data obtained from scoring MF-S in occlusal surfaces from bite-wing radiographs

The filled and missing premolars and molars were scored from bite-wing radiographs according to the criteria presented in par. 8.2.2a in 15 birth classes containing 15-year-old children from Culemborg and Tiel born between 1937 and 1958. For these birth classes see figure 3-12.

Data of MF-S for the various categories of teeth apart and for the total of all teeth will be presented for each birth class.

8.2.4 Standardization with respect to the use of fluoridated water pre- and posteruptively

The number of MF-surfaces per 100 15-year-old children born between 1937 and 1958 were classified - separately for each tooth - according to the relation between the median time of eruption and the moment of start of the water fluoridation in Tiel (see below under a.). This was also done for the percentages caries reduction in Tiel of teeth with an identical period of use of fluoridated water pre- and posteruptively (see below under b).

This method has been described extensively in Chapter 2.0 and it is was also used for the proximal surfaces.

a. The totals of the MF-surfaces per 100 15-year-old children from both towns were compared with each other. The result of this procedure is a range of MF indices of occlusal surfaces of various teeth which have in common that those from Tiel have an identical period of use of fluoridated water post- and additionally pre-eruptively. The MF index in Culemborg concerns surfaces examined in the same year as in Tiel.

b. The mean of the percentages reduction in each group of teeth with the same pre- or posteruptive age at start of the water fluoridation has been used. The result of this method is also a range of percentage reduction resulting from water fluoridation starting at different intervals after and progressively before eruption. As has been pointed out in Chapter 2.0 this method has the advantage that the result is independent of the differences in the caries level of the various teeth. However, the disadvantage is that teeth with an extremely low caries level may show an extremely high percentage of caries reduction although there is no significant difference.

8.3 RESULTS

8.3.1 Clinical examinations

The DMF-S of occlusal surfaces as obtained from the clinical examinations are presented in table 8-1. If children had consumed fluoridated water from the age of 8 years on, a reduction of only 9% of the total DMF-S in these surfaces could be observed. The maximum reduction, which is attained if fluoride has been used from birth on, varies between 35 and 40%. The maximum percentage reduction in the separate teeth, however, show considerable differences, ranging from 70% for the premolars to about 20% for the first molar.

Table 8-2 is based on the data in table 8-1, but these data are now classified according to the relation between the time of eruption and the start of the water fluoridation in Tiel. The effect of this procedure is that the column of data for the M1 is shifted one position upward with respect to the other data. The first row only refers to the DMF-S of the first molar, because no data are available from children who were older than 7 3/4 years at start of the water fluoridation in Tiel. In the last row the data for the M1 are estimated, taking the mean of those in the fourth and the fifth row. The column containing the percentage reduction in the first molar shows that posteruptive use only (first two rows) does not result in a caries reduction. If the use of fluoridated water starts at about the beginning of the calcification period, 13% reduction is observed. A maximum reduction of about 20% is obtained if fluoridated water had been used from before the calcification period (i.e. from birth on). The maximum percentage reduction which is obtained is comparable to that in table 8-1.

Figure 8-1 is based on table 8-2. It shows the reduction in

DMF-S in Tiel as a percentage of the maximum reduction in DMF-S in Tiel for the occlusal surface of the M1 separately and for the occlusal surfaces of the P1, P2 and M2 together. The surfaces are classified according to the relation between the time of eruption and the start of the water fluoridation in Tiel. On the top of the staves the real percentage reduction is presented.

Table 8-1: DMF-S in occlusal surfaces clinically scored in 15-year-old children from Culemborg and Tiel, born between 1937 and 1957 inclusive and the percentage reduction in Tiel.

year of birth	number of boys/girls C	number of boys/girls T	mean age at start F^- cons. in Tiel	M2 C	M2 T	M1 C	M1 T	P2 C	P2 T	P1 C	P1 T	TOTAL C	TOTAL T
1945	44/46	50/50	7 3/4	299	272	389	381	136	105	87	71	910	829
1949	56/53	53/54	3 3/4	350	232	393	382	173	95	131	57	1047	767
1953	68/70	68/58	-1/4	333	202	393	343	153	57	97	33	976	634
1954	73/74	65/70	-1 1/4	318	188	388	301	127	67	98	30	932	587
1957	72/70	71/59	-4 1/4	336	207	387	313	183	59	107	29	1012	608

Per cent reduction in Tiel

year of birth	mean age at start F^- cons. in Tiel	M2	M1	P2	P1	TOTAL
1945	7 3/4	9	2	23	19	9
1949	3 3/4	34	3	45	56	27
1953	-1/4	39	13	63	66	35
1954	-1 1/4	41	22	47	70	37
1957	-4 1/4	38	19	68	72	40

Table 8-2: Classification of the clinical data according to the relation between the time of eruption and the start of the water fluoridation in Tiel. Between brackets, eruption time of second molar and premolars

number of years between median time of eruption and start of fluoridation	M1			P1+P2			M2			all		
	C	T	%red.	C	T	%red.	C	T	%red.	C	T	%red.
Eruption -												
1-2 years before	389	381	2	--	--	--	--	--	--	389	381	2*
2-3 yrs. after	393	382	3	223	177	21	299	272	9	915	831	9
6-7 years after	393	343	13	305	152	50	350	232	34	1048	727	31
7 (10-12) yrs after	388	301	22	250	90	64	333	202	39	971	592	39
10 (11-13) years after	387	313	19	226	97	57	318	188	41	930	598	36
(14-16) years after	388**	306**	20**	290	89	69	336	207	38	1014	602	40***
- the start of the water fluoridation												

-- no data available
* concerns M1 only
** mean of the two rows above this one
*** percentage based on observed index for the P1,P2 & M2 and mean of the two rows above this one for the M1.

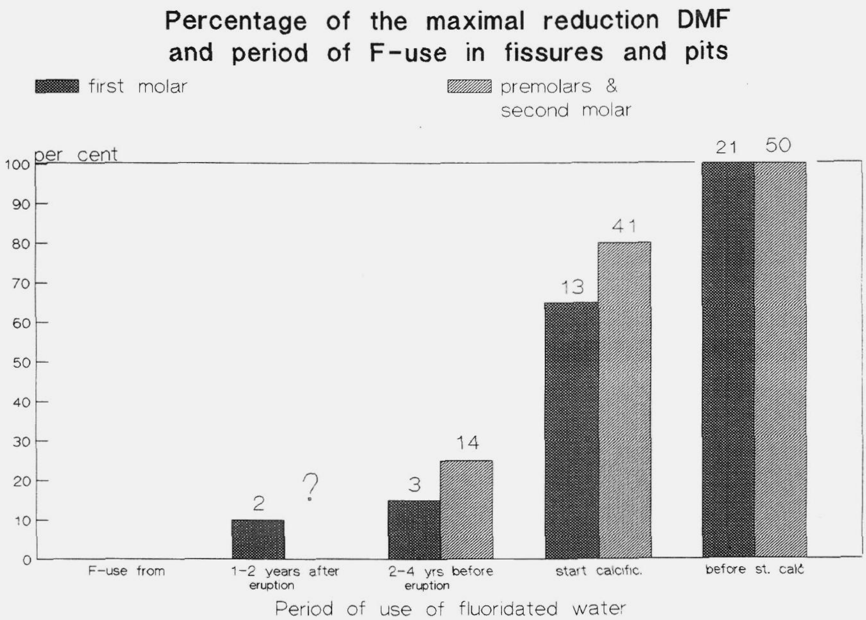


Fig. 8-1: The percentage less occlusal DMF-S in 15-year-old children from Tiel expressed as a percentage of the maximal reduction in surfaces classified according to the relation between the time of eruption and the start of the water fluoridation in Tiel. On top of the staves the real percentage reduction DMF-S.

8.3.2a Scoring dental caries and fillings in occlusal surfaces from bite-wing radiographs in comparison to clinical diagnosis

Contrary to the clinical examination, it was not possible to distinguish on the radiographs if caries or a filling was located in the mesio-occlusal fissure, the disto-occlusal fissure, the palatinal pit or the carabelli fossa of the upper molars, because these sometimes overlap each other, especially in the case of one or more fillings. The same was true for the occlusal surface and the buccal pit in lower molars. For each of these teeth only one score per tooth was given for all fissures and pits instead of clinically, where two scores were given for the upper and lower molars.

For the palatinal pits of the upper front teeth it appeared that, apart from the fact that from the clinical dentinal lesions none could be detected on the radiographs, there were only a few fillings.

Comparison between the clinical and radiographical examination of occlusal surfaces in premolars and molars of 15-year-old children from Culemborg born in 1953, revealed that radiographical scores '3' (filling) and 'w' (root) showed a 100% correlation with the clinical data.

Since score 'x' was copied from the clinical data it was also identical to these.

A comparison of clinical scores 0, I, II, III and IV with radiographical scores 0, 1 and 2 in this birth class is shown in table 8-3.

Taking the clinical diagnosis as the reference, the table shows a poor agreement between clinical and radiographical diagnosis. For the teeth with a clinical diagnosis of a small cavity: only 27% (42 out of 156) were recognized as a lesion in the dentin on the bite-wing radiographs. The deeper cavities (score IV) showed a higher degree of agreement: 18% (10 out of 55) were not detected as a dentinal lesion on the bite-wing radiographs. However, the number of large cavities was only a small fraction of the DMF score.

Table 8-3: Comparison between the number of cavities in occlusal surfaces, diagnosed clinically (score III and IV) and from bite-wing radiographs (scores 1 and 2) in 126 15 years old children (68 boys and 58 girls) from Culemborg, born in 1953.

	clinical diagnosis			
x-ray diagnosis	0,I,II	III	IV	TOTAL
0	772	114	10	896
1	11	38	4	53
2	3	4	41	48
TOTAL	786	156	55	997

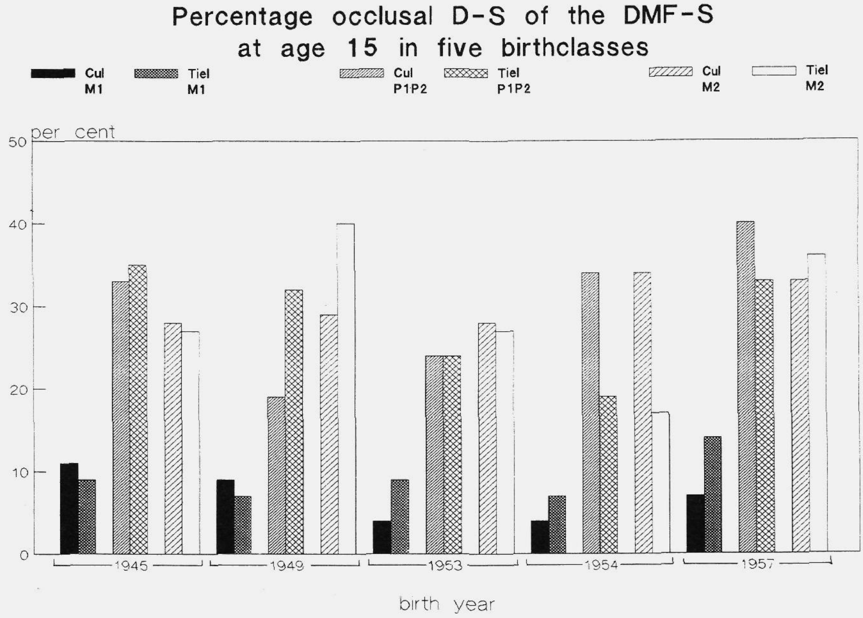


Fig. 8-2: The percentage MF-S (scored on the bite-wing radiographs) of the DMF-S (clinical diagnosis) 1968, 1969, 1972). in five groups of 15-year-old children from Culemborg and Tiel

8.3.2b Comparison of the MF index with the clinical DMF index in occlusal surfaces of the premolars and molars

Figure 8-2 shows the percentage D-S of the DMF-S (which is complementary to the percentage MF-S)in the first and the second molar and the premolars per child in 15-year-old children from the two towns, obtained from bite-wing radiographs of five groups of children born in 1945, 1949, 1953, 1954 and 1957 (see table 8-4)

These percentages show that there is not only a considerable difference between the different types of teeth, but also between the different years of examination. In the first molar the D-fraction is smallest. It ranges between 4 and 11 per cent in Culemborg and 7 and 14 per cent in Tiel. In the second molar and the premolars the D-fraction is much greater. The data of the various examination years show minor differences in the second molar in Culemborg (28 - 33%) and larger differences in Tiel (17 - 40%), whereas for the second premolar the range in Culemborg is greater than in Tiel. The greatest range, however, is between the data of the first premolar in the various years of examination. Except for the birth class 1954 in Tiel, the percentage D-S of the four teeth together is rather constant. It varies from 17 to 25% in Culemborg and from 17 to 24% in Tiel (see table 8-5).

8.3.3 Cross-sectional data obtained from scoring MF-S in occlusal surfaces from bite-wing radiographs

Table 8-4 shows the number MF-S per 100 children (weighted average of boys and girls) of 15 year classes of 15-year-old children from Culemborg and Tiel examined in the period 1952 - 1972. Data of left and right as well as upper and lower teeth are counted together. Figure 8-3 shows the MF-S and DMF-S of these children.

Table 8-6 shows the percentage less MF-S in Tiel with respect to Culemborg for each separate tooth in the same years of examination and the mean of the percentages. Figure 8-4 shows, besides the percentage less MF-S of table 8-6, also the percentage less DMF-S in the five clinical birth classes.

It has to be kept in mind that these data are partly the result of the care by the dentist. Starting with low values at the first examination, especially in Tiel, they increase rather fast in both towns and reach their maximum in children born in 1946. The MF-S of children born after this year from Culemborg remain rather constant, whereas those of children from Tiel show a gradual decrease (see table 8-4 and figure 8-3).

In the children born between 1937 and 1942 the premolars show generally far more MF-surfaces in Tiel than in Culemborg. Hence the low number of MF-S in the premolars has a disproportionate influence on the mean of the percentages reduction as presented in the last column of table 8-6.

Table 8-4: MF-S in occlusal surfaces scored from bite-wing radiographs in 15-year-old children from Culemborg (8-4a) and Tiel (8-4b), born between 1937 and 1958, and the percentage caries reduction in Tiel (8-4b, last column).

Table 8-4a: CULEMBORG - MF-S per 100 children (weighted average of boys and girls) at age 15

		M2	M1	P2	P1	TOTAL
median age of eruption		11 3/4	6 1/4	11	10 1/4	
year of birth	b / g					
1937	49 / 37	127	206	37	9	379
1938	38 / 52	107	234	31	16	388
		(122	252	32	13	419)
1940	46 / 50	137	271	34	9	451
1941	36 / 45	124	239	33	21	417
1942	52 / 50	156	317	51	38	562
		(181	335	62	38	616)
1944	50 / 52	206	353	74	38	671
1945	50 / 50	217	345	93	57	712
1946	63 / 61	238	371	120	77	806
		(216	368	144	87	815)
1948	55 / 56	193	366	167	97	823
1949	53 / 54	248	359	143	103	853
1950	59 / 57	227	348	134	68	777
		(217	356	117	62	752)
1952	58 / 56	207	365	99	55	726
1953	68 / 58	241	378	122	68	809
1954	65 / 70	210	373	91	57	731
		(215	369	95	62	741)
		(219	364	98	67	748)
1957	71 / 59	224	360	102	72	758

Table 8-4b: TIEL - MF-S per 100 children (weighted average of boys and girls) at age 15

median age of eruption		M2 11 3/4	M1 6 1/4	P2 11	P1 10 1/4	TOTAL	Percentage reduction of the total DMF-S
year of birth	b / g						
1937	53 / 45	82	170	20	17	289	23
1938	69 / 38	92	223	34	28	377	3
		(113	235	42	23	413	1)
1940	53 / 50	135	248	49	19	451	-0
1941	51 / 54	148	283	66	44	541	-30
1942	42 / 40	110	252	43	27	432	23
		(118	287	42	25	472	23)
1944	53 / 48	125	322	41	22	510	24
1945	44 / 56	200	346	71	44	661	7
1946	58 / 60	200	356	73	40	669	17
		(164	346	69	41	620	24)
1948	55 / 59	128	336	64	42	570	31
1949	56 / 53	138	355	66	38	597	30
1950	57 / 58	113	314	38	25	490	37
		(119	301	35	22	477	37)
1952	53 / 60	124	287	31	19	461	36
1953	68 / 70	147	313	43	25	528	35
1954	73 / 74	156	280	53	25	514	30
		(149	277	50	22	498	33)
		(141	273	47	18	479	36)
1957	72 / 70	133	270	44	15	462	39

Table 8-5: Percentage occlusal D-S of the DMF-S in 15-year-old children from Culemborg and Tiel, as scored clinically and excluded from the scores of the bite-wing radiographs and the mean of these percentages.

	Year of birth	Tooth	M2	M1	P2	P1	MEAN
			Percentage occlusal D-S of DMF-S				
CULEMBORG	1945		28	11	31	35	22
	1949		29	9	17	22	19
	1953		28	4	20	29	17
	1954		34	4	28	42	21
	1957		33	7	44	33	25
TIEL	1945		27	9	32	38	20
	1949		40	7	30	34	22
	1953		27	9	24	25	17
	1954		17	7	21	15	12
	1957		36	14	26	50	24

Table 8-6: Percentage reduction MF-S scored from bite-wing radiographs in Tiel with respect to Culemborg in 15-year-old children born between 1937 and 1958 for the premolars and molars separately and the mean of these percentages.

Year of birth	M2	M1	P2	P1	MEAN
	Percentage reduction in Tiel				
1937	35	17	45	-94	1
1938	14	5	-13	-67	-15
	(8	7	-28	-87	-25)
1940	1	8	-44	-107	-35
1941	-20	-18	-100	-109	-62
1942	30	20	14	28	23
	(34	15	29	35	28)
1944	39	9	44	43	34
1945	8	-0	23	22	13
1946	16	4	39	49	27
	(25	6	50	53	33)
1948	34	8	62	57	40
1949	44	1	54	63	41
1950	50	10	71	63	49
	(45	16	70	64	49)
1952	40	21	68	66	49
1953	39	17	65	64	46
1954	26	25	42	56	37
	(31	25	47	64	42)
	(36	25	52	71	46)
1957	40	25	57	79	51

Table 8-7: The number of occlusal MF-S scored from bite-wing radiographs in premolars and molars of 15 years old children from Culemborg (C) and Tiel (T). Surfaces are classified according to the relation between the median time of eruption and the start of the water fluoridation in Tiel.

