

MARCEL STEINER  
GIORGIO MENGHINI  
THOMAS M. MARTHALER  
THOMAS IMFELD

Clinic for Preventive Dentistry,  
Periodontology and Cariology,  
Centre for Dental Medicine,  
University of Zurich

#### Corresponding author

Dr. med. dent. G. Menghini  
Zentrum für Zahn-, Mund- und  
Kieferheilkunde der Universität  
Zürich  
Plattenstrasse 11  
8032 Zürich  
Tel. 044 634 34 88  
Fax 044 634 43 01  
E-mail:  
giorgio.menghini@zsmk.uzh.ch  
Schweiz Monatsschr Zahnmed 120:  
1084–1094 (2010)  
Accepted for publication:  
6 September 2010

# Changes in dental caries in Zurich school-children over a period of 45 years

Keywords: caries decline, causes, school-children

**Summary** In 16 rural communities of the Canton of Zurich, school-children of all age groups participated in dental examinations conducted at intervals of 4 years since 1963/64. The same standardised method was used throughout the entire period. This study documents the caries experience over a period of 45 years. From 1964 to 2009, the DM\*FT per 14-year-old child fell from 12.50 to 1.31, corresponding to a caries reduction of 90%. The caries experience in 8-, 10- and 12-year-olds decreased by 90% to 92%.

From 1964 to 2009, the "Significant