	M2		M1		P2		P1		TOTAL		percent reduction	
start F/H2O in Tiel	C	T	C	T	C	T	C	T	C	T	total	M1
+4y after	127	82	326	270	35	31	15	25	503	408	19	17
+3y	107	92	344	305	31	40	11	21	493	457	7	11
+2y	122	113	349	334	33	47	15	31	519	526	-1	4
+1y	137	135	358	351	34	62	29	35	558	583	-5	2
eruption	124	148	369	351	37	49	38	26	568	574	-1	5
-1y before	156	110	367	341	54	43	38	23	614	517	16	7
-2y	181	118	362	346	65	42	48	33	656	538	18	5
-3y	206	125	353	335	79	64	67	42	706	566	20	5
-4y	217	200	352	307	100	73	82	40	751	620	17	13
-5y	238	200	361	294	126	70	92	41	817	605	26	19
-6y	216	164	372	300	150	65	100	40	837	569	32	19
-7y	193	128	376	297	161	66	85	31	815	522	36	21

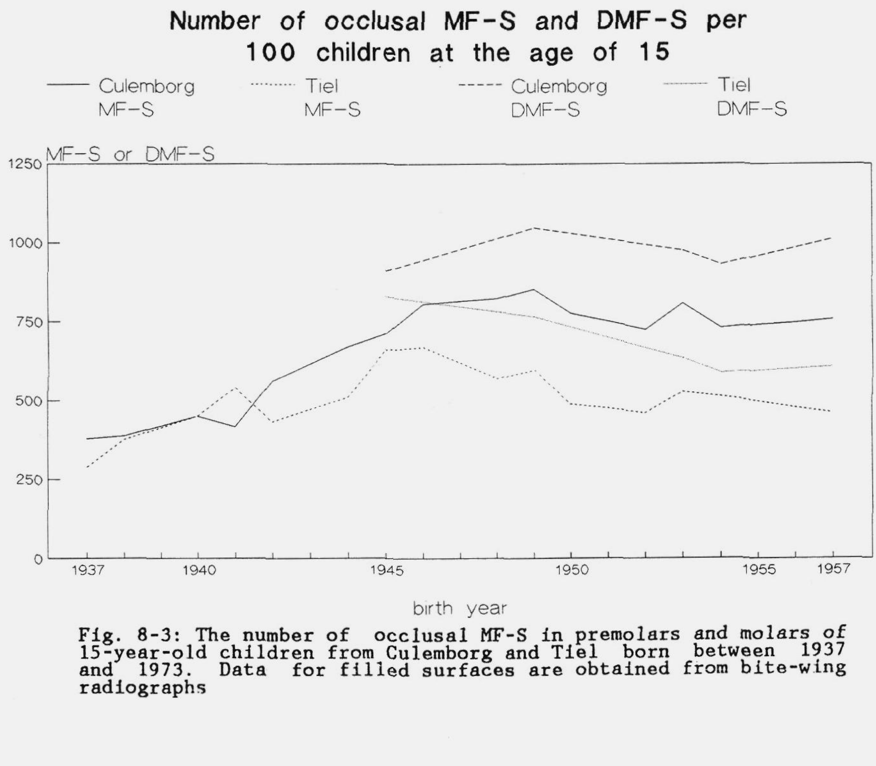


Fig. 8-3: The number of occlusal MF-S in premolars and molars of 15-year-old children from Culemborg and Tiel born between 1937 and 1973. Data for filled surfaces are obtained from bite-wing radiographs

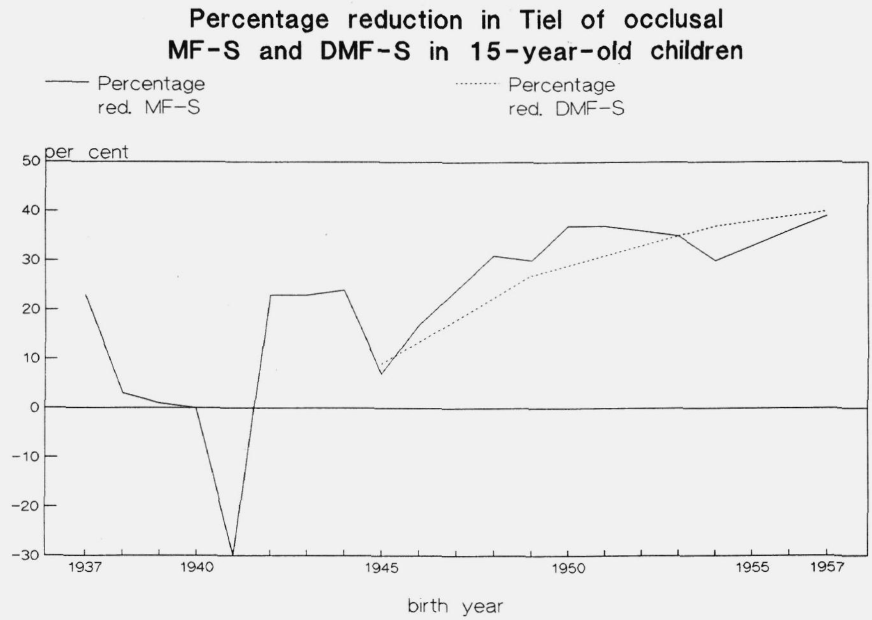


Fig. 8-4: The percentage less occlusal MF-S and DMF-S in premolars and molars of 15-year-old children from Tiel born between 1937 and 1958. Data for filled surfaces are obtained from bite-wing radiographs

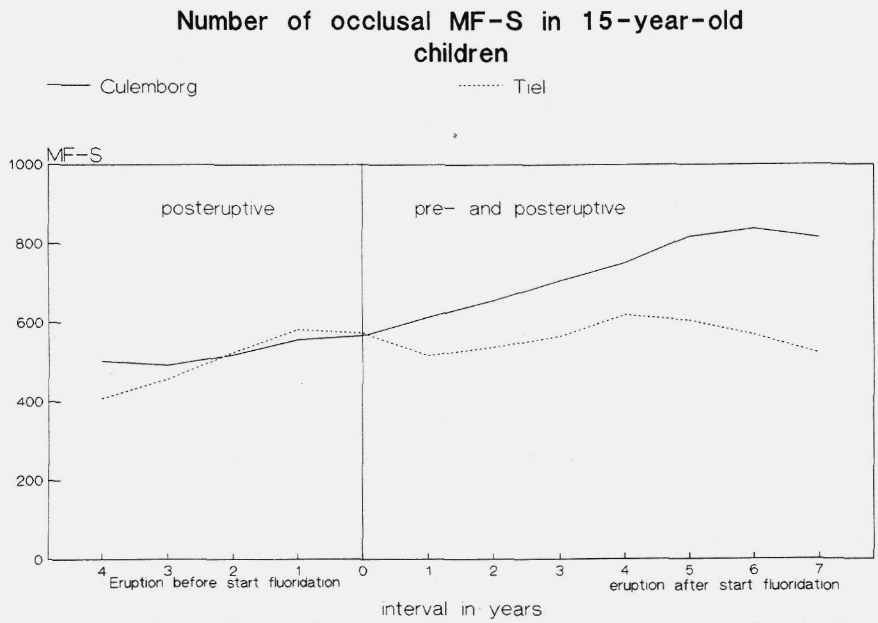


Fig. 8-5: The number of MF-S in premolars and molars of 15-year-old children from Culemborg and Tiel scored from bite-wing radiographs. Surfaces are classified according to the relation between the median age of eruption and the start of the water fluoridation.

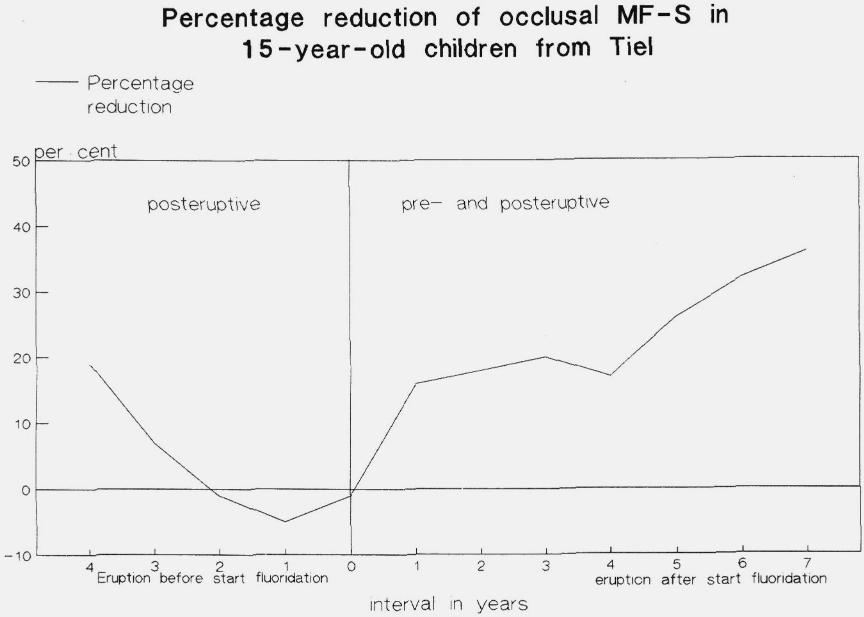


Fig. 8-6: The percentage less occlusal MF-S in premolars and molars of 15-year-old children from Tiel. Data for the filled surfaces are obtained from bite-wing radiographs. Surfaces are classified according to the relation between the median age of eruption and the start of the water fluoridation.

8.3.4 Standardization with respect to te use of fluoridated water pre- and posteruptively

Table 8-7 shows for 15 years old children from Culemborg and Tiel born 16 years before up to one year after the start of the water fluoridation, the MF-S per 100 children obtained from bite-wing radiographs. The data of the teeth are classified according to the relation between the median time of eruption and the start of the water fluoridation in Tiel. The last but one column represent the percentage reduction of the total MF-S in teeth with the same post- or pre-eruptive age at start of the water fluoridation. In the last column the percentage reduction in the first molar is given apart. This tooth has been chosen because the D-fraction, as assessed in the clinical examinations, was relatively small in relation to the DMF-S (between 4 and 14%) and also rather constant in various years of examination (see table 8-6).

Figure 8-5 is based on table 8-7 and shows the total MF-S in Culemborg and Tiel classified according to the relation between the time of eruption and the start of the water fluoridation. Figure 8-6 shows the percentage reduction in Tiel as presented in the last but one column of table 8-7.

8.4 DISCUSSION

8.4.1 Clinical data already available from the Culemborg - Tiel study

Analysis of the clinical data shows that only those for the first molar give some information about the caries reducing effect of posteruptive use of fluoridated water (table 8-1). However, in the group born in 1945, the consumption of fluoridated water started about one and a half year after the eruption, so there was not yet a full posteruptive effect. The group born in 1949 had received fluoride from two and a half years before eruption, thus also during the pre-eruptive maturation. Nevertheless, the effect is equally negative. Only if fluoridated water has been consumed from birth on (i.e. start of the calcification), a reduction of 13% can be observed. The age class born one year after start of the water fluoridation shows a 22% reduction. This might be due to chance or to the fact that this birth class experienced a continuous flow of fluoride which passes the placenta.

The data of the other surfaces not only show a greater maximal reduction (second molar 40%; premolars 70%) in comparison with the first molar, but also the effect of posteruptive and additionally about three years pre-eruptive consumption of extra fluoride is greater (9 - 21% reduction, see table 8-2). For a right comparison of the pre- and posteruptive contribution to the effect of fluoride the reductions in all groups must be compared proportionally to the maximum which can be attained if fluoride is consumed from before the start of the calcification period (70% for the premolars and 40% for the second molar instead of 20% for the first molar). In that case the difference between the first molar and the other teeth becomes smaller (see fig. 8-1).

The total data (table 8-2, last column) suggest that, in order to obtain an optimal caries reduction in fissures ad pits fluoridated water has to be consumed from before the start of the calcification period on. Start of the consumption during the pre-eruptive maturation period causes only a limited protection in the premolars and the second molar (25% of the maximal reduction) but hardly any or none at all in the first molar.

The difference in maximum reduction between first and second molar might be explained by the fact that the first molar is not enough in contact with the fluoride before the start of the calcification period on, thus around birth, whereas for the second molar enough fluoride is available.

Posteruptive consumption only, seems to cause no reduction at all in the first molar. The data are lacking to provide more information about the effect of posteruptive use in the premolars and the second molar.

8.4.2 Scores of fillings in occlusal surfaces from bite-wing radiographs. The comparison with clinical data

Comparison of the clinical diagnosis for the large and deeper cavities (score IV) with that of the bite-wing radiographs (score 2) reveals that 79% of these clinical cavities were also observed on the radiographs (table 8-3). Unfortunately, the larger cavities form only about 10% of the total DMF-S in occlusal surfaces.

However, the majority (73%) of the smaller cavities (clinical diagnosis III) could not be detected on the radiographs (radiographical diagnosis 1 or 2). In order to avoid an extra unmeasurable inaccuracy introduced by the method it was decided that only the radiographical diagnosis for filled occlusal surfaces would be used. Selfevidently in a test these showed a 100% agreement with the clinical scores.

The diagnosis extraction was taken from the records. Thus the

D-fraction is thus not counted at all. The degree of treatment (MF-S) is used to compare children from both towns and to assess the pre- and posteruptive contribution of water fluoridation to caries reduction. The problem is that in fact the MF-S number is the combined result of the decision of the child (or his parents) to visit the dentist and of the dentists to treat the caries lesion. It is therefore more influenced by other factors than the caries experience and thus less reliable. Since the children between the ages of 6 and 13 years attended probably the (school)dentist more regularly than older children, this applies more to the first molar than to the second molar.

The MF-S index could be made available for the same 15 years of examination as for the proximal surfaces (see figure 2-12). The bite-wing radiographs formed the only information about occlusal caries except the five year classes examined clinically.

As long as the proportion of the (clinically diagnosed) D-fraction in the DMF-S is comparable between both towns and in the same town for various examination years, the MF index can be used, even if data from different examination years are mixed.

Unfortunately the data in table 8-5 show that the percentage of the D-fraction in the premolars show a considerable variation, especially in Tiel. However, the total DMF-S indices are hardly influenced by this variation. The number of MF-surfaces in the premolars is relatively small (maximally about 20% of the total MF-S) in relation to the indices of the molars. Moreover, the D-fraction of the four teeth together has in Culemborg a rather constant proportion with respect to the total DMF-S. In Tiel only the group examined in 1954 had a very small D-fraction as compared with the other years. For the part of the study however, dealing with the classification according to the relation between the median time of eruption (par. 8.4.3) only the data of the first molar from this year of examination will be used and these fit well within the range.

On the other hand the small proportion of D-surfaces in the first molar means also that the caries diagnosis of the local dentist is determining for the DMF index in this tooth. The value of the percentage reduction of dentinal caries in the fissures and pits of the first molar is thus not a reliable index.

Nevertheless, the MF-S data ought to be used with the restriction that they serve as a supplement for the period that no clinical data are available. The latter must be used, if available.

The increase of the MF-S in both towns between the first examination in 1952 and the one in 1960 as presented in table 8-4 and figure 8-3 should not be interpreted as being the only result of an increase of dental caries experience, but also as the result of an increase of the degree of treatment, which is mainly due to the work of the school dental service. This service has probably played an important role in the "dentist visit patterns" of the children. Therefore the information is relevant that the school dental service was started in 1949 in Culemborg and in 1951 in Tiel with six-year-old children. That means that in 1958 and 1960 respectively the 15-year-old children could have participated to the school dental service. The percentage of children who participated in the school dental service was about 78% in the Geldermalsen area, to which belonged Culemborg and about 70% in the Tiel area (see Chapter 4.0).

On the bite-wing radiographs of children born in 1937 and 1938, examined in 1952 and 1953 respectively (table 8-4), it has been observed that on the radiographs in both towns nearly all first molars which were not filled, showed an advanced occlusal cavity (score 2). Accordingly as later birth classes were also treated by the school dental service the number of MF-surfaces increased considerably until the year classes born in 1945 and 1946, examined in 1960 - 1961 respectively. These are the birth classes which participated in the school dental service. The increase between examinations in 1952 and 1961 can thus mainly be conceived as an increase of the degree of treatment.

The increasing number of MF-S in the first molar during the examination period 1957 - 1960 (children born in 1942 - 1945) is generally greater in Culemborg than Tiel (figure 8-3). The MF-S in Tiel are similar with those of Culemborg two years before. The two years earlier start of the school dental service in Culemborg is most probably the cause of this difference. It can, however, not be excluded that a small caries reducing effect of the consumption of fluoridated water could be responsable for the difference between the two towns in this period.

From table 8-4 can also be observed that in the examination period 1960 - 1972 the MF-S index in Culemborg remains on a rather constant level, whereas that in Tiel shows a decrease in the same period. The maximal reduction of total MF-S in premolars and molars which is obtained, fluctuates between 30 and 40%. These values are comparable with the 35 - 40% reductions observed in the clinical study where the D fraction was included (see table 8-2).

8.4.3 Standardization of the radiographical data with respect to the period between the time of eruption and the start of the water fluoridation

Also for this part of the study must it be kept in mind that the data refer exclusively to the missing and filled surfaces. Data of the D-surfaces are lacking for all years except for the five years with clinical examination. These have been discussed in par. 8.4.1).

The percentages reduction in the last but one column of table 8-7 and the course of the curves in figure 8-5 suggest that the use of fluoridated water posteruptively causes hardly any or no caries reducing effect. Teeth erupting at the start of the fluoridation and one, two or three years before showed no reduction in MF-S (-1, -5, -1 and 7 per cent respectively). Only the percentage reduction of the group of children who started to consume fluoridated water four years after eruption (19%) (table 8-7) is situated out of the range of the other data. As has been stated above the higher degree of treatment due to the earlier start of the school dental service in Culemborg might have been the cause of the greater number of MF-surfaces in this town. Of all teeth the data of the first molar, which has the lowest D-fraction and which erupted at the start of the primary school period, are best comparable with the clinical DMF-S. As has been discussed in the preceding paragraph, the degree of dental treatment is mainly determined the DMF index in the occlusal surface of the first molar.

As is the case with the reduction of the total MF-S, the range of reductions in the first molar (table 8-7 last column) also shows a gradual decrease if the start of the fluoride consumption moves from four to one year posteruptively. This is, of course, contradictory to what is expected from a gradual earlier use of fluoride and can only be explained as a difference of treatment degree at start which is eliminated after a few years when also in Tiel all primary school groups (age 6 - 12 years) could be treated by the school dentist.

For the total group no reduction (-1%) could be observed at the coincidence of eruption and fluoridation and for the first molar separately a very small reduction (5%).

Comparison of the maximal percentages reduction in table 8-4 and table 8-7 reveals that for the total group as well as for the first molar apart the maximal reduction MF-S, after classification according to the relation between the time of eruption and the start of the water fluoridation in Tiel, was comparable with the one of the cross-sectional study.

Summarizing the results it can be concluded that it appears from the part of the study using clinical data that the use of fluoridated water has only then a reducing effect on the caries in fissures and pits if it is consumed from before the eruption on. The maximum effect is only attained if the consumption starts before the calcification period, that is for the first molar from before birth. This conclusion is the same as that expressed by Backer Dirks (1963).

The data for extractions and occlusal fillings, obtained from bite-wing radiographs does not contradict this statement.

9.0 THE ASSESSMENT OF THE PRE- AND POSTERUPTIVE CARIES REDUCING EFFECT AFTER DISCONTINUATION OF THE WATER FLUORIDATION

9.1 INTRODUCTION

As has been stated in chapter 3.0 the discontinuation of the use of fluoridated water creates a possibility to assess the contribution of the pre-eruptive consumption only in comparison with consumption pre- and posteruptively.

On the 24th of december 1973 the addition of 1 mg F^-/l to the drinking water in Tiel was stopped as a result of a judgement of the county-court in Arnhem, which ruled that water fluoridation required a special law, because the addition of products not required for the treatment of tap water was not allowed by the law. The bill for the regulation of the addition of fluoride to the drinking waters was introduced in parliament (1973). However, it was later withdrawn by the minister of health after lengthy discussions, because there was no majority for its implementation. Soon thereafter fluoridation was stopped for the four million people in the towns and cities where the water was fluoridated.

After the study concerning the effect of fluoridated drinking water, which was closed after the examination in 1968, other methods were studied which might effect an extra caries reduction beyond the 50-60% obtained by the water fluoridation. These activities, besides the discontinuation of the water fluoridation, may have influenced the dental health of children in Tiel.

Starting in 1969 special attention was given to dental health education in the infant welfare centre. In 1972 a centre for dental care for children was founded in Tiel. Because only children born after 1968 and aged between two and four years were accepted as new participants, the eldest children in this centre were each year one year older with 13 as a maximum. In this centre special emphasis was put on dental health education and comprehensive treatment was given. After the discontinuation of the water fluoridation the use of fluoride tablets was stimulated and they were distributed free at the dental centre (Kalsbeek, 1985).

This means that with respect to their dental health, children born after 1968 who attended this centre might differ from other children in Tiel.

9.2 AIM OF THE STUDY

The aim of this study is to investigate the effect of the use of fluoridated water during the pre-eruptive, and also during a part of the posteruptive period, after the discontinuation of the water fluoridation. The caries data of 15-year-old children from Culemborg and Tiel born between 1964 and 1971 will serve for this part of the study.

In chapter 10.0 the results will be compared with those in the literature.

9.3 REVIEW OF THE LITERATURE

9.3.1 Russell (1949a and 1949b)

There are a few other studies concerning the temporary use or the discontinuation of fluoridated water. Two papers by Russell appeared in 1949. Both were mentioned in paragraph 2.3.1.5.

In the first study Russell (1949b) presented the results of examinations of children 11 - 15 years of age in Mitchell (South Dakota) who had been exposed to fluoridated water (1.15 mg F^-/l) during 18 months, some time after birth and prior to the eruption of the first molar. A reduction of the caries experience in the permanent dentition could not be demonstrated.

Russell concluded this study with the statement that his findings "...tend to weaken the hypothesis that the mechanism whereby dental caries is inhibited through exposure to fluoride-bearing drinking waters depends essentially upon the deposition of fluorine in dental enamel during the period of calcification."

In a second publication Russell (1949a) compared three groups of children:

- a group of migrant children with a fluoride exposure before the age of six years
- a group of migrant children with a fluoride exposure before and after the age of six years
- a group of continuous resident children, who did not drink fluoridated water.

He also made an attempt to analyse the contribution of posteruptive use of fluoridated water versus combined pre- and posteruptive use by regrouping 13 - 17 year-old migrant children and comparing the tooth-specific DMF rates of teeth of the two different periods of fluoride exposure with each other and with those of teeth without any fluoride exposure. These three groups were:

- teeth with fluoride exposure during the major portion of the calcification period
- teeth with fluoride exposure during the calcification period and beyond eruption
- teeth without fluoride exposure (from children living in Hagerstown)

The results showed that the DMF rate of teeth with only pre-eruptive exposure showed hardly any or no reduction, whereas teeth with fluoride exposure pre- and posteruptively showed a marked reduction. Because the posteruptive exposure was interrupted at various intervals before examination it is impossible to obtain a DMF rate for a group of children exposed to fluoridated water from birth on.

The working hypothesis as put forward by Russell demands our attention because the items are still of current interest. They are therefore reprinted verbatim below:

A. Fluorides may be incorporated into tooth enamel either during the process of calcification or after eruption and when so incorporated are effective in the inhibition of dental caries.

B. This inhibitory effect tends to persist so long as fluoride exposure is continued but tends slowly to be lost after fluoride exposure is discontinued, particularly in teeth highly susceptible to caries; hence

C. Periodic or continuous renewal of the fluoride content of tooth enamel is required for maintainance of the maximum caries-inhibitory effect.

9.3.2 Jordan (1962)

Between 1952 and 1959 Jordan yearly examined children from Austin who were 6 - 12 years old and who had consumed fluoridated water during various periods. In Austin fluoride was added to the drinking water upto a concentration of 1.2 mg/l from 1952 until april 1956.

Table 9-1 is based on table 1 from his study, but now the DMF-T indices per child are classified according to the period of fluoride consumption. The data of the successive age groups only partly concern the same children, although they were examined in succeeding years.

Table 9-1: DMF-T indices per child of 6 - 12 years old children from Austin with a consumption of fluoridated water during various periods.
* - base-line data, assessed before the start of the fluoridation.
** - minimum value of each column.
Diagonally from the upper left to the lower right the data are from one examination year.

	age at examination						
Age of F - consumption	6	7	8	9	10	11	12
-1 - 3	0.5						
0 - 4	0.5	1.4					
1 - 5	0.3**	1.1	2.1				
2 - 6	0.4	1.0**	1.9	2.6			
3 - 7	0.4	1.2	1.9**	2.5**	3.0**		
4 - 8	0.4	1.2	1.9	2.6	3.2	3.8**	
5 - 9	0.5	1.3	2.1	2.7	3.2	4.0	4.1**
6 - 10	1.0*	1.4	2.3	3.1	3.4	4.1	4.5
7 - 11		1.7*	2.3	2.9	3.5	4.1	4.6
8 - 12			2.9*	2.7	3.6	4.2	5.0
9 - 12				3.4*	3.3	4.2	5.2
10 - 12					4.0*	3.9	5.8
11 - 12						5.0*	4.9
no fluoride							6.4*

The DMF-T index in the 6 - 11 years age groups presented here will mainly be determined by the caries in the first molar and most probably in its occlusal fissure.

Unfortunately for most age groups there are not sufficient data to assess the optimal effect of four years of fluoride consumption. Only in the four left columns data are available above and below the position of the minimum value (indicated by **). Reading horizontally the three groups which received fluoride between the age of one and the age of seven years seem to profit most from fluoridation. This is before and around the eruption of the permanent teeth, which could indicate the existence of a pre-eruptive effect. This conclusion is limited by the fact that for these groups no data are available from examinations above the age of 10 years.

9.3.3 Way (1964)

In May 1959 the source of the drinking water in Galesburg (Ill., USA) changed from a naturally fluoridated source containing 2.2 mg F^-/l to a fluoride-free communal watersupply. In October 1961 the water was artificially fluoridated to 1.0 mg/l.

Way examined 6, 10 and 14 years old children in 1958 and in 1961. The former group had used fluoridated water from birth, whereas the latter did not receive fluoridated water during the last two years before examination.

Some results of his study are summarized in table 9.2.

Table 9-2: The DMF-T per 100 children 6, 10 and 14 years of age respectively who had used drinking water with 2.2 mg F^-/l from birth (1958 group) and until two years before examination (1961-group) and the difference of DMF/100 children between the two groups.

	1958	1961	
Age	DMF-T	DMF-T	F^- until age
6	3	42	4
10	80	127	8
14	202	279	12

Way's conclusion that "...the continued use of fluorides was essential for children of all age groups" is confirmed by the data in the table in which all age groups examined in 1961 showed a higher DMF-T than the groups examined in 1958. The importance of the posteruptive effect of water fluoridation can especially be observed from the figures of the 14-year-old children. At the age of 12 years nearly all permanent teeth except the third molars had received fluoridated water during the full pre-eruptive period. Discontinuation of the use of fluoridated water at the age of 12 years, thus posteruptive, results in a 38% greater caries experience at the age of 14 years.

9.3.4 Lemke et al. (1970)

The interruption of the water fluoridation in Antigo between November 1960 and October 1965 was studied by Lemke et al. (1970). Examinations in 1964 and in 1966 revealed that eight-year-old children showed a higher DMF-T index of 183 and 233 per cent respectively and that ten-year-old children showed a higher DMF-T index of 41 and 70 per cent respectively. Table 9-3 summarizes these data.

Table 9-3: Caries experience (DMF-T index) in eight and ten years old children from Antigo where water fluoridation was stopped in 1960.

age at examination	year of examination	termination of F^- consumption at age	DMF-T per 100 children
8 group A	1960	8	63
group B	1964	4	169
group C	1966	2	206
10 group A	1960	10	166
group B	1964	6	240
group C	1966	4	296

In both age groups caries in the permanent teeth was mainly found in the first molars and the upper incisors which erupt at the age of six and between seven and eight years respectively.

In the eight-year-old children group A has 63% less DMF-T than group B. This can be caused by consumption pre- as well as posteruptively. Group B has 18% less DMF-T than group C. This could be a part of the effect of pre-eruptive use of fluoridated water.

Group A of the ten-year-old children has 31% less DMF-T than group B. This could mainly be due to posteruptive consumption of fluoridated water. Group B has 19% less DMF-T than group C, which could be the effect of the consumption of fluoridated water in the last phase of the pre-eruptive period.

9.3.5 Mansbridge (1969)

This author discussed the effect of the cessation of the water fluoridation in Kilmarnock where the water had been fluoridated from April 1956 until October 1962 (Mansbridge, 1969).

Some results for the permanent teeth from this study have been summarized in table 9-4.

Table 9-4: DMF-T per child in 9 - 14-year-old children from Ayr (no fluoride added) and Kilmarnock (fluoridated from April 1956 until October 1962) examined in 1968.

Age group	Period of F^- - use	Ayr (no F^-)	Kilmarnock (F^-)	% less in Kilmarnock
9	- 4	4.2	3.7	12
10	- 5	5.3	4.1	23
11	- 6	6.5	4.9	25
12	0.5 - 7	9.1	6.6	27
13	1.5 - 8	10.2	8.4	18
14	2.5 - 9	12.4	9.6	23

The DMF-T in the 9, 10 and 11-year-old age groups is mainly determined by the first molars and the upper incisors. Thus the upto 25% reduction in these groups may be caused by pre-eruptive use of fluoridated water until the age of six years. The reduction in the older age groups can be caused by an effect of pre- and posteruptive consumption of fluoride on the first molar and the upper incisors and a pre-eruptive effect on the premolars and second molar. Since no data were presented for the separate teeth the difference in effect can not be assessed from this study.

9.3.6 Kuenzel (1980)

Using data from Karl-Marx-Stadt (since December 1959 1 mg F^-/l) and Plauen (0.2 mg F^-/l this author studied the effect of interruption of water fluoridation from October 1970 until 1973 and subsequently varying suboptimal fluoride concentrations in the drinking water of the fluoridated town in the period from October 1973 until 1978.

In table 9-5 a part of the DMF-T for permanent teeth in 10 - 13-year-old children, compiled from table II of the study by Kuenzel has been summarized. This table shows that in all age groups the DMF-T rapidly increases after the interruption of the fluoridation. For the 10 - 12-year-old children this forms an indication for the effect of posteruptive use of fluoridated water since the DMF-T is determined by caries in the first molar and the upper incisors.

On the other hand Kuenzel reports in the discussion of his paper that in individuals aged 16-18 years who had used drinking water with an optimum level of fluoride upto the age of about 12 years the DMF-T was scarcely affected by the interruption of the water fluoridation and the suboptimal levels of fluoride in the subsequent years. According to the author this "...supports the

Table 9-5: DMF-T in 10 - 13-year-old children in Karl-Marx-Stadt who had received varying concentrations of fluoridated water from birth.

Year of examination, mg F^-/l and interval since start fluoridation

year	1963	1965	1967	1969	1970	1971	1972	1973	1974	1975	1976	1977
conc. F^-	1.0	1.0	1.0	1.0	0.5	0.2	0.4	0.9	0.7	0.65	0.8	0.9
interval since start fluoridation (in years)	4	6	8	10	11	12	13	14	15	16	17	18
age												
10	2.3	1.3	1.3	0.9	0.7*	0.8	0.8	1.0	-	1.4	-	1.3
11	3.1	2.0	1.9	1.1*	1.1*	1.2	1.1*	1.3	-	1.9	-	1.5
12	3.7	3.1	2.1	1.8	1.7	1.7	1.4*	1.8	-	1.6	-	1.9
13	4.4	3.9	2.8	2.4	2.5	2.0	1.9*	-	-	2.2	-	2.8

* - minimum value in each age group

frequently expressed hypothesis that enamel which had matured under the influence of systemically available fluoride, is more stable towards caries attack."

9.3.7 Burt et al. (1986)

In the above mentioned studies about the discontinued use of fluoridated water the gradual decrease of effect after discontinuation of the fluoridation was compared with the effect in optimally fluoridated groups. However, in the study by Burt et al. (1986) children with discontinued use of fluoridated water were compared with children who had not consumed fluoridated water at all, in order to demonstrate the effect of limited exposure to fluoridated water during childhood.

Using questionnaires on residence history, use of fluoride supplements and topical fluoride, toothbrushing habits, and antibiotic history, these authors investigated the caries experience and the presence of S. mutans in small samples of the fissure plaque of schoolchildren who had lived at least the last three years in the non-fluoridated community of Coldwater (Mich.) (0.2 mg F^-/l) in a longitudinal study of three years. At the start of the study the children were 6-7 years old.

With the aid of the residence histories the total group could be divided into a group which had lived in a non-fluoridated community for various periods from birth onwards and a group which had lived in a fluoridated community for some time. Children whith a previous residence in a fluoridated community developed 27% less caries in permanent teeth than those who had never lived in a fluoridated community. Since caries in permanent teeth consists mainly of caries in first molars at the age of nine and ten years, this reduction may be due to the use of fluoridated water pre-eruptively.

There were no detectable differences in the proportions of S. mutans of the two populations.

9.4 MATERIAL AND METHODS

9.4.1 Cross-sectional study in Culemborg and Tiel

From 1979 to 1986 dental examinations were carried out yearly on 15-year-old children born and having lived continuously in Culemborg or Tiel.

For a survey of the various groups and the kind of examinations is referred to figure 3-12.

Table 9-6 shows the number of 15-year-old boys and girls in the various examination years. The 15-year-old children examined in 1972, who will serve as a reference, have been added.

TABLE 9-6: The number of 15-year-old children in Culemborg and Tiel examined from 1979 until 1986 inclusive.

		Year of examination							
CULEMBORG	1972	1979	1980	1981	1982	1983	1984	1985	1986*
number of children	142	135	111	101	120	115	166	136	102
TIEL									
number of children	130	180	189	175	193	157	219	177	186

* - data for 1986 are preliminary

The mean age of the children at examination was 15 years and 4 months (± 3 months).

The criteria for the diagnosis of enamel and dentinal caries and the other aspects of the method were the same as those published in paragraph 3.7.2 of this study and are conform to those used by Backer Dirks and coworkers (Backer Dirks et al., 1953; Backer Dirks and Kwant, 1954; Backer Dirks et al., 1957).

For reasons of comparison the results of 15-year-old children examined in 1972 were also used, because this was in Tiel the last group in Tiel which had received fluoridated water from birth.

9.4.2 Standardization with respect to the relation between the time of eruption and the discontinuation of the water fluoridation in Tiel

Each separate surface was classified, taking the coincidence of the median time of eruption and the discontinuation of the fluoridation in Tiel as the moment of reference. This was done for the three types of surfaces separately: proximal surfaces, fissures and pits and free smooth surfaces.

In each of these three groups the data of the various surfaces with the same relation between eruption and discontinuation of the fluoridation were then added.

This method has been described extensively in Chapter 3.0

9.5 RESULTS

9.5.1 cross-sectional study

Table 9-7 shows the DMF index per 100 children aged 15 years of each proximal surface that could be used for this study.

Table 9-8 shows the DMF-S per 100 children aged 15 years of the fissures and pits and of the buccal smooth surfaces as obtained from clinical examination of the same groups.

The data of the yearly examinations are presented from 1979 to 1986 inclusive. Data for 1986, however, are preliminary and thus presented with some restriction. Data of the examination in 1972 have been added to both tables as a reference.

The number of DMF-S of all categories of surfaces in Culemborg decreases in successive years of examination.

In Tiel the DMF of the proximal and smooth surfaces remain more or less constant during the study period, whereas those of the fissures and pits decrease in successive examination years.

Figure 9-1 shows the DMF-S for all categories of surfaces separately from 1972 to 1986 inclusive. The groups in Tiel examined in 1982 had a mean age of 6 1/2 years at the discontinuation of the water fluoridation. The effect of the fluoridated water on the permanent teeth in this group is nearly entirely caused by the use of fluoridated water pre-eruptively. For the proximal surfaces, the buccal smooth surfaces and the fissures and pits the percentage less DMF in this year is 41, 57 and 3 respectively.

Table 9-7: Radiographical observations. DMF of proximal surfaces (mesial and distal) in children from Culemborg and Tiel who were 15 years old in 1972 and between 1979 and 1986 inclusive.

C U L E M B O R G

year of examination	1972		1979		1980		1981		1982		1983		1984		1985		1986	
tooth type	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis
I1s	50	85	45	54	44	54	51	51	26	40	19	26	20	26	10	16	5	9
I2s	70	40	57	33	55	24	48	22	39	14	31	7	26	10	17	7	10	5
Csu	19	-	16	10	11	6	5	9	5	6	2	5	5	3	3	6	4	3
P1s+i	51	92	24	67	11	32	10	35	15	26	11	23	6	22	6	18	3	11
P2s+i	90	115	53	93	32	59	28	77	24	76	30	49	34	78	18	41	9	17
M1s+i	205	181	209	181	165	131	161	130	163	121	131	72	142	102	104	72	43	37
M2s+i	74	29	47	7	26	5	45	4	38	10	35	7	43	8	24	9	7	0
TOTAL	559	542	451	445	344	311	348	328	310	293	259	189	276	249	182	169	81	82
TOTAL proximal	1101		896		655		676		603		448		525		351		163	

T I E L

year of examination	1972		1979		1980		1981		1982		1983		1984		1985		1986	
age at discontinuation			9 1/2		8 1/2		7 1/2		6 1/2		5 1/2		4 1/2		3 1/2		2 1/2	
tooth type	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis
I1s	13	17	21	21	21	26	17	17	22	26	20	24	12	21	14	12	13	14
I2s	19	4	24	13	25	13	16	9	28	7	23	11	23	5	14	5	16	8
Csu	2	-	4	1	2	3	5	3	2	4	5	3	4	3	3	3	1	3
P1s+i	13	21	4	23	5	19	8	28	6	29	7	29	5	29	5	24	3	15
P2s+i	27	57	23	56	22	46	31	59	28	51	31	64	24	61	24	59	19	35
M1s+i	67	32	114	74	87	44	100	52	98	40	121	56	126	52	118	64	69	32
M2s+i	11	4	28	2	14	2	19	3	12	2	34	3	22	3	27	3	10	1
TOTAL	151	135	218	190	176	153	196	171	196	159	241	190	216	174	205	170	131	108
TOTAL prox	286		408		329		367		355		431		390		375		239	
PERCENTAGE REDUCTION in TIEL	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis	mes	dis
	73	75	52	57	49	51	44	48	37	46	7	-1	22	30	-13	-1	-62	-32
PERCENTAGE REDUCTION PROXIMAL in TIEL	74		54		50		46		41		4		26		-7		-47	

Table 9-8: Clinical observations. DMF of fissures and pits (occ) and of buccal smooth surfaces (ss) in children from Culemborg and Tiel who were 15 years old in 1972 and between 1979 and 1986 inclusive.

C U L E M B O R G

year of examination	1972		1979		1980		1981		1982		1983		1984		1985		1986	
tooth type	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss
I1s	19	8	4	8	14	4	1	5	7	8	3	3	2	1	1	0	0	0
I2s	41	13	22	11	27	10	19	7	9	5	14	5	14	2	4	1	2	1
Csu	13	8	4	3	1	4	0	1	0	0	0	1	2	1	0	1	0	0
P1s+i	107	6	56	11	44	2	41	3	17	2	23	5	13	1	15	1	4	1
P2s+i	183	7	80	5	77	4	72	0	53	5	38	3	43	2	37	2	18	2
M1s+i	387	55	384	90	362	49	361	60	367	64	335	47	321	31	327	22	323	17
M2s+i	336	63	281	47	238	32	233	34	186	26	170	23	163	17	161	21	139	19
TOTAL CULEMBORG	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss
	1086		831		763		727		639		583		558		545		486	
		160		175		105		110		110		87		55		48		40

T I E L

age at discontinuation			9 1/2		8 1/2		7 1/2		6 1/2		5 1/2		4 1/2		3 1/2		2 1/2	
year of examination	1972		1979		1980		1981		1982		1983		1984		1985		1986	
tooth type	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss
I1s	8	4	3	3	1	3	3	2	4	2	1	3	0	2	1	2	2	2
I2s	31	4	11	8	19	4	16	3	13	2	10	4	11	1	8	1	11	3
Csu	2	1	1	1	1	2	1	2	1	1	3	1	0	1	0	0	1	2
P1s+i	29	2	27	2	38	1	35	2	33	2	28	2	22	2	22	1	16	2
P2s+i	59	4	76	2	62	3	63	3	59	2	49	1	44	0	42	1	47	1
M1s+i	313	10	342	21	331	15	322	19	331	21	311	27	300	21	255	31	337	26
M2s+i	207	10	222	16	204	13	186	15	177	17	182	17	161	14	146	24	157	10
TOTAL TIEL	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss	occ	ss
	649		682		656		626		618		584		538		474		571	
		35		53		41		46		47		55		41		60		46
PERCENTAGE REDUCTION in TIEL																		
	40		18		14		14		3		-0		4		13		-17	
		78		70		61		58		57		37		25		-25		-15

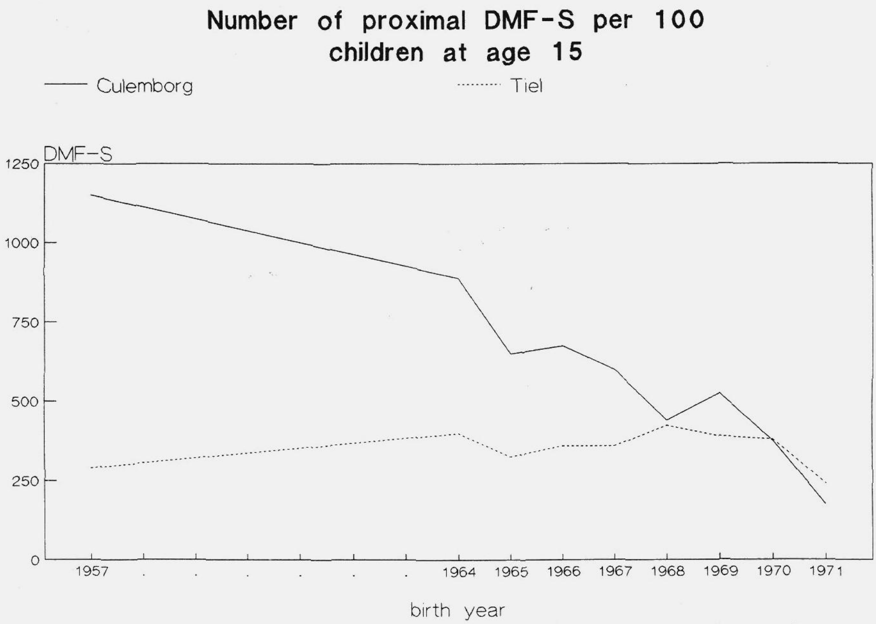
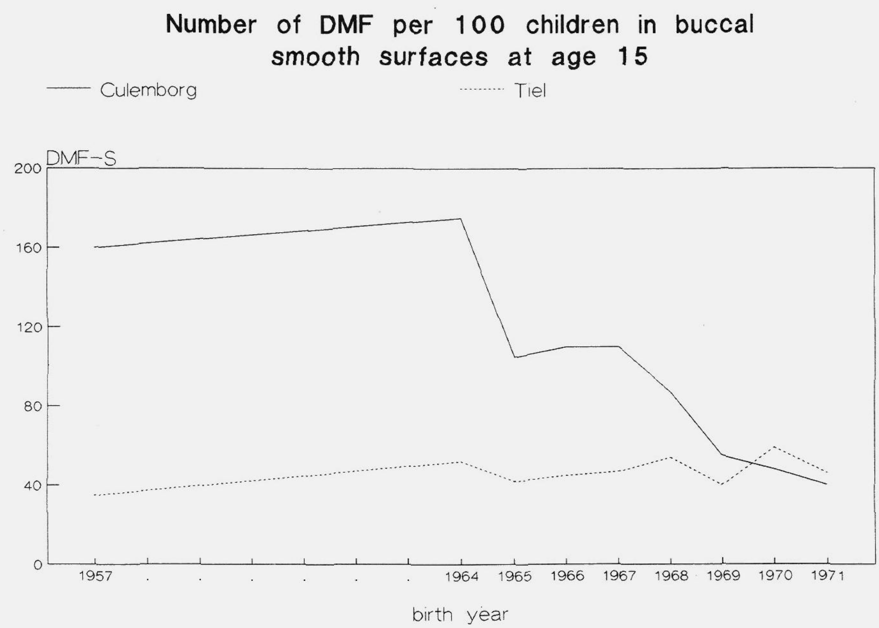
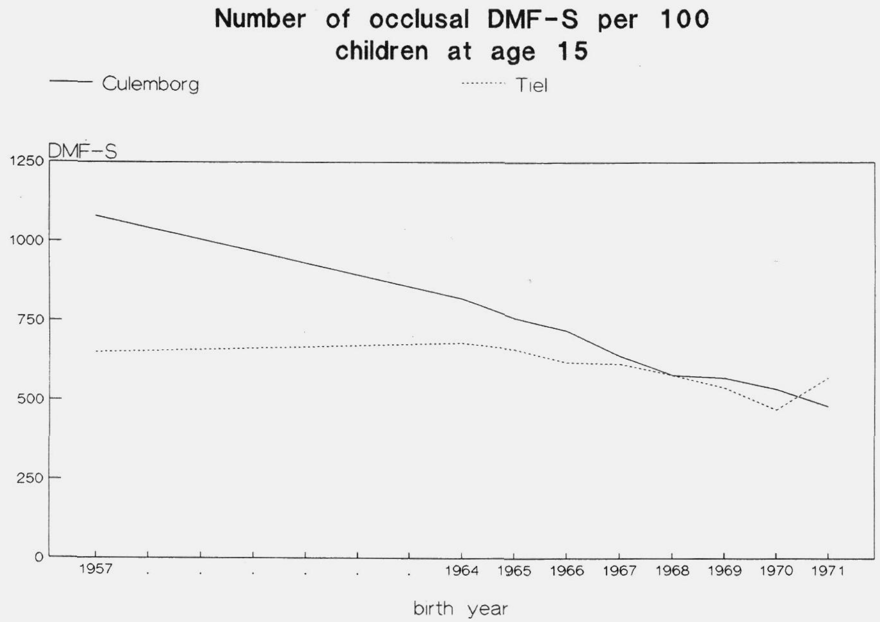


Fig. 9-1: DMF-S of proximal surfaces (9-1a), smooth surfaces (9-1b) and fissures and pits (9-1c) in 15-year-old children from Culemborg and Tiel born between 1964 and 1972.



(9-1b) smooth surfaces



(9-1c) fissures and pits

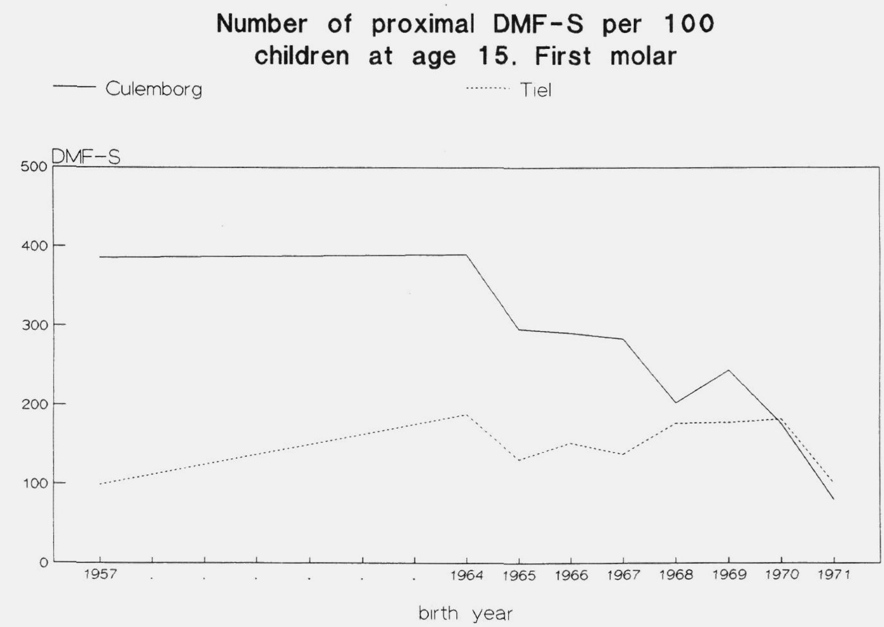


Fig. 9-2a: DMF-S of proximal surfaces in the first molar in 15-year-old children from Culemborg and Tiel born between 1964 and 1972.

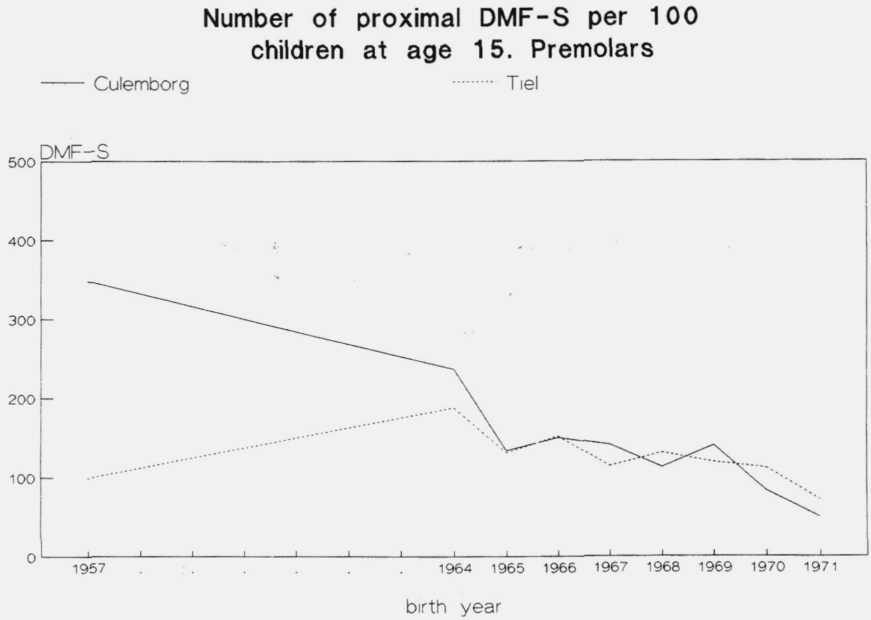


Fig. 9-2b: DMF-S of proximal surfaces in the premolars in 15-year-old children from Culemborg and Tiel born between 1964 and 1972.

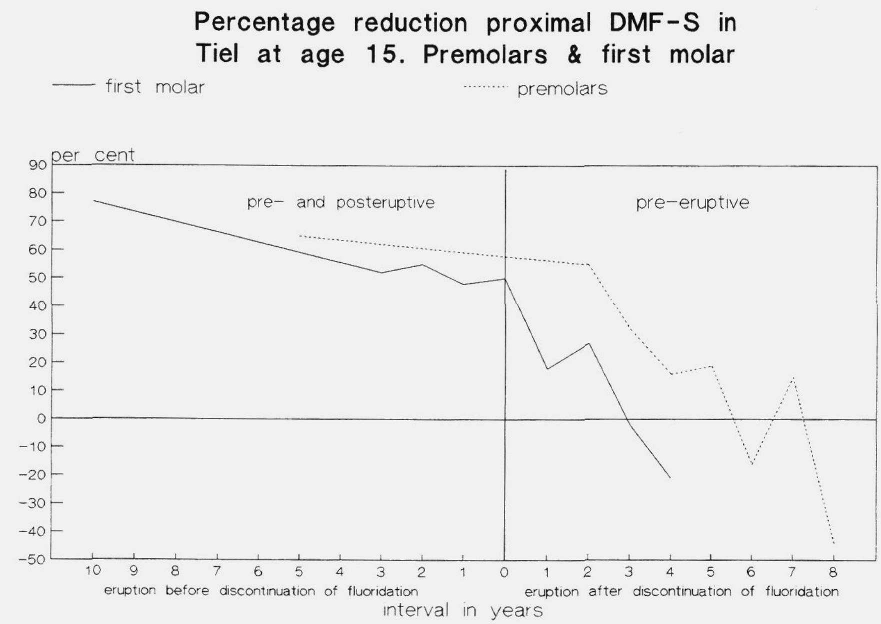


Fig. 9-2c: Percentage less proximal DMF-S in Tiel in the first molar and the premolars in 15-year-old children born between 1964 and 1972.

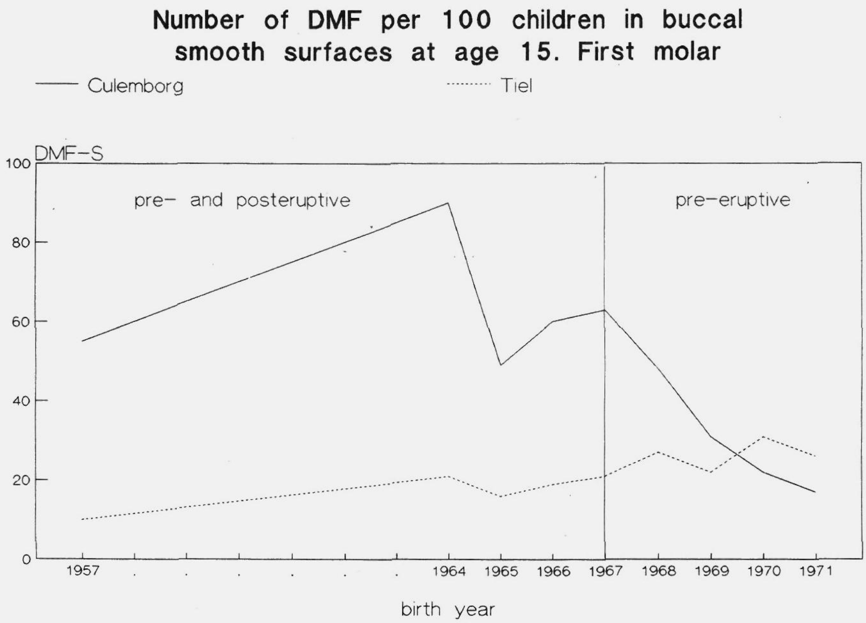


Fig. 9-3a: DMF-S of smooth surfaces in the first molar in 15-year-old children from Culemborg and Tiel born between 1964 and 1972.

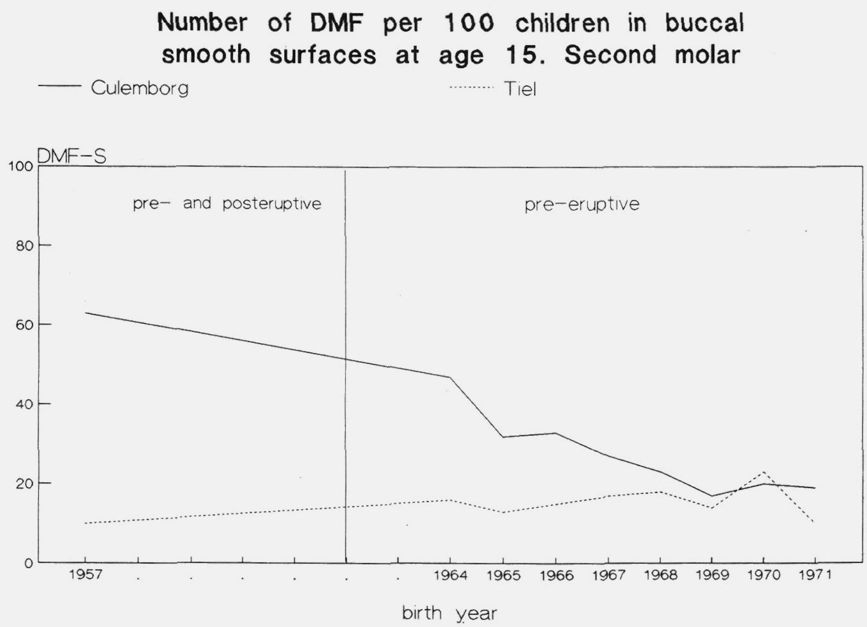


Fig. 9-3b: DMF-S of smooth surfaces in the second molar in 15-year-old children from Culemborg and Tiel born between 1964 and 1972.

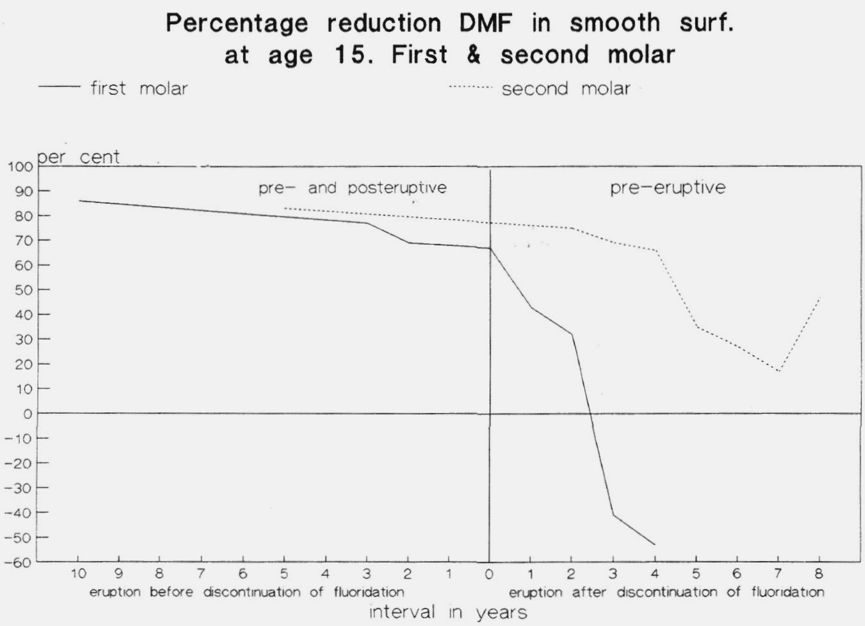


Fig. 9-3c: Percentage less DMF-S in Tiel in smooth surfaces in the first and second molar in 15-year-old children born between 1964 and 1972.

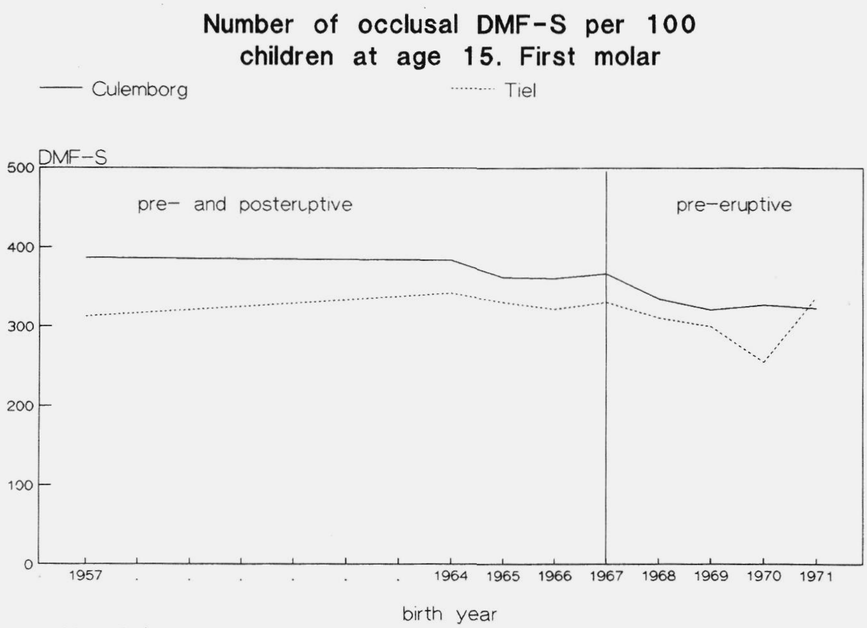


Fig. 9-4a: DMF-S of fissures and pits in the first molar of 15-year-old children from Culemborg and Tiel born between 1964 and 1972.

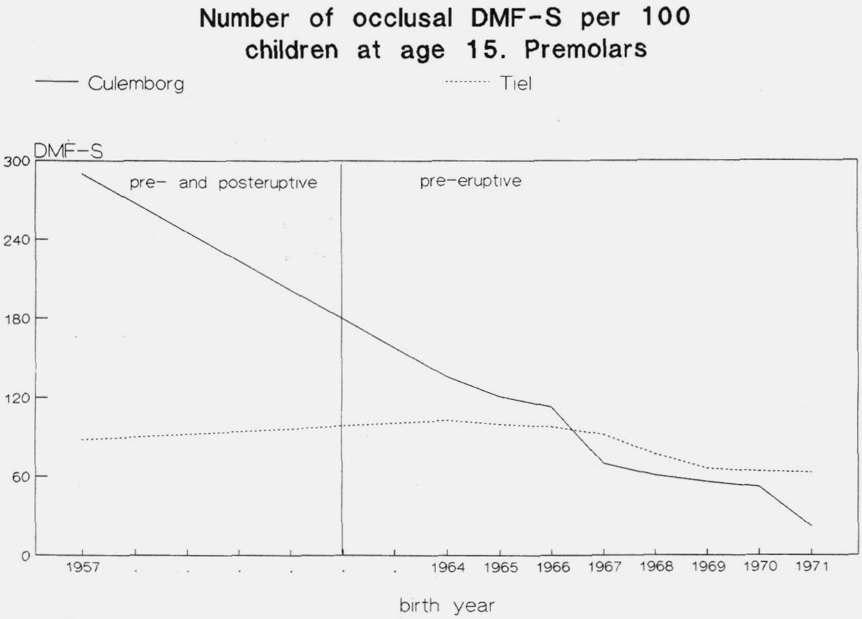


Fig. 9-4b: DMF-S of fissures and pits in the premolars of 15-year-old children from Culemborg and Tiel born between 1964 and 1972.

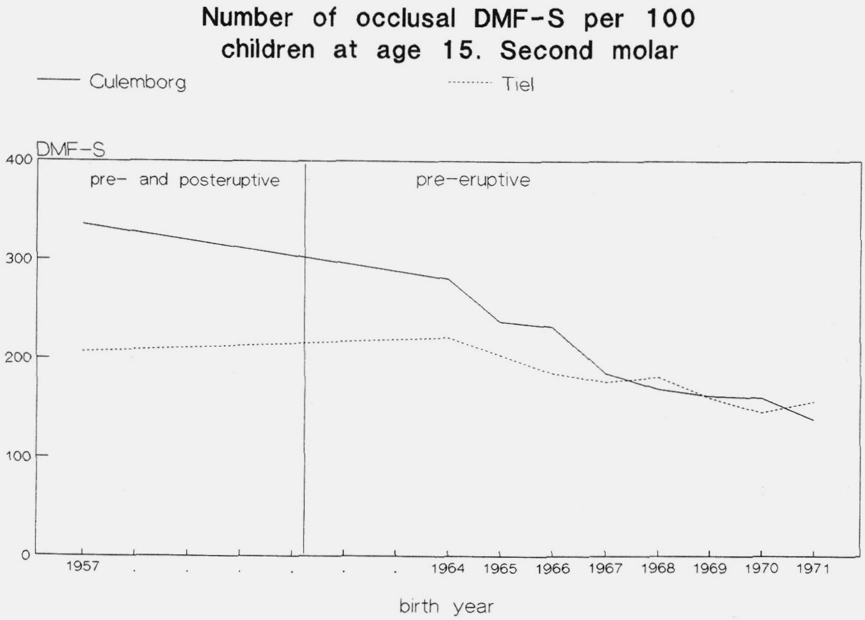


Fig. 9-4c: DMF-S of fissures and pits in the second molar (9-4c) of 15-year-old children from Culemborg and Tiel born between 1964 and 1972.

9.5.2 Standardization with respect to the use of fluoridated water pre- and posteruptively

For the first molar and the upper incisors data are not yet available for those groups which consumed extra fluoride during the mineralization, i.c. from birth until the age of three years (see table 3-1) .

These two groups of children have stopped to use fluoridated water between birth and the age of two years.

For the upper canines, the premolars and the second molars no data are available of groups who still used fluoridated water after or until eruption (between 10 1/4 and 12 years). The first groups which are examined (1979) are those who had discontinued the consumption of fluoridated water in 1973 at the age of nine years, thus about two years before eruption.

Figure 9-2a shows the DMF-S of proximal surfaces of the first molars classified according to the relation between the median time of eruption and the discontinuation of the fluoridation in Tiel.

Figure 9-2b shows the DMF-S of proximal surfaces of the premolars classified in the same way.

The percentages reduction in Tiel deduced from figures 9-2a and 9-2b are presented in figure 9-2c. The maximal reduction at the left side of the graph is based on the data in 1972, obtained from table 9-7.

Figures 9-3a, 9-3b and 9-3c show the same data for the smooth surfaces. For the DMF-S at the left side of the graph in figures 9-3a and 9-3b and for the maximal reduction at the left side of the graph in figure 9-3c served the values for the 15-year-old in 1972 obtained from table 9-8.

Figures 9-4a, 9-4b and 9-4c show the DMF-S for the fissures and pits in the first molar, the premolars and the second molar.

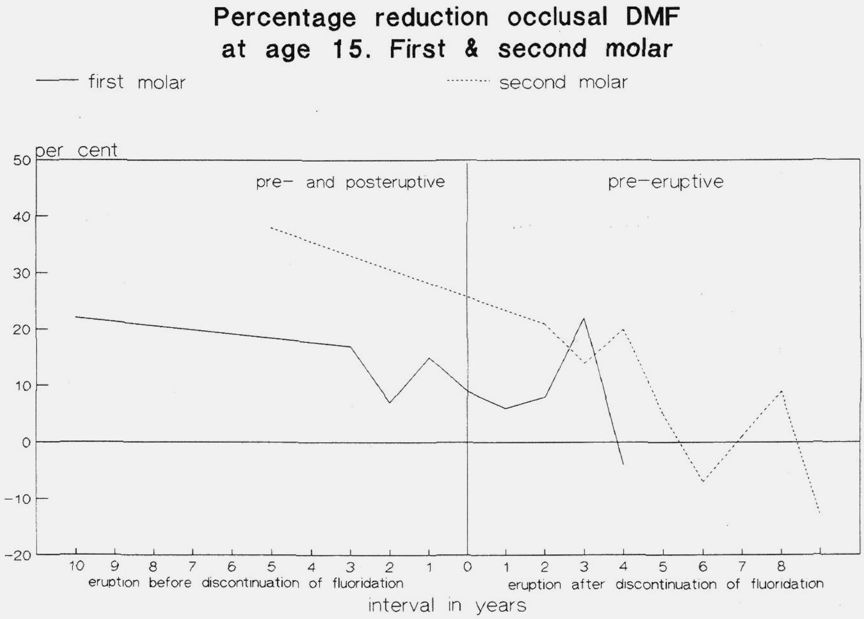


Fig. 9-4d: Percentage less DMF-S in Tiel of fissures and pits in the first and second molar in 15-year-old children born between 1964 and 1972.

Figure 9-4d shows the percentage reduction in these surfaces of the first and the second molar. The values for the 15-year-old children in 1972, obtained from table 9-8, served for the DMF-S at the left side of the graph in the first three figures and for the maximal reduction at the left side of the graph in fig. 9-4d.

9.6 DISCUSSION

9.6.1 Cross-sectional study

For an assessment of the reduction in DMF-S, regardless of whether this is done for children using fluoridated water until different ages or for surfaces in contact with extra fluoride until various stages of development, it is necessary to compare Tiel with the control town Culemborg.

If the total number of DMF-S in the separate categories of surfaces and the percentage reduction in 1979 is compared with those in 1972 it can be observed that six years after the discontinuation of the fluoridation only part of the maximal reduction of the caries experience still exists (fig. 9-1). In the surfaces used for this study the total DMF-S in 15-year-old children from Culemborg decreased from 23.5 per child in 1972 to 19.0 per child in 1979 during this period, whereas in Tiel the same index showed an increase from 9.8 in 1972 to 11.4 in 1979. This can also be observed in the separate categories. The DMF-S in Culemborg continues its drop from 19.0 in 1979 to 6.9 in 1986, whereas in Tiel it decreases in the same period from 11.4 to 8.6. The data in Culemborg show that obviously a combination of changing factors and preventive means other than water fluoridation or a lessening of the caries attack may cause an even greater reduction than water fluoridation.

Amongst the reasons for the decline in dental caries in Culemborg, the increased use of fluoride (topical applications, tablets and toothpaste) will have played an important role. If solely water fluoridation was replaced by fluoride in an other form (between 1974 and 1979), the DMF scores in Tiel would proportionally have followed the decreasing trend in Culemborg. The non-fluoride factors, such as less sugar intake and better dietary habits, probably influence both towns in a similar way.

If in 1972 the DMF index in Tiel has attained a minimum for that time, this means that as a result of the decrease in Culemborg during the period 1972 - 1986 the percentage reduction might be relatively too low, because the DMF-S in Tiel does not proportionally follow that in Culemborg.

Another result of the decrease of DMF-S in Culemborg is that a relatively smaller difference in DMF-S may have a relatively great influence on the percentage reduction.

For a more extensive discussion of these data is also referred to the publication by Groeneveld and coworkers (1987).

In 1979 the difference in total DMF-S per child between Culemborg and Tiel (19.0 and 11.4 respectively) is 7.6, which means 40% less caries in Tiel. However, this difference decreases in subsequent years of examination. In 1985 there is only a not significant reduction of five per cent total DMF-S.

The preliminary data of 1986 show that there are even more DMF-S in Tiel than in Culemborg. In the proximal surfaces (2.4 and 1.6 proximal DMF-S per child) this difference is 0.8 DMF-S per child (47%).

The DMF index of proximal and buccal smooth surfaces in Tiel, on which fluoride exerted a greater reducing effect on caries experience than on fissures and pits, remains rather stable during the whole study period (see fig. 9-1). In Culemborg the number of DMF-S surfaces in these categories shows an high decrease between 1979 ad 1986.

It is notable that in Tiel in 1985 less fissure and pit cavities were scored in the first and second molars than in the preceding and succeeding years of examination in the same town. Between 1979 and 1982 the DMF index of the fissures and pits in the first molar remained more or less constant in this town and showed a slight decrease since then. The difference between 1984 and 1985, however, is remarkably great. This feature might be due to chance.

It might be possible that the decreasing trend in the proximal and buccal smooth surfaces observed in Culemborg as well as in other non-fluoridated communities in The Netherlands, - if proportionally applicated to Tiel, - is exactly compensated by the declining effect of the water fluoridation. If no effect of the (pre-eruptive) fluoridation on these surfaces can be expected anymore the DMF-S in Tiel will follow the general decreasing trend. The preliminary data in 1986 form an indication of this feature.

In the fissures and pits, however, where water fluoridation causes a much smaller effect, the general decrease of DMF-S is more perceptible in Tiel in the period 1979 - 1986 than in the two other categories. Apparently other factors than the increased use of fluoride are also of importance for the decrease in Culemborg.

The trend observed in 1986, that more DMF-S are scored in Tiel than in Culemborg is supported by hitherto unpublished longitudinal data of children from the two towns, born in 1973, which show that in children from Tiel examined at the age of seven, nine and 11 years more DMF-S are observed than in children from Culemborg (NIPG-TNO, unpublished data).

The causes for this difference are yet unknown and can be manifold. The relation is even contrary to what would be expected, because between 70 and 80 per cent of the children from Tiel born after 1968 attended the centre for youth dentistry where special attention was paid to the prevention of dental caries (Kalsbeek, 1985), whereas in Culemborg no special preventive measures were taken.

9.6.2 Standardization with respect to the use of fluoridated water pre- and posteruptively

9.6.2.1 General observations

For a more precise assessment of the effect of pre- and posteruptive fluoride consumption on caries experience, analysis of the data after classification of the teeth according to the relation between the median time of eruption and the discontinuation of the fluoridation could provide more information.

In order to compare the percentages reduction after the discontinuation of the fluoridation with those which were observed if fluoridated water had been used from birth until examination, the latter, obtained from the examination in 1972 were added to tables 9-7 and 9-8 and to the left side of the graphs in figures 9-2c, 9-3c and 9-4c. Unfortunately no data are available from examinations in the first six years after discontinuation (1973 - 1979).

The results will be discussed for the three categories of surfaces separately.

9.6.2.2 Proximal surfaces

Table 9-7 and figure 9-2c show that the percentage reduction in the proximal surfaces of the first molars remains about 50%, regardless if fluoridation is discontinued three years after eruption or at eruption. This is about 70% of the maximal reduction.

Between the group which had discontinued consumption of fluoridated water at eruption and the one which had done so three years before eruption the reduction gradually disappears.

The proximal surfaces of the premolars show a reduction of 55% if fluoridation is discontinued two years before eruption (see fig. 9-2c). This is approximately two-third of the about 70-75% reduction that is obtained if fluoride is consumed continuously from birth on (year of examination 1972). This portion is greater than that in the group with comparable fluoride use in the first molar (40%). The fact that the use of fluoridated water until the same moment before eruption is more effective in premolars and second molars than in first molars, might be related to the longer time of mineralization and pre-eruptive maturation of the premolars and the second molar. Moreover, the first stage of calcification in the first molar is around birth, when less fluoride is available than during the calcification period of the premolars and the second molar. This also might have resulted in a smaller effect.

No reduction in caries experience is observed anymore in premolars and second molars if the discontinuation takes place five years before eruption.

9.6.2.3 Buccal smooth surfaces

The first molar shows 55 and 10 DMF-S respectively per 100 children in the buccal smooth surfaces in Culemborg and Tiel if fluoridated water is consumed continuously from birth (fig. 9-3c, examination in 1972). This is a difference of 77%. If the use of fluoridated water is discontinued three years after eruption the percentage reduction is still the same, although in that examination year (1979) the DMF-S has approximately doubled in both towns. The percentage reduction then gradually decreases until 67% if consumption is discontinued at eruption. Discontinuation of the consumption between eruption and four years before eruption results in a complete loss of the reduction. In later years there are even more cavities in Tiel

(26 DMF-S per 100 children) than in Culemborg (17 DMF-S per 100 children). The very steep decrease of the DMF in Culemborg (fig. 9-3a) from 90 DMF-S in 1979 to 17 DMF-S in 1986, is the cause that, due to the small number at the end of the period, the numerical small difference (9 DMF-S per 100 children) results in a higher percentage of DMF-S in Tiel (35%).

9.6.2.4 Fissures and Pits.

The data for the first molar show that, if fluoridation is discontinued three years after eruption, the percentage reduction of dental caries in 15-year-old children is 11%, which is about half of the 19% less DMF-S observed in 1972 in children who had used fluoridated water from birth continuously. However, the small differences in the year of examination 1979 and in later years are of no real significance.

The parallel decreasing trend in the two towns after 1979 might form an indication that other factors than an increased use of fluoride might also have played an important role in the decrease in Culemborg. If fluoride would have been the main cause also the DMF index of the proximal and the free smooth surfaces surfaces would have decreased in this period.

The fissures and pits of the premolars and second molars still show a reduction in caries experience of 31 and 21% respectively if the use of fluoridated water is discontinued two years before eruption. This is almost half the reduction which is observed if fluoridated water has been consumed from birth continuously.

As in the proximal surfaces, here too the higher percentage than that of the first molars in the group with use of fluoridated water until two years before eruption can be the result of a longer period of pre-eruptive development and to the fact that fluoride is better available in the first phase of calcification.

The reduction in premolars and second molars gradually decreases if the use of fluoridated water is discontinued earlier and disappears if the use stops at four years before eruption.

Table 9-9: Reduction of DMF-S as a percentage of the maximal reduction (fluoridated water from birth continuously) at different moments of discontinuation in relation to the time of eruption..

All figures have been rounded off to unities of five.

	Moment of discontinuation											
	3 yrs after			at eruption			2 yrs before			3 yrs	5 yrs before	
tooth surface	M1	P1P2	M2	M1	P1P2	M2	M1	P1P2	M2	M1	P1P2	M2
proximal	70	-	-	70	-	-	40	85	55**	0*	30	80**
smooth	95	-	-	85	-	-	40	75**	65**	0**	40**	35**
fissure and pit	60	-	-	40	-	-	35	35	50	95***	0*	10

\- = no data available
* = negative figure, replaced by zero
** = low DMF-S index, not reliable
*** = high percentage reduction due to relatively low DMF index in Tiel in 1985.

9.6.2.5 Combined results of the different categories of surfaces

The reduction in DMF-S in relation to the time of eruption at the different moments of discontinuation of water fluoridation is presented in table 9-9. The reduction is expressed as a percentage of the maximal reduction caused by fluoridation for each of the three categories of surfaces separately.

In the table percentages > 100 have been reduced to 100.

It must be kept in mind that, although the first molar as well as the group containing the premolars and the second molar have been classified according to the relation between the discontinuation of the use of fluoridated water and the time of eruption, the interval between eruption and examination was different for the two groups. This might have influenced differently caries experience in relation to the effect of the pre-eruptive fluoridation. It could, for instance, be supposed that in the first molar through the longer period between eruption and examination, which is more than twice that in the other group (premolars and second molar), an initially existing effect would decrease.

The table also shows that, - regardless of whether this is until three years after eruption or until eruption, - the relative effect of the use of fluoridated water has an inverted relation proportional to the percentage of attacked surfaces in the three different categories of surfaces. Thus fissures and pits show the smallest effect, proximal surfaces a greater effect, whereas the buccal smooth surfaces show the greatest effect regardless of whether the consumption of fluoridated water is discontinued three years after eruption or not before examination.

The effect at the coincidence of the discontinuation of the water fluoridation and the eruption shows the same relationship with regard to the percentage of attacked surfaces. However, as compared to the data in the column dealing with discontinuation three years after eruption the percentage for the proximal surfaces remains equal, whereas those for the buccal smooth surfaces and fissures and pits show a small decrease. An explanation might be that the development of cavities in the fissures and pits already starts during or immediately after eruption, so protection in the eruption period is essential. This is to a lesser extent also the case for the buccal smooth surfaces. Here a white spot lesion generally often develops also during and immediately after eruption. The progression unto dentinal caries, however, is rather slow.

In the proximal surfaces the development of the cavities generally takes more than 2 - 3 years, often as a result of the contact with a later erupting adjacent tooth, so that the presence of fluoride also in the first three years after eruption can give little additional protection.

The data of the groups who discontinued to use fluoridated water two years before eruption show a slightly lower percentage for the first molar and the premolars as compared with the second molars. As has been suggested in par. 9.6.2.4, this could have been caused by the fact that at that moment the pre-eruptive maturation in the second molars is more advanced, whereas in the first molar and premolars not yet.

Based upon the reliable data it can be supposed that there is no effect anymore of fluoridation in the group with discontinuation at five years before eruption (three years for the first molar).

From this study it can be concluded that the use of fluoridated water during the pre-eruptive period still has a reducing effect on caries experience, even if it is not followed by posteruptive use. However, posteruptive use increases substantially the effect. The degree of the pre-eruptive effect has an inverted relationship to the percentage caries in the three categories of surfaces.

The cross-sectional data show that changed circumstances in Culemborg have caused in the examination period 1972 - 1986 a decrease of DMF-S to a level comparable to the maximal effect of the water fluoridation in Tiel in the examination period 1968 - 1972.

10.0 GENERAL DISCUSSION

10.1 Combined results

A synthesis of the effect of the use of fluoridated water in Tiel from March 1953 upto December 1973, pre- and posteruptively for the different surfaces apart, will be presented.

The caries experience (DMF-S) and the percentages reduction in the 15-year-old children are summarized in table 10-1.

Table 10-1a shows for 15-year-old children born in 1953 and 1954 the DMF-S per 100 children in Culemborg and Tiel and the percentage reduction in caries experience in Tiel for all teeth and for the first molar separately.

Table 10-1b shows the reduction of caries experience in Tiel expressed as a percentage of the maximal reduction if fluoridated water is used only post- or pre-eruptively.

Table 10-1c shows the interval in years between the time of eruption and the time of the:

a) start of the fluoridation posteruptively in surfaces which show no reduction (left column).
b) start of the fluoridation in surfaces which show the maximal reduction for the first time.
c) discontinuation of the fluoridation in surfaces which did not show a reduction anymore.

Table 10-1a: The number of DMF-S and the percentage DMF-S in Culemborg and Tiel and the maximal percentage reduction of caries experience in Tiel.
all = I1sup., I2sup., Csup., P1, P2, M1 and M2.
M1 = first molar only.

F-use pre-/post-eruptively	Number of DMF-S in molar and upper anterior region per 100 children aged 15 year*: no fluoride		1 mg F-/l pre+post		percentage reduction		Percentage DMF-S in molar and upper anterior region.*: no fluoride		1mg F-/l pre+post	
	all	M1	all	M1	all	M1	all	M1	all	M1
proximal surfaces (molars, premolars, upper anterior)	1170	402	321	122	73	70	28	50	8	15
smooth surfaces (bucco-gingival cavities)	236	68	38	16	84	78	11	17	2	4
fissures and pits (premolars and molars)	954	388	611	307	36	21	60	97	38	77

* mean of children born in 1953 and 1954

Table 10-1b: The effect of pre- or posteruptive use of fluoridated water in 15 year-old-children from Culemborg and Tiel born between 1937 and 1970.

F-use pre-/post-eruptively	Percentage of the maximal reduction if eruption coincides with start fluoridation		end fluoridation	
	all	M1	all	M1
proximal surfaces (molars, premolars, upper anterior)	45	35	--	70
smooth surfaces (bucco-gingival cavities)	--	60	--	75
fissures and pits (premolars and molars)	0-10	2	--	60

Table 10-1c: Interval in years between eruption and the start of water fluoridation after which a reduction could be observed and interval in years between start of the fluoridation and eruption to reach the maximal reduction. The last column indicates the interval in years between discontinuation and eruption after which no reduction could be observed (first molar only).

	no reduction	maximal reduction	no reduction	
F-use pre-/post-eruptively	partly pre/post	pre/post	pre/-	
time of eruption in years	before start	after start	after end	of fluoridation
proximal surfaces	3	6	3*	
smooth surfaces	--	6-8	3-6*	
fissures and pits	1	6-7	5*	

-- = examined not later than two years after start of fluoridation.
* = based on data from first molar only.

The values in the column denoted "end" of table 10-1b give the percentage of the maximal reduction if the end of the fluoridation coincides with the eruption of the tooth (pre-eruptive effect only) and are based on DMF-S of the first molar only. The values in the column "start" are based on the DMF-S of all posterior teeth and the upper anterior teeth.

Table 10-1a shows the inverted relationship between the percentage DMF-S of the three categories of surfaces and the percentage reduction in caries experience of the use of fluoride, from birth onwards, only before eruption, or only after eruption.

The results of this study show that the use of fluoridated water until eruption only, has a greater effect than the use only between eruption and examination in all categories of surfaces of the first molar .

However, additional use of fluoridated water consumed continuously from birth, results in the greatest effect: pre- as well as posteruptive consumption are both necessary to benefit most from water fluoridation. This is discussed for the different categories of surfaces apart:

In the **proximal surfaces** posteruptive use only results in about 45% (35% for the first molar) of the maximal reduction (70%). The use during the pre-eruptive phase adds the remaining 55% of the maximal effect. The consumption of fluoridated water until eruption shows still 70% of the maximal effect in these surfaces at examination nine years later. When also consumed after eruption the remaining 30% are apparently due to posteruptive use.

The **buccal smooth surfaces** show the highest effect of only posteruptive use: 60% (which is the mean of 45% at start fluoridation two years after eruption and 75% at start fluoridation two years before eruption) of the maximal reduction (82%). Additional pre-eruptive cosumption adds the rest of the maximal reduction. If fluoridated water is only used before eruption about 75% of the maximal effect is still observed at examination nine years later.

In the **fissures and pits** hardly any, or no effect is observed if fluoridated water is only used after eruption, whereas the use until eruption shows about 60% of the maximal reduction (22%) nine years later. The additional posteruptive use adds 40% of the maximal reduction.

The results for the three categories of surfaces reveal that in all cases the reducing effect of fluoridated water on caries experience is increased by an additional posteruptive use on top of the pre-eruptive use and vice versa.

The data of the table suggest that surfaces with a higher percentage of caries lesions need fluoridated water pre - as well as posteruptively, in order to attain the maximal effect of water fluoridation.

The results in the separate categories of surfaces show that the actions of the use of fluoride pre- and posteruptively apart may either overlap each other more or less (smooth and proximal surfaces) or show a gap. The degree of overlap is inversely proportional to the percentage of caries lesions. In the smooth surfaces the sum of the percentages reduction caused by exclusively pre- and exclusively posteruptive effect is 145%, in the proximal surfaces the sum is 105% and in the fissures and pits the 100% is not reached at all. Apparently the effect of pre- and posteruptive use can not be added in order to calculate the total effect.

In the proximal surfaces of the first molar (fig. 9-2c) the relative effect of the use of fluoride either only before eruption or only after eruption, is smaller than in smooth surfaces. In the group which had received fluoride from birth (thus pre-eruptively) it makes no difference if fluoridation is discontinued at eruption or three years later: the percentage reduction does not increase. Apparently continuation of fluoridation must be extended beyond three years after eruption in order to add the remaining part of the maximal effect. A possible explanation for this feature might be that the caries progression observed in proximal surfaces is rather slow and that most initial lesions only become a dentinal lesion more than three years after eruption. Here the radiographical diagnosis may play an important role, because the lesion might be in a more advanced stage as can be observed on the radiograph. Extra fluoride during the period that only few dentinal lesions develop apparently causes no extra reduction. For an increased reduction fluoride must be present during an extended period.

Unfortunately the data lack to provide more information about the exact course of the curve in fig. 9-2a if the discontinuation took place between three and six years after eruption. It might, for instance, be possible that the percentage of the maximal reduction is still 70 even if fluoridation is discontinued four or five years after eruption (Winkler and Backer Dirks, 1958).

It may be that the relative smaller effect of fluoride posteruptively in proximal surfaces than in smooth gingival surfaces, is caused by the greater plaque thickness and consequently the much longer diffusion route for proximal surfaces.

In the buccal smooth surfaces, which have a low caries level, the effect of the fluoride administered before eruption is apparently sufficient to resist most of the caries attack. If fluoride is available to the enamel surface only after eruption still a great deal of the maximal reduction can be attained, probably because these surfaces have a relatively low caries risk as compared to the other categories. Although an incipient enamel lesion is often formed very early during eruption and in a very short period only a small percentage progresses into a cavity.

Moreover the accessibility of the smooth surface for the fluoride in the drinking water is rather good due to a relative small effective plaque thickness and hence a short diffusion route for the fluoride into the deepest layers of the plaque. Also the fluoride present in the sulcus fluid may give some extra protection. After dissolution of the most soluble parts of the crystals, fluoride stimulates remineralization and transformation leading to a less soluble enamel.

If during the first three years after eruption fluoridated water is also consumed the effect is nearly 90% of the maximal effect (fig. 10-3c). For the effect of fluoridation on these surfaces apparently the periods before and the first years after eruption are the most important. This may be explained by the fact that most incipient lesions in smooth surfaces originate soon after tooth eruption (Backer Dirks, 1966).

In order to obtain a maximal effect in fissures and pits fluoridation has to start early during tooth development and it has to be continued posteruptively. Use after eruption only, has hardly any or no effect. For the first molar the maximal effect was 21% fewer cavities (table 10-1a). In the group where fluoridation was discontinued at eruption the reduction was only 10%. Apparently the use before eruption must be followed by use after eruption, otherwise an important part of the effect is not reached.

An explanation for this might be that the diffusion route to the lower parts of the walls of the fissures, where the dentinal lesion is formed, is very long, so that only the effect caused by the fluoride available during a very early pre-eruptive phase becomes apparent. On the other hand the attack in this category of surfaces is apparently so strong that, if there had been no extra fluoride before eruption, the low concentration of topically present fluoride in the drinking water would not be capable to provide enough fluoride in the plaque for enough resistance against the carious attack and for the remineralization of the enamel. There may be enough fluoride effect at the entrance of the fissure, however, not at the deepest parts. If, however, the tooth received fluoride before eruption, posteruptive continuation can add upto nearly half of the maximal reduction thanks to the basic protection by the pre-eruptive fluoride.

There is an important difference in pre-eruptive effect of fluoride in fissures of first and second molars (table 9-4d). The deepest part of the fissures is formed in an early phase of tooth development, proximal surfaces later and the gingival parts of the enamel last. The formative phases of the first molar take place before birth and the mineralization/calcification starts around birth. One third of the calcification takes place before the end of the first year of life. During pregnancy the fluoride peaks in the blood of the mother will be cutt off in the placenta and thus not be available for the bone surrounding the forming teeth. After birth the fluoride supply to the baby is still small, because mothermilk contains hardly more fluoride in a fluoridated town than without the use of fluoridated water (± 0.05 mg F^-/l. Cow's milk contains somewhat more fluoride (± 0.10 mg/l).

This means that in particular the fissures of the first molar are formed under relatively low fluoride conditions. During the subsequent phases fluoride will probably be less available in the (deep) fissures than on the other surfaces of the tooth.

For the second molar where formation and calcification of the fissure starts at the age of two years the extra fluoride will be present in time. These differences in fluoride availability for the fissures during formation could account for the differences in caries reduction and may also explain why there are no obvious differences for the percentages reduction for proximal and smooth surfaces between the first and second molar.

One aspect to be discussed here is the increase (examinations 1952 - 1969) and the decrease (examinations 1972 - 1986) of the DMF index in the control group. Although the percentage reduction on caries experience is independent of the level of the DMF index, the caries attack will be raised in Tiel as well. The reduction on caries increment is affected by the increasing DMF index in Culemborg during the examination period 1952 - 1969 and by the impressive decrease of the DMF index after 1969. This is illustrated below by means of the data for the proximal surfaces (see chapter 6.0).

In the first years of examination the DMF index in Culemborg showed an increasing trend in each subsequent year (fig. 6-1). The fluoridation in Tiel started at an age that many proximal lesions were already present. A reduction in caries increment could only take place in a relatively small portion of the still sound surfaces during a short period. As a consequence its effect on the reduction in caries experience (i.e. the total DMF-S) is very small. In subsequent years the number of surfaces which is still at risk at the start of the fluoridation increases, because in each subsequent year the examined 15-year-old children were one year younger at the start of the fluoridation. The period between the posteruptive start of the fluoridation and the moment of examination also becomes longer. If fluoridated water has been available posteruptively only a few years, the effect on the reduction of dental caries experience is small, whereas the effect on caries increment has been much greater.

During the period that the DMF index in Culemborg decreases a similar influence on the reduction of caries experience might happen.

In the first years after the discontinuation the teeth in Tiel are not protected during a short period, which results in a greater caries increment. The increase of the caries experience, however, is relatively smaller than that of the caries increment. Each subsequent year the relative influence of the increment has more weight on the caries experience.

Another feature to be discussed during the period that the DMF index in Culemborg decreases (between examination years 1969 and 1986) is that the index in Tiel does not show a proportional decrease (fig. 10-1). This must, of course, be explained by the decreasing effect of fluoride after the discontinuation of the water fluoridation. On the other hand it can not be excluded that in Tiel a kind of minimum DMF index is attained in children who had used fluoridated water from birth on (fig. 6-1, birth class 1953). Kwant et al. (1972) showed the frequency distribution of children born in 1954, at the age of 15 years. The D10, D50 and D90 of the number of total DMF-S per child was in Culemborg 11, 23 and 42 respectively and in Tiel 2, 10 and 22 respectively. In Tiel the small group of children with the most cavities has a relatively great influence on the mean DMF-S. Probably it is difficult to attain a DMF index below this value in the surfaces which have not a high risk of caries in the period 1965 - 1972.

Only for the proximal surfaces of the first molar a rather complete range of DMF data at start and after discontinuation is available. The DMF index in these surfaces as recorded in the period 1952 - 1986 (compiled from tables 6-1, 6-2 and figure 9-2a) is presented in figure 10-1 (p. 252). Curve C presents the values for Culemborg and curve T for Tiel. In the same figure four hypothetical curves have been drawn additionally. The two curves A represent the DMF-S in Tiel if only posteruptive use should cause an effect and curves B the reduction if only pre-eruptive use should cause an effect.

At the coincidence of eruption of the first molar and start of the fluoridation (children born between 1946 and 1947) the quotient of the horizontal distances TB:AB (0.35) represents the posteruptive part of the maximal reduction. At the coincidence of eruption of the first molar and discontinuation (children born in 1967) the quotient of the horizontal distances TA:AB (0.7) represents the pre-eruptive part of the maximal reduction. If this figure is compared with those presented in Chapter 3.0 it is clear that the reduction in caries experience by fluoridated water in the proximal surfaces of the first molar is for about 70% due to pre-eruptive use.

The mode of action of pre-eruptively administered fluoride is different from that of fluoride used after eruption. If it is sufficiently available during the matrix formation and crystallization period as in the case of water fluoridation, it has a beneficial effect on the crystallization process in the enamel. The crystals are larger and more regularly formed (less dislocations), so that demineralization is slower (Driessens, 1982). However, it is suggested before that the amount of fluoride incorporated in the enamel pre-eruptively has hardly any or no positive correlation with the reduction of caries at all (Fejerskov et al. 1981). The presence of fluoride during the mineralization phase effects probably a purer and more regular hydroxyapatite or fluoridated hydroxyapatite in the tooth enamel than without fluoride.

From in-vitro investigations (Theuns, 1987) it appears that the influence of the pre-eruptively incorporated fluoride on the solubility of the enamel mineral comes only to expression if the enamel is exposed to a mild cariogenic attack.

The positive influence of pre-eruptively supplemented fluoride on the properties of the enamel crystals has the greatest effect in the occlusal surfaces. The enamel can be very thin in the fissures and, due to the anatomy of the occlusal surface, also the arrangement and the shape of the crystals is more irregular than in the proximal and buccal surfaces where the crystals are situated in a nearly parallel way. The shape of the fissures is also the cause of the fact that dental plaque can easily be accumulated, which in its turn is the cause of the carious attack. It has been suggested, however, that pre-eruptively administrated fluoride may cause shallower and more v-shaped fissures, which are less susceptible to plaque accumulation (Forrest, 1956, Ockerse, 1946; Cooper and Ludwig, 1965; Simpson and Castaldi (1969). This effect can, in its turn, prevent cavity formation.

As has been discussed above the difference between the reduction in the fissures of the first and the second molar originates probably from the fact that in the first molar the calcification of the bottom of the fissures occurs around birth and in the lactation period, when the F- concentration is low, whereas in the second molar the calcification period of the fissures starts much later. Fluoride is then sufficiently available to have a positive influence on the crystallization process.

The effect of posteruptive use of fluoridated water is probably the stimulation of transformation and remineralization of the enamel after initial demineralization. Contrary to the progression of caries the formation of incipient enamel lesions is not prevented by fluoride (Groeneveld, 1985) (see also paragraph 10.6). Here too its presence may accelerate the transformation of brushite into fluoridated hydroxyapatite which is less soluble than the original mineral components of the enamel.

Simply said, when the pH drops the most soluble part of the enamel crystals is dissolved first (at a relatively high pH) and when the pH rises again the most insoluble crystals will be formed first (at a relatively low pH). The resulting enamel after each attack must be less soluble than before the attack. Therefore is this process of fluctuating pH (at a low level) essential for the maturation and strenghtening of the surface enamel.

The enamel of surfaces with an incipient lesion, visible as a chalky white area, contains upto 10-15 times as much fluoride as sound enamel of a comparable surface (Jongebloed, 1976; Weatherell et al., 1977).

In categories of surfaces with a low attack (approximal and smooth surfaces) the fluoride originating from frequent supplementation of vehicles with low to moderate concentrations (drinking water, F^- tablets, toothpaste) is continuously accumulated and adsorbed in the plaque. When the pH drops it is released and not charged HF molecules appear which can pass the bacterial membrane and lower the bacteric acid formation. As soon as the pH rises again fluoride will stimulate the remineralization and prevents that most of the initial lesions will progress into cavities. However, in categories of surfaces with a high attack rate (fissures and pits) the locally present fluoride is less capable to induce remineralization and transformation of the enamel, so that more initial demineralizations progress into cavities. Only extra pre-eruptive fluoride provides some protection in these surfaces, because it has had a beneficial effect on the physical and chemical properties of the enamel.

The effect of high fluoride concentrations which are applied posteruptively with a low frequency (topical applications), is different from that of low concentrations. After application the dissolved tooth mineral precipitates as fluoridated hydroxyapatite and as calciumfluoride. Calciumfluoride crystals dissolve slowly in the plaque and may contribute to the F-content in the plaque in this way.

10.2 COMPARISON WITH RESULTS OF OTHER STUDIES

Comparison of the results in the present study with those of other studies dealing with start or discontinuation of the water fluoridation, is not always possible due to the differences in method and by the use of a DMF-T index in most other studies. Also the lack in a number of studies of a control group from a non-fluoridated town makes a direct comparison more difficult. Since the DMF-T reflects almost entirely the DMF of occlusal surfaces the data of the occlusal DMF-S from the Culemborg - Tiel study can serve for comparison with the DMF-T in other studies.

The Culemborg - Tiel study is the only one which embraces a year class examined before the start of the water fluoridation, some year classes with permanent teeth which have used fluoridated water from birth, and a number of year classes after the discontinuation of the fluoridation.

The method of this study putting surfaces of teeth with the same relation between time of eruption and start or discontinuation of the fluoridation in groups together was not applicable on the published material of the other studies.

The papers by Backer Dirks (1966 and 1967), Backer Dirks et al. (1961a, 1961b, 1963, 1969) and Kwant et al. (1972, 1973) will be considered since these deal with the same fluoridation experiment as the present study.

About the other studies the following can be remarked:

At start only Ast et al. (1956) published data with DMF-S indices of exclusively the first and second permanent molar from the Newburgh - Kingston study. Unfortunately they published data of only a few year classes.

From the papers dealing with the start of the fluoridation the studies by Arnold (1957a, 1962) in Grand Rapids, Ast et al. (1956) in Newburgh, Ludwig (1958, 1965, 1971) and Ludwig and Pearce (1963) in Hastings, contain groups of the same age, but with the use of fluoridated water during an increasing period. From these Ast is the only one who has published DMF-S data.

Only Hayes et al. (1956) in Grand Rapids and Ast et al. (1956) in Newburgh used a control group from another town which was not fluoridated.

The analysis of Table 2-11 (par. 2.3.3.1) in the present study, which is based on the study by Arnold (1957b), indicated the existence of an additional pre-eruptive effect on reduction of caries experience.

The exclusively posteruptive effect of fluoride on the first molars studied by Hayes et al. (1957) (age of the children at start of the fluoridation 6 1/2 year) shows a much greater reduction for the occlusal surface (11%) than our study (2%). However, the reduction for the smooth (31%) and the proximal surfaces (14%) is smaller then in the present study (47% and 25% respectively).

The four per cent reduction in first molars of 16-year-old children from Newburgh who started the use of fluoridated water at the age of six years is comparable to the percentage observed in the present study (2%), but the percentages observed in 13- and 14-year-old children who started the use at the age of three and four years respectively, are much higher in his study, about 14% instead of 3% for the first molars in children from Tiel born in 1949 at the age of 15 years.

The data from the Hastings study (Ludwig and Pearce, 1963, Ludwig, 1965, 1971) are compiled in Table 2-10 (par. 2.3.2.4). They show in 16-year-old children that, if fluoridation starts one year before birth instead of at the age of six years, in the occlusal and proximal surfaces the reduction had more than doubled at the age of 16 years (from 15 to 34% and from 33 to 67%

respectively), whereas in the smooth surfaces the reduction hardly increased (from 71 to 88%). Except for the occlusal surfaces these findings are comparable to those in the Culemborg - Tiel study.

The data from the Brandon study (Connor and Harwood, 1963) (par. 2.3.2.5) indicated that for the first molar no reduction was observed by posteruptive fluoridation only. This is in line with the findings in the present study for this tooth.

In the studies dealing with the discontinuation of fluoridation by Lemke et al. (1970) and Jordan (1962) retrospective control groups were used. As has been stated in chapter 2.0 this could lead to misinterpretation of the data, therefore a control group from another town, which is comparable except for the subject to be studied is of prime importance.

Russell (1949a) (Mitchell) used a control group from another town (Hagerstown) for his study about the effect of accidentally fluoridated water during 18 months before eruption on caries, but no base-line examination was available in order to check the necessary similarity at the start of the study. Besides the short duration of the fluoridation which may be responsable for the fact that no reduction could be observed, the lack of base-line data from experimental and control groups might have contributed to the disagreement between the conclusions of the first (Russell, 1949a) and the second study (Russell, 1949b). In the first study he reported that hardly any or no effect of the pre-eruptive use of fluoridated water was found. In the second study, however, still a reduction, also caused by pre-eruptive use only, but now during a much longer period, was observed. This reduction however, is much smaller for all categories of surfaces than that caused by the use of fluoridated water from birth onwards.

In other studies dealing with the discontinuation of the fluoridation the longest interval between the discontinuation and examination was four years, whereas in our study the first examination took place nearly six years after discontinuation. This caused a lack of information about the first six years after discontinuation, which could be complemented by the data of these studies. They show that 1 - 2 years after discontinuation the DMF-S in the study group increases gradually and that the reduction in caries experience decreases (Way, 1964; Lemke, 1970; Kuenzel, 1980). Two years after the discontinuation of the fluoridation Way observed an increase of the mean DMF-T per child from 2.0 to 2.8 in a cross-sectional study of 14-year-old children. Lemke reported an increase from 2.4 to 4.6 DMF-T per child, which is 91% more, six years after discontinuation in a cross-sectional study of 12-year-old children . The data for 6 - 8-year-old children presented by Jordan showed that after discontinuation the maximum effect was still present one year later. From then on the DMF-T index increases slowly.

The reduction in caries experience in Tiel remains rather stable at examination six to nine years after the discontinuation, but here the DMF index in Culemborg decreases in subsequent years. For the period between 1972 and 1979 it can be supposed that the DMF index in Tiel remained at the minimum attained in 1972 until about one or two years after the discontinuation. From then on the reduction caused by the fluoride decreases gradually, but this is more or less compensated by the decrease of the mean DMF index in Culemborg.

As has been shown in chapter 2.0 the effect of pre- and posteruptive use of fluoridated water has been discussed repeatedly in the series of papers about the fluoridation experiment Culemborg - Tiel.

In the publication by Backer Dirks about the posteruptive changes in dental enamel (Backer Dirks, 1966) the author showed the results of a method comparable to the one used in the present study applied to the distal surface of the first molar. The only difference is that, instead of the stage of eruption he used the age at start of the fluoridation which makes no difference for one tooth. One year later he also presented some percentages reduction in smooth surfaces and fissures and pits (see Fig. 2-1 of the present study). Unfortunately, early use during the pre-eruptive period could not yet be studied at that time because of lack of data. Basically this method is the same as the one used in the present study.

10.3 EXPERIMENTS IN ANIMALS

One of the first researchers who investigated the effect of topical versus systemic fluoride supplementation on experimental caries in rats was Sognnaes (1940, 1941), who observed an exclusively systemic effect in his studies. Bowen (1973), who used monkeys for his experiment, showed a greater protection in permanent teeth which were formed during the use of this drinking water with 2 mg F^-/l, than in teeth formed prior to the use of that water. Also in other experiments it was found that the additional use of fluoridated water pre-eruptively leads to a decrease of caries incidence in rats (Hunt and Navia, 1975; Larson, 1977; Ekstrand et al., 1986) or hamsters (Fitzgerald and Fitzgerald, 1986). However, in other studies with experimental caries in rats only a topical effect was observed (Koenig, 1960; Poulsen et al. (1976); Mirth et al., 1985).

Some other means of fluoride administration provide also the possibility to study the effect of pre-eruptively ingested fluoride.

10.4 PRE-ERUPTIVE FLUORIDE ADMINISTRATION: alternative ways

Some papers have been published about school water fluoridation. Horowitz et al. (1972) conducted a study in Elk Lake, (Pa.) where for 12 years children received fluoridated school water between the age of six and the age of 12 years. Using a retrospective control group the authors reported that late erupting teeth (premolars and second molars), having received fluoride pre- and posteruptively, showed more reduction than early erupting teeth (first molars and incisors) which received only fluoride during the pre-eruptive phase. This can be due to the longer calcification period of the former.

Studies about the pre- and posteruptive use of fluoride tablets and the effect on caries of permanent teeth in children were extensively discussed by Marthaler (1979) who recognized that it was extremely difficult to carry out a tablet study in order to study the effect of the use pre-eruptively. The main problems to cope with are among others a combination of the following items:

- the long-term duration, at least during the whole pre-eruptive period followed by several years posteruptively which are necessary, so that caries can develop at all.

- a controlled intake of the tablets during the period independent of the dental consciousness of parents and/or children.

Marthaler and Koenig (1967) showed in a tablet study over an eight year period that in children who were 5 - 7 years of age at the start of the study and 13 - 15 years of age at the examination all surfaces of the first molar showed a reduction in caries experience: occlusal surfaces 23%, gingival smooth surfaces 52%, mesial and distal surfaces 50 and 44% respectively. The authors suggested that this was mainly due to direct contact between the fluoride and the enamel.

Andersson and Grahnen (1976) found that the intake of fluoride tablets during the pre-eruptive period gave an additional reduction to that already obtained by fortnightly rinsing with a fluoride solution. However, in a tablet study carried out by Marthaler (1969) the results suggested that the topical effect of tablets was more important than the systemic.

Fluoridation of salt (Marthaler et al., 1978; Toth, 1976) or milk (Rusoff et al., 1962; Ziegler 1964) are other means of providing fluoride pre-eruptively. Although a cariostatic effect was found in all investigations about these two ways of fluoride administration the design of the studies was not suited to assess the part of the reduction due to consumption pre- or posteruptively.

10.5 POSTERUPTIVE EFFECT OF FLUORIDE

The topical effect of fluoride irrespective of the way of administration has been demonstrated in different studies. Backer Dirks (1979) published a survey of the estimated various concentrations of fluoride in the mouth, the frequency of use and the maximal quantity of fluoride each time it is used, as obtained with the different ways of fluoride administration. Table 10-2 is partly based on this table. In the last column the mean percentage reduction of DMF-S of some studies has been added. For the topical supplementations these data are based on a review by Bruun et al., (1982). The percentage reduction of DMF-S of domestic salt studies is published by Marthaler et al. (1978) and the reduction of DMF-T in fluoridated water studies by Murray and Rugg-Gunn (1982).

Studies about water fluoridation and fluoridation of salt show data of caries experience. In one tablet study (Marthaler and Koenig, 1967) and a study about the application with stannous fluoride (Houwink et al., 1974) also showed data of caries experience, whereas in the other studies caries increment was used. Water fluoridation brings about the lowest concentration of fluoride in the mouth and has the highest frequency of use. Compared with the other means of supplementation in the table it also has the greatest reducing effect on the increment of the total DMF-S if it is used from birth.

Domestic salt and tablets have the same properties with respect to the systemic and topical supplementation, but the frequency of use is lower. However, the peak concentration of fluoride in the mouth directly after tablet use is much more elevated. If tablets have been ingested from birth onwards following the instructions they might cause a reduction comparable to that of water fluoridation (Marthaler and Koenig, 1967).

Unfortunately, DMF-S of separate categories of surfaces are exceptionally published, so that for these categories the effect of only posteruptive use of fluoridated water can be compared directly with the other means in some studies. Only Houwink et al. (1974) published for the different surfaces the effect of semi-annual topical applications with a solution containing 4% stannous fluoride after nine years. He observed 20% reduction of caries experience in fissure and pit caries of children with a mean age at examination of 16 1/2 years. Since these applications started at the age of seven years many fissures of first molars were already decayed before the start of the experiment. As a result the effect, if applied immediately after eruption might still be better.

Table 10-2: Comparison of the various applications of fluoride as a prophylactic against caries and the mean reduction of dental caries. Figures in parentheses in the last column indicate the minimum and maximum reduction found in the series of studies.

	Fluoride concentration in the mouth mg F-	Frequency of use	Maximal quantity fluoride each time when following instructions	% mean reduction DMF-S experience or increment
Water fluoridation separately or with food	1	5-10 x daily	0.5 mg (=500 ml water)	56% DMF-T experience
Fluoridation of domestic salt 100 mg F/kg 250 mg F/kg (5 g salt in food (250-500g))	1-2 2.5-5	1-2 x daily	1 mg (=10 g salt) 2.5 mg (= 10 g salt)	40% experience
Toothpaste 0.1% F 1mg F- +3ml saliva	300	2-3 x daily	1 mg (= 1 g paste)	24 increment (14-39)
Tablet 0.25 mg F- + 2 ml saliva	125	1-4 x daily	0.25 mg	28 exp./incr. (23-34)
Mouth rinse 0.025% F- 0.1% F- 7 ml	250 1,000	1 x daily 1 x weekly	1.75 mg 7 mg	28 increment (11-47)
Application of solution 1% F- 4 ml	10,000	1-2 x yearly	40 mg	34 exp./incr. (12-70)
Application of gel 1% F- 8 ml	10,000	1-2 x yearly	80 mg	25 increment (17-36)
Brushing with gel 1.25% F- 6 mg F- + 3 ml saliva	2,000	1 x weekly	6 mg	? increment

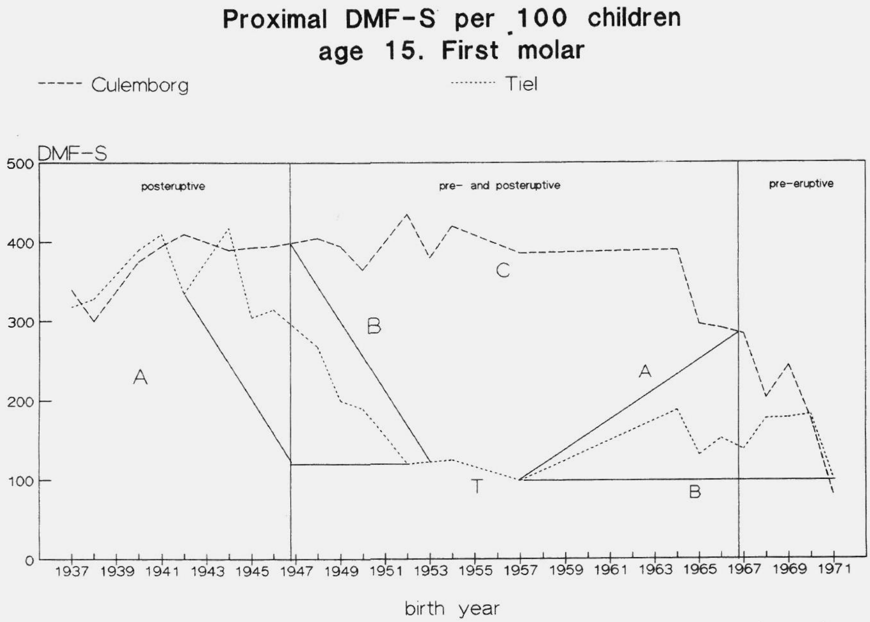


Fig. 10-1: DMF-S of proximal surfaces in the first molar in 15-year-old children from Tiel (curve T) and Culemborg (curve C) born between 1937 and 1972 and the hypothetical curves if only a posteruptive effect (curve A) or only a pre-eruptive effect (curve B) of the use of fluoridated water would be present.

In the present study, however, the use of fluoridated water only after eruption showed hardly any or no cariostatic effect at all in fissures and pits. For a topical effect on these tooth sites, which are exposed to a high carious attack, it seems that other mechanisms as attained with SnF_2 and higher F-concentrations are necessary. It is striking that by topical application of fluoride a caries reduction can be achieved which equalizes or exceeds the one caused by the use of fluoridated water.

10.6 FLUORIDE AND PLAQUE

The concentration of fluoride in the bacterial plaque is generally higher than in the mouth fluids. It ranges between one and 20 microgr/g. Jenkins and Edgar (1977) reported in scrapings from dental plaque even concentrations which ranged between 15 and 64 microgr/g. The topical use of high concentrations of fluoride, such as in mouthrinses, fluoride toothpastes and topical solutions and gels, cause a transient peak level of plaque fluoride (von der Fehr et al., 1971; Tatevossian, 1980). Jenkins and Edgar (1977) observed a mean plaque fluoride concentration of 4.5 microgr/g in 5-year-old children living in a fluoridated area (0.8 mg/l), against 3.6 in children of the same age in a low fluoride area. This difference is remarkably small.

The fluoride is partly bound, but the plaque can serve as a reservoir for release of free F^- ions as soon as the pH drops.

Waterborne fluoride does not seem to influence the plaqueflora (Kilian et al., 1979). There is no agreement whether high concentrations of fluoride, - as used in mouthrinses, topical applications and toothpastes, - reduce the level of S. mutans in the plaque by inhibiting their metabolism (Loesche et al., 1976, Woods, 1971), or not (Myers and Handelman, 1971).

In a recent experiment, studying the effect of adaptation of

S. mutans to fluoride in vitro on experimental rat caries, it was showed that the fluoride-adapted strain was less cariogenic than the parent strain (van Loveren and ten Cate, 1987).

Combining the different findings could lead to the following hypothesis about the cariostatic action of the plaque fluoride:

During posteruptive supplementation the plaque serves as a reservoir, releasing fluoride ions at a drop of the pH.

By the presence of fluoride in the period before eruption of the permanent teeth the plaqueflora adapts slowly to the fluoride and becomes less cariogenic, thus creating an environment with a lower caries attack rate. Although this is an effect of pre-eruptive fluoride use the action itself is topical.

10.7 FLUORIDE AND ENAMEL LESIONS

Groeneveld (1985) studied longitudinally the number of caries lesions including all enamel lesions in 7-18 years old children from Tiel (1 mg F^-/l since birth) and Culemborg (F^- free). Using data from Rugg-Gunn (1972), who compared approximal enamel lesions both clinically and radiographically, Groeneveld calculated the portion of the proximal enamel lesions which could not be detected on the bite-wing radiographs. If these were also included the number of lesions in the two groups was equal to each other at the age of 15 years and at the age of 18 years. In Tiel only a small retardation of the initiation of lesions at younger ages, was observed.

This means that hardly any or no effect at all of fluoride on incipient caries would exist, neither after pre- nor after posteruptive use of fluoridated water. Protection against caries by fluoride became apparent in the stages where the caries process had already reached the dentin. The reduction progressively increased with lesion depth.

The outer layers of the enamel contain the highest concentrations of fluoride. In non-fluoridated areas the concentration in the surface enamel is about 2,000 microg/g, whereas in fluoridated areas (1 mg F^-/1) it is about 3,000 microg/g (Weatherell et al., 1977). Combination of these findings with the observations by Groeneveld leads to the conclusion that the fluoride concentration in the outer layers of the enamel as a protection against caries attack of this surface enamel seems to be of minor importance. On the other hand it remains possible that after formation of an enamel lesion the higher concentrations of fluoride incorporated in the surface enamel during the pre-eruptive period reprecipitate more easily in deeper layers and then can give a protection against carious attack. A continuous supply of fluoride during this process could enhance the protective effect. From this it follows that the frequent presence of topical fluoride is more needed in surfaces which experience a higher caries attack rate. The role of the fluoride incorporated in the dentin or present at the dentino-enamel junction is hardly studied and deserves our attention.

10.8 CONCLUSION

The reduction of dentinal lesions by the use of water containing 1 mg F^-/1 either only pre-eruptively or only posteruptively, or continuously from birth (pre- and posteruptively) is inversely proportional to the caries frequency of each category of surfaces in the control group.

In all categories of surfaces the use of fluoridated water - only after eruption - shows less effect than the use - only before eruption. This difference was in proportion positively correlated to the percentage of DMF-S in a category of tooth surfaces.

The effect of fluoride consumption continuously from birth onwards (birth class 1957, examined in 1972) was about 70% (72) for the approximal surfaces, about 85% (82) for the buccal smooth surfaces and about 35% (19) for the fissures and pits (in brackets the values for the first molar).

The effect of exclusively pre-eruptive consumption could only be assessed for the first molar. This was 50%, 67% and 11% for the proximal surfaces, the smooth surfaces and the fissures and pits which is about 70%, 75% and 60% respectively of the full reduction which could be obtained in each category. The effect of exclusively posteruptive consumption in these three categories of surfaces in the first molar was 23%, 36% and 2% which is about 40%, 65% and 0-10% respectively of the full reduction which could be obtained in each category.

In order to obtain the maximal reduction in all surfaces the use of fluoridated water must be started at the onset of the calcification of a tooth. Since the first molar starts to calcify in the period around birth, consumption continuously from birth onwards gives the maximal protection. According as the use of fluoridated water is discontinued earlier after or before eruption the effect becomes gradually less.

A possible explanation for the fact that topical fluoride supplements, such as solution or gel applications, mouth rinses and toothpastes, show a greater effect on fissures and pits than the posteruptive use only of fluoridated water, might be ascribed to the far higher concentrations of fluoride in these products.

Another explanation for the effect of use before eruption besides the positive influence on crystallization might be a gradual decrease of the cariogenic activity of the bacteria in the plaque due to fluoride adaptation in this period.

The question whether the effect of controlled water fluoridation is mainly due to consumption pre- or posteruptively is not purely theoretical. Extrapolation to the use of fluoride tablets, which is an alternative way of supplementation that resembles most that of water fluoridation, implicates that also the ingestion of fluoride tablets should start shortly after birth in order to obtain an effect which resembles that of the water fluoridation.

APPENDIX A

Author and year of publication	Years of exami-nation	Age groups study - control (between brackets age at start of fluoridation)	teeth/ surfaces	method (t = teeth s = surfaces)	results (t = teeth, s = surfaces p = proximal, m = mesial d = distal, o = occlusal fissures and pits, s = smooth surfaces, v = vestibular surf. and l = lingual surfaces)	conclusion
GRAND RAPIDS - MUSKEGON						
Arnold 1957	Each year from 1945 until 1956	In each year 16 16, 15 15, - -, 8 8, 7 7, 6 6, 5 5, 4 4	all (DMFT)	The DMFT from children with a certain age from the study-group were compared with children of the same age from the base-line examination.	Children with a lower age who also started to drink fluoridated water at a lower age showed a greater reduction of dental caries The effect has been obscured by the fact that in the control town the water was fluoridated since 1951	Fluoridation will effectively reduce the dental caries experience of those persons exposed to its effect continuously from birth onward. fluoridation has a beneficial effect on teeth which are not fully formed, or are not fully maturated in the oral environment
Arnold 1962	see Arnold 1957 -					
Hayes et al. 1957	1956.	18 18	M1/ o.p.s.	116 18-year-old children from the studygroup (mean age at start of fluoridation 6.46 yr; 3.53 1st molars erupted) were matched with 116 children from the control group (mean age at start of fluoridation 6.65 yr; 3.56 1st molars erupted). Comparison between X-ray and clinical examination.	Mean caries score: Sum of the scores for 1 ind. / Number of tooth surf. at risk *all surf.: 17% reduction* proximal: 14% vestibular and lingual: 31% occlusal: 11% Results are obscured because of fluoridation in control town since 1951	----------
NEWBURGH - KINGSTON						
Ast et al. 1956	1955	6- 9 6- 9 (-3 -1) 10-12 10-12 (0- 2) 13-14 13-14 (3- 4) 16 16 (6)	all (DMFT)	The DMFT of children in an age group were compared between study- and controlgroup. The DMFT of the 1st and 2nd molar were compared at age 13, 14 and 16.	% reduction resp.: 57.9 (6-9) 53.0 (10-12) 47.9 (13-14) 40.9 (16) % reduction at age: M1 M2 13 14.7 51.2 14 13.5 44.2 16 3.9 28.7	Ingested water-borne fluoride at the optimum concentration affords selective protection for the proximal surfaces of posterior teeth in comparison with occlusal surface

Author and year of publication	Years of examination	Age groups study - control (between brackets age at start of fluoridation)	teeth/ surfaces (t = teeth s = surfaces)	method	results (t = teeth, s = surfaces p = proximal, m = mesial d = distal, o = occlusal fissures and pits, s = smooth surfaces, v = vestibular surf. and l = lingual surfaces)	conclusion
TIEL - CULEMBORG						
Backer Dirks et al. 1961a NTvT	from 1953 each year	cr.-sectionally 10-15 10-15 (3 3/4 - 8 3/4) longitudinally birth year 1946 7-11 7-11 (6 3/4) birth year 1949 7,8,9 7,8,9 (3 3/4)	all/ prox. all/ o.s. all/ o.s.	The DMFS of children in the studygroup were compared with those of children of the same age from the controlgroup	% reduction at age 10 (3 3/4) 67 11 (4 3/4) 50 12 (5 3/4) 60 13 (6 3/4) 38 14 (7 3/4) 28 15 (8 3/4) 22	Theoretically it can be expected that the greatest effect on the permanent dentition occurs in those children who are exposed to water fluoridation from birth onward, that is to say during the calcification of the first molar. As compared with the results in the USA studies caries in the proximal surfaces showed already a maximal reduction if the children were exposed from about the age of five. Fluoride which is incorporated in the outer layers of the enamel shortly before and after eruption plays an important role in the reduction of dental caries.
Backer Dirks et al. 1961b Arch		cr.-sectionally: 9,12,13 9,12,13 (3 3/4,6 3/4,7 3/4)	all/ prox.	The DMFS of children in the studygroup were compared with those of children of the same age in the controlgroup.	DMF-S/child age p. o. s.(v.) 9 C 0.9 5.7 0.5 T 0.3 4.1 0.2 12 C 3.9 10.0 0.9 T 2.0 7.8 0.3 13 C 5.2 11.4 1,0 T 3.6 9.6 0.4 M1 DMF-S/child m. d. o. s.(v.) 9 C 0.8 0.4 5.8 0.41 T 0.4 0.2 4.1 0.14 12 C 1.5 1.1 6.7 0.40 T 1.3 0.8 6.0 0.16	Three stages: 1. First consumption of fluoridated water after eruption: Reduction only at readily accessible surfaces e.g. smooth buccal surf., prox. surf. of incisors, dist. surf. of 1st molar. 2. first consumption during pre-eruptive maturation: Incorporation of F-ion in smooth surf. In occl. surf. the access is more difficult because of the presence of fissures. 3. first consumption during matrix formation and calcification: In all surf. equal uptake of F-ion, hence larger reduction than in stage 2 except for vestibular surfaces. Pits and fissures are the only surfaces which show an extra reduction of early consumption.

<table>
<tr><th>Author and year of publication</th><th>Years of exami-nation</th><th>Age groups study - control (between brackets age at start of fluoridation)</th><th>teeth/ surfaces (t - teeth s - surfaces)</th><th>method</th><th>results (t - teeth, s - surfaces p - proximal, m - mesial d - distal, o - occlusal fissures and pits, s - smooth surfaces, v - vestibular surf. and l - lingual surfaces)</th><th>conclusion</th></tr>
<tr><td>Backer Dirks et al. 1963
BDJ</td><td></td><td>11,12,13, id.
14,15.
(2 3/4, 3 3/4,
4 3/4, 5 3/4,
6 3/4)</td><td>all/
prox.</td><td>The DMF-S of children in the studygroup were were compared with those of children of the same age in the controlgroup.</td><td>% reduction at age
11 (2 3/4) 60
12 (3 3/4) 65
13 (4 3/4) 54
14 (5 3/4) 55
15 (6 3/4) 36</td><td>...if fluoridation starts at the age of 4 or 5 the effect on the number of approximal lesions is still about maximal. As the tooth crowns are to a large extent already calcified at this age, it does not seem necessary that the extra fluoride is present during the entire tooth formation.</td></tr>
<tr><td></td><td></td><td>7,12,14,15 id.
(-1/4,3 3/4,
6 3/4, 7 3/4)</td><td>all/
o.</td><td></td><td>% reduction at age
7 (-1/4) 62
12 (3 3/4) 26
14 (6 3/4) 22
15 (6 3/4) 12</td><td>...In order to have an important effect on fissure caries, the extra fluoride must be present in an early stage of tooth formation.</td></tr>
<tr><td></td><td></td><td>15, 12 15, 12
(3 3/4, 6 3/4)</td><td>M1/
o.p.s.</td><td></td><td>% reduction (M1) at age
(surfaces) o. m. d. s(v).
15 (6 3/4) 8 13 32 42
12 (3 3/4) 14 59 82 72</td><td>(concerning the first molar of children born in 1949) ...the impression is given that the effect for all surfaces-except the occlusal - is at its maximum (see also Table I)</td></tr>
<tr><td>Kwant et al.
1969

Kwant et al.
1972
and
Kwant et al.
1973</td><td></td><td>cr.-sectionally: 11-15 11-15
(15 3/4 - 2 3/4)</td><td>all/
prox.</td><td>The DMF proximal surfaces of children in the studygroup were compared with those of children from the same birth class in the controlgroup</td><td>(1973) %reduction in children examined in:

'52 (15 3/4) 0 '59 (8 3/4) 34
'53 (14 3/4) 0 '61 (6 3/4) 51
'55 (12 3/4) 0 '63 (4 3/4) 63
'57 (10 3/4) 27 '65 (2 3/4) 72
'68 (-1/4) 75</td><td>(1969) Since not all children examined in 1965 consumed fluoridated water from birth onward it can be expected that the effect will increase.
(1973) ...it may be assumed that the maximum caries reducing effect of water-fluoridation has now been reached (in the group examined in 1968).</td></tr>
<tr><td></td><td></td><td>longitudinally
7-15 7-15
(-1 1/4 - 7 3/4)</td><td>M1/
pit</td><td>The DMF surfaces of the M1 in children from the studygroup were compared with those of the controlgroup</td><td>(1973) % reduction
<table>
<tr><th></th><th colspan="5">birth year</th></tr>
<tr><th>age</th><th>'45,</th><th>'46,</th><th>'49,</th><th>'53,</th><th>'54</th></tr>
<tr><td>7</td><td></td><td></td><td>27</td><td>65</td><td>55</td></tr>
<tr><td>8</td><td></td><td>28</td><td>30</td><td></td><td></td></tr>
<tr><td>9</td><td>14</td><td></td><td>29</td><td>50</td><td>54</td></tr>
<tr><td>10</td><td></td><td>14</td><td>24</td><td></td><td></td></tr>
<tr><td>11</td><td>13</td><td></td><td>19</td><td>37</td><td>44</td></tr>
<tr><td>12</td><td></td><td>9</td><td>13</td><td></td><td></td></tr>
<tr><td>13</td><td>9</td><td></td><td>13</td><td>27</td><td>35</td></tr>
<tr><td>14</td><td></td><td>7</td><td>12.5</td><td></td><td></td></tr>
<tr><td>15</td><td>8.5</td><td></td><td>11</td><td>22.5</td><td>30</td></tr>
</table></td><td>(1969) A few years of additional pre-eruptive consumption of fluoride (1st molar of birth class 1949) inhibits the occlusal caries This effect gets lost with an increasing age.
(1973) ...to achieve an important preventative effect on the formation of pit and fissure cavities, fluoride is necessary from an early stage in enamel formation.</td></tr>
<tr><td></td><td></td><td>longitudinally
7-15 7-15
(-1 1/4 - 7 3/4)</td><td>all/
s(v).</td><td>The DMF smooth surfaces in children from the studygroup were compared with those of the controlgroup</td><td>(1973) % reduction
<table>
<tr><th></th><th colspan="5">birth year</th></tr>
<tr><th>age</th><th>'45,</th><th>'46,</th><th>'49,</th><th>'53,</th><th>'54</th></tr>
<tr><td>7</td><td></td><td></td><td></td><td>90.5</td><td>91.5</td></tr>
<tr><td>8</td><td></td><td></td><td>69.5</td><td></td><td></td></tr>
<tr><td>9</td><td></td><td></td><td>55</td><td>89.5</td><td>87</td></tr>
<tr><td>10</td><td></td><td></td><td>66</td><td></td><td></td></tr>
<tr><td>11</td><td></td><td></td><td>74</td><td>91</td><td>86</td></tr>
<tr><td>12</td><td></td><td>70.5</td><td>71.5</td><td></td><td></td></tr>
<tr><td>13</td><td>66</td><td></td><td>75.5</td><td>90.5</td><td></td></tr>
<tr><td>14</td><td></td><td>68.5</td><td>77</td><td></td><td></td></tr>
<tr><td>15</td><td>66</td><td></td><td>76</td><td></td><td></td></tr>
</table></td><td>(1973) It can be seen from the Culemborg figures that the number of smooth surface lesions has increased annually...
...Water-fluoridation ...appears to have a significant posteruptive caries reducing effect on these tooth surfaces.</td></tr>
</table>

Author and year of publication	Years of *exami-nation*	Age groups study - control *(between brackets* age at start of fluoridation)	teeth/ surfaces (t = teeth s = surfaces)	method	results (t = teeth, s = surfaces *p = proximal, m = mesial* d = distal, o = occlusal fissures and pits, s = smooth surfaces, v = vestibular surf. and l = lingual surfaces)	conclusion
HASTINGS						
Ludwig and Pearce 1963 Ludwig 1965 and Ludwig 1971	1954, 1963, 1964, 1970,	6-16 (0) 6-16 (-2.5 - 7.5) 6-16 (-4 - 6) 13,14,15,16 (-3,-2,-1,0)	all/o. p.s.	The DMFS of children examined in 1963, 1964, and 1970 were compared with those of children with the same age from the base-line examination	% reduction DMFS (see below)	----------

% reduction DMFS

	examination year 1963 surface			examination year 1964 surface		
age	o.	p.	s.	o.	p.	s.
6	81	60	100	86	100	100
7	69	69	100	77	77	75
8	62	68	78	68	85	100
9	51	72	95	53	73	95
10	50	73	95	49	69	90
11	44	73	90	42	72	83
12	31	62	83	40	58	89
13	36	56	85	34	54	87
14	27	52	83	33	54	83
15	30	46	82	38	58	84
16	15	33	71	30	47	70

	examination year 1970 surface		
age	o.	p.	s.
13 (-3)	46	76	91
14 (-2)	42	74	89
15 (-1)	39	73	87
16 (0)	34	67	88

Conclusion: (1971) the effectiveness of fluoridation in New Zealand children to some extent diminishes with age.

Author and year of publication	Years of examination	Age groups	teeth/ surfaces	method	results	conclusion
BRANDON						
Connor and Harwood 1963	1955 (1956) (1957) (1958) 1960 1962	6-8, 9-11, 12-14 6-8, 9-11, 12-14 (1-3) (4-6) (7-9) 6-8, 9-11, 12-14 (-1-1)(2-4) (5-7)	all/t M1,	The DMFT in children examined in 1960 and 1962 were compared with those in children examined in 1955	DMF (see below)	Another survey will probably be carried out in 1966 when the maximum benefit in dental caries prevalence, brought about by the consumption of water with the fluoride content adjusted to 1 ppm, should be evident in the 6-8 and 9-11 age groups.

DMF

age group	year	permanent teeth all	M1	I1/I2 sup.
6 - 8	1955	1.95	1.91	-
	1960	0.77	0.79	-
	1962	0.51	0.48	-
9 -11	1955	4.57	3.18	0.69
	1960	2.87	2.40	0.17
	1962	1.95	1.85	0.06
12 -14	1955	7.39	3.20	1.14
	1960	5.80	3.33	0.86
	1962	4.77	3.13	0.51

11.0 SUMMARY

In this thesis it is studied to which extent the use of fluoridated water before and after eruption contributes to the reduction of dental caries.

After the introduction, which contains the statement of the problem and the implementation for other fluoride vehicles, chapter 2.0 contains a review of the literature which discusses the effect of pre- and posteruptive use of fluoridated water or which contains relevant information about the subject. It appears from this review that first it was thought that fluoridated water should only be used at a younger age (until eight years) and that the protection would be permanent. This is not surprising since apparently a parallel was drawn with fluorosis (mottled enamel), a deficiency of the enamel caused by the presence of too high a concentration of fluoride during the formation and calcification period of the teeth. Only later it was discovered that also the use of fluoride after eruption of the teeth can cause a reduction of dental caries. In the more recent literature the effect of posteruptive use of fluoride is accentuated, whereas a minor role is attributed to pre-eruptive supplementation.

In chapter 3.0 a method is described to assess the effect of pre- as well as posteruptive use of fluoridated water on dental caries experience. Such a study has to fulfil several basic conditions. The most important of these is that it has to contain a study and a control group, due to its long duration. A retrospective control group is unsuitable, because a possible fluctuation of the number of DMF surfaces cannot be observed. The method is described as follows:

At the start and at the discontinuation of the water fluoridation the caries data of the three categories of surfaces (proximal surfaces, free smooth surfaces, fissures and pits) are

collected in children who were born in successive years. The data are then classified in such a way that at start of the fluoridation teeth with the same increasing period of the use of fluoride after, and later also before eruption, are put in one group. In each subsequent group of surfaces the use of fluoridated water is one year longer.

At the discontinuation of the water fluoridation the teeth in a group classified according to this method, have the same decreasing period of use of fluoridated water, first before and after eruption and later only before eruption.

By comparison of the thus classified groups of DMF indices in study and control group, the groups erupting at the start or at the discontinuation of the fluoridation indicate the contribution of post- and pre-eruptive use of fluoridated water respectively to the total caries reduction.

In the second part of this chapter it is studied to which extent this method can be applied to the data which were available from the water fluoridation experiment Tiel (1mg F^-/l from 01.03.1953 to 25.12.1973) - Culemborg (no fluoride).

For the proximal surfaces enough data were available. For the free smooth surfaces and for the fissure and pit caries the method cannot be applied at the start of the water fluoridation, because the data were only available for a few examination years. Starting six years after the discontinuation of the water fluoridation the data were collected for all categories of surfaces.

In chapter 4.0 some demographical data and information about the availability of dental care in the two towns is presented. It appears from these data that with respect to the groups examined in this study no change in comparability between the two towns could be observed during the study period. In chapter 5.0 the distribution of the time of eruption of the permanent teeth is investigated in the two towns using unpublished data of groups which were cross-sectionally examined in the period 1955 - 1959. The cumulative frequency distribution, constructed with the aid of these data shows that in Tiel teeth erupt about three months earlier than in Culemborg. This difference is stable for all age groups, irrespective of the age at the start of the use of fluoridated water. Besides, in another study it was demonstrated that this difference was already present in 1952. The median age of eruption is on average six months lower in girls than in boys, which is according to what is known from the literature.

In chapter 6.0 the caries data of the proximal surfaces in 15-year-old children examined in the period 1952 - 1972, - thus at the start of the fluoridation, - are presented and discussed. The DMF-S of the separate teeth were classified according to the method described in chapter 3.0. Then the DMF-S of the different teeth which received fluoridated water during an equal period, - first posteruptively only and later also pre-eruptively, - are added. The percentage less DMF in Tiel with respect to Culemborg in the group which received fluoridated water since eruption represents the effect of posteruptive use only. This percentage is approximately 30% for the proximal surfaces, whereas the total reduction is approximately 70%.

In order to study a possible influence of the difference in period between eruption and examination of the different teeth the proximal DMF-S of some teeth erupting between the age of six and the age of eight years (central and lateral upper incisor and first molar) were assessed at the age of 11 years. If, after classification according to the time of eruption and the start of the fluoridation, the DMF index at the age of 11 years was compared with that of the same teeth at the age of 15 years, it appears that the maximal reduction at the age of 11 years is greater than at the age of 15 years, but the reduction by only posteruptive use of fluoridated water is smaller. Comparison of the DMF-S in this group of teeth (M1, I1sup., I2sup.) at the age of 11 years (group A) with the DMF-S at the age of 15 years of a group of teeth erupting at about the age of 11 years (group B), so that the period between eruption and examination is similar in the two groups, revealed that in group A, which had the higher DMF index of the two groups at the start of the study, the relative contribution of posteruptive use of fluoridated water only was smaller.

For the free smooth surfaces, discussed in chapter 7.0 the caries data were only available for a restricted number of birth classes. After classification according to the relation between the time of eruption and the start of the water fluoridation in Tiel, as far as this was possible, the results show that the use of fluoridated water during the posterupive period, starting about two years after eruption, causes a caries reduction of 50% in the first molar. The maximal reduction in this category of surfaces is about 85%.

For the caries in the fissures and pits discussed in chapter 8.0 the data were available of the same birth classes as for the buccal smooth surfaces. After classification in the same way as for the buccal smooth surfaces it appeared that only pre-eruptive use caused a reduction of dental caries. In order to get information on the caries experience in the fissures and pits over a longer period the filled occlusal surfaces of premolars and molars were scored from bite-wing radiographs which were available for the examination of the proximal surfaces. By employing this method the diagnosis of the local dentist is used. The results for the effect of the pre- and posteruptive use of fluoridated water are similar to those of the clinical data.

In chapter 9.0 the effect of the use of fluoridated water is studied during a decreasing post- and pre-eruptive period and later a decreasing pre-eruptive period using data collected after the discontinuation of the fluoridation in 1973. One of the most striking features is the decrease of the DMF index in Culemborg in the period of examination 1972 - 1986. At the end of this period the DMF index in Culemborg reached a level that was lower than that in Tiel in the years when the maximal effect of the fluoridation was reached. In the proximal and free smooth surfaces in Tiel on which fluoride causes an important reduction of dental caries a small increase can be observed, whereas the occlusal caries, on which fluoride has a small caries reducing effect, shows a small decrease. Apparently also other factors such as another way of use of fluoride have played a role in the decrease of the DMF index in Culemborg.

In chapter 10.0 de data from chapter 6.0 - 9.0 are discussed and the results of this study are compared with those from other studies. The pre-eruptive effect of fluoride is explained by the hypothesis that the use before the eruption results in a better formation of crystals in the enamel which are less soluble. The quantity of fluoride incorporated in the enamel seems not to be of importance.

Posteruptively, by the availability of low concentrations of fluoride during the periods that the pH drops, a less soluble form of apatite is precipitated.

In surfaces which are exposed to a low carious attack the sum of the percentages reducton of only pre- and only posteruptive use is greater than the percentage reduction when fluoridated water is used continuously since birth. However, in fissures and pits which are exposed to a strong carious attack, this sum is much less than the maximal percentage reduction. In the latter the continuous use from before the start of the calcification until at least a few years after eruption is of great importance.

12.0 SAMENVATTING

In dit proefschrift is nagegaan in welke mate het gebruik van gefluorideerd drinkwater voor en na de tanddoorbraak een bijdrage leveren aan de reductie van de cariës.

Na de Introductie, waarin de probleemstelling wordt omschreven, vindt in hoofdstuk 2.0 een analyse plaats van de literatuur, waarin het effect van het gebruik van gefluorideerd drinkwater gedurende de pre- en posteruptieve periode is onderzocht, of waarin voor dit onderwerp relevante gegevens voorhanden zijn. Uit deze analyse blijkt, dat men aanvankelijk meende dat fluoride slechts op jongere leeftijd (tot 8 jaar) gebruikt diende te worden en dat de hierdoor veroorzaakte cariës reductie een blijvend effect was. Dit is niet verwonderlijk, omdat men blijkbaar een parallel trok met fluorosis (mottled enamel), een glazuurafwijking die wordt veroorzaakt door een te hoge fluorideconcentratie gedurende de matrixvorming en calcificatieperiode van de gebitselementen. Pas later vond men dat er ook een cariësreductie kon plaatsvinden onder invloed van het gebruik van gefluorideerd drinkwater na de tanddoorbraak. In de recentere literatuur is vooral het accent gelegd op de posteruptieve werking van fluoride, waarbij aan het pre-eruptieve effect een ondergeschikte rol wordt toegekend.

In hoofdstuk 3.0 wordt een methode beschreven om zowel het pre- als het posteruptieve effect van gefluorideerd drinkwater op de cariës te bepalen. Een dergelijke studie zal aan een aantal basisvoorwaarden dienen te voldoen, waarvan de belangrijkste is dat gezien de lange duur van het onderzoek zowel een test- als een controlegroep noodzakelijk is. Een retrospectieve controlegroep is onvoldoende, omdat eventuele schommelingen in het aantal DMF vlakken welke zich gedurende de onderzoeksperiode kunnen voordoen dan niet waargenomen kunnen worden. De methode bestaat hieruit dat zowel bij de start als bij de beëindiging van de fluoridering de cariësgegevens van de afzonderlijke elementen en van de drie soorten vlakken (proximale vlakken, vrije gladde vlakken en fissuren) worden verzameld bij kinderen die in opeenvolgende jaren zijn geboren. De gegevens worden daarna zodanig gerangschikt dat bij de start alle elementen die gedurende eenzelfde periode na, en later ook voor de doorbraak fluoride toegediend hebben gekregen in een groep tezamen zijn gebracht. In elke opeenvolgende groep is het fluoridegebruik een jaar langer. Bij de beëindiging van de fluoridering hebben na deze rangschikking de elementen in een groep gedurende eenzelfde periode, aanvankelijk voor en na de doorbraak en later in afnemende mate alleen voor de doorbraak, fluoride gekregen. Door de DMF indices van controle- en proefgebied van de diverse groepen elementen, die op de hierboven geschetste wijze gerangschikt zijn, per groep met elkaar te vergelijken, kan men de bijdrage van de pre- en posteruptieve toediening aan de totale cariësreductie berekenen. In het tweede deel van dit hoofdstuk wordt nagegaan in hoeverre deze methode toepasbaar is op het materiaal dat voorhanden is van de fluorideringsstudie in Tiel (1 mg F^-/l van 01.03.1953 t/m 24.12.1973) en Culemborg (geen fluoride). Van de proximale vlakken blijken voldoende cariës gegevens voorhanden te zijn. Voor de pit en fissuurcariës en bij de vrije gladde vlakken echter is de methode echter niet zonder meer toepasbaar.

In hoofdstuk 4.0 zijn een aantal gegevens betreffende de demografische situatie en betreffende de beschikbaarheid van tandheelkundige zorg bijeengebracht. Uit deze gegevens blijkt dat voor de in deze studie onderzochte groepen beide steden vergelijkbaar zijn gebleven gedurende het onderzoek.

In hoofdstuk 5.0 wordt de spreiding van de doorbraaktijd van de blijvende gebitselementen in beide plaatsen gepresenteerd aan de hand van reeds voorhanden zijnde basisgegevens van transversaal onderzochte groepen, welke waren verzameld in de periode 1955 - 1959. Uit de cumulatieve frequentiekrommen, die met behulp van deze gegevens geconstrueerd konden worden blijkt, dat de elementen in Tiel gemiddeld drie maanden eerder doorbreken. Dit verschil is constant voor de diverse leeftijdsgroepen, ongeacht de leeftijd waarop zij voor het eerst gefluorideerd water gebruikten en was ook reeds aanwezig in onderzoeksjaar 1952. De gemiddelde doorbraakleeftijd is bij meisjes gemiddeld zes maanden lager dan bij jongens, hetgeen overeenkomt met wat uit de literatuur bekend is.

In hoofdstuk 6.0 worden de cariësgegevens van de proximale vlakken bij 15-jarigen in de onderzoeksperiode 1952 - 1972, dus startend bij de aanvang van de fluoridering, gepresenteerd en besproken. De DMF-S van de afzonderlijke elementen werden gerangschikt volgens de methode beschreven in hoofdstuk 3.0. De DMF-S van de verschillende elementen die gedurende een gelijke periode,- aanvankelijk alleen posteruptief en later ook pre-eruptief,- gefluorideerd water hebben gekregen, worden bij elkaar opgeteld. Het percentage reductie van de DMF-S in Tiel t.o.v. Culemborg in de groep, die vanaf de doorbraak gefluorideerd water heeft gebruikt geeft het maximale posteruptieve effect aan. Dit is voor de proximale vlakken ongeveer 45%, terwijl de maximaal te bereiken totale reductie rond de 70% ligt. Om een mogelijke invloed van het verschil in periode tussen doorbraak en onderzoek voor de verschillende gebitselementen te bestuderen zijn van een aantal elementen die tussen de leeftijd van 6 en 8 jaar doorbreken (1e en 2de bovensnijtand, 1e molaar) de proximale DMF-S op 11-jarige leeftijd gebruikt. Indien, na rangschikking volgens het pre- en posteruptieve fluoride gebruik, deze DMF-S index wordt vergeleken met die van dezelfde elementen op 15-jarige leeftijd, dan blijkt dat de maximale reductie op 11-jarige leeftijd groter is dan op de leeftijd van 15 jaar, maar dat de reductie door alleen posteruptief gebruik op 11-jarige leeftijd lager ligt. Vergelijking van de DMF-S van deze groep elementen op 11 jarige leeftijd (groep A) met de DMF-S van een groep die rond de leeftijd van 11 jaar doorbreken en op 15-jarige leeftijd zijn onderzocht (groep B), zodat voor beide groepen de periode tussen doorbraak en onderzoek vergelijkbaar is, toont dat in groep A, die bij aanvang van de studie het hoogste aantal DMF-S bezat de relatieve bijdrage van uitsluitend posteruptieve toediening relatief het laagst was.

Voor de vrije vlakken, besproken in hoofdstuk 7.0, waren de cariësgegevens slechts voor een beperkt aantal geboorteklassen voorhanden. Nadat deze, voorzover mogelijk, waren gerangschikt naar het gebruik van gefluorideerd water voor- en na de doorbraak, lieten de resultaten zien dat in deze vlakken gebruik van gefluorideerd water gedurende de (niet gehele) posteruptieve fase alleen, in de eerste molaar een cariësreductie van 36% kan geven. De maximale reductie ligt bij deze vlakken rond de 85%.

Van de pit en fissuurcariës, besproken in hoofdstuk 8.0, waren slechts van dezelfde jaarklassen als bij de vrije gladde vlakken de cariësgegevens voorhanden. Nadat deze op dezelfde wijze als de vrije gladde vlakken waren gerangschikt, bleek alleen pre-eruptief gebruik een cariësremming te veroorzaken. Teneinde over een langere onderzoeksperiode voor de start van de drinkwaterfluoridering een inzicht te verkrijgen in het verloop van de occlusale cariës werden de occlusale vullingen geregistreerd vanaf de bite-wing foto's die voor het onderzoek van de proximale vlakken voorhanden waren. Met deze methode wordt in wezen gebruik gemaakt van de door de tandarts gestelde diagnose. Wat betreft het effect van pre- en posteruptief gebruik kwamen de resultaten overeen met die van de klinische gegevens.

In hoofdstuk 9.0 wordt het effect van het gebruik van gefluorideerd water gedurende de pre-eruptieve periode bestudeerd aan de hand van gegevens verkregen na de beëindiging van de fluoridering in 1973. Het meest opvallende aan de resultaten is hier de sterke cariësdaling die in Culemborg is opgetreden in de onderzoeksperiode 1972 - 1986, waarbij uiteindelijk een niveau wordt bereikt dat lager is dan dat in Tiel ten tijde van het maximale effect van de drinkwaterfluoridering. In Tiel kan in de proximale en vrije vlakken, waarop fluoride een sterk cariësremmend effect uitoefent, een geringe stijging van de cariës worden waargenomen, terwijl de occlusale cariës, waarop fluoride een veel geringer effect heeft, een lichte daling vertoont. Blijkbaar hebben ook andere factoren, zoals mogelijk een ander fluoridegebruik, aan de cariësdaling in Culemborg ten grondslag gelegen.

In hoofdstuk 10.0 worden de gegevens uit de hoofdstukken 6.0 t/m 9.0 gezamenlijk besproken en worden de resultaten van dit onderzoek vergeleken met die van andere studies. Het pre-eruptief effect kan worden verklaard aan de hand van de hypothese dat het gebruik van fluoride voor de doorbraak leidt tot een betere kristalstructuur van het glazuurmineraal, dat daardoor, met name in de diepere lagen, minder oplosbaar zal zijn. Het aantal initiele laesies wordt door gefluorideerd water niet of nauwelijks geremd. De hoeveelheid pre-eruptief in het glazuur geincorporeerde fluoride schijnt niet van belang. Bij posteruptief gebruik van lage concentraties zorgt fluoride dat er bij een daling van de pH een minder oplosbare vorm van apatiet kan ontstaan. De som van het effect van alleen pre- en alleen posteruptief gebruik is veel groter dan het totale effect bij continu gebruik vanaf de geboorte in de vrije gladde vlakken, waarvan slechts een gering percentage carieuze aantastingen vertoont. Deze som is iets groter dan het totale effect in de proximale vlakken, waar de aantastingsgraad beduidend hoger is. In de fissuren en pits, die de hoogste aantastingsgraad vertonen, is deze som echter veel kleiner dan het totale effect. Bij deze laatste categorie vlakken is continu gebruik tot zeker een aantal jaren na de doorbraak van groot belang.

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CURRICULUM VITAE

De schrijver van dit proefschrift werd geboren op 26 maart 1948 te Schijndel.

Hij behaalde in 1966 het eindexamen Gymnasium B aan het Aloysiuscollege te 's Gravenhage.

Het Doctoraalexamen tandheelkunde werd behaald in 1971 aan de Rijksuniversiteit te Utrecht en het Tandartsexamen in 1972 aan dezelfde universiteit.

Van september 1972 t/m december 1973 was hij ter vervulling van zijn militaire dienstplicht als tandarts werkzaam bij de Koninklijke Luchtmacht.

Sinds december 1973 is hij als algemeen practicus gevestigd te Voorburg.

In 1977 en 1978 was hij werkzaam als part-time instructeur op de afdelingen volledige prothese en conserverende tandheelkunde van het Tandheelkundig Instituut van de Rijksuniversiteit te Gent (B).

Sedert maart 1979 is hij als part-time medewerker verbonden aan de Sector Tand en Mondziekten NIPG-TNO (Sectorcoördinator Dr. A. Groeneveld).

Hij is tevens werkzaam als uitvoerend toonkunstenaar.

In 1974 behaalde hij het Staatsexamen Muziekonderwijs Orgel B. Hij studeerde o.m. bij Marie-Claire Alain te Parijs en bij Bernard Bartelink te Haarlem, onder wiens leiding hij in 1981 het diploma Uitvoerend Musicus voor orgel behaalde aan het Sweelinck Conservatorium te Amsterdam. Hij behoorde tot de prijswinnaars op diverse internationale orgelconcoursen, geeft concerten en verzorgde een aantal publicaties over orgelhistorische onderwerpen en over uitvoeringspraktijk.

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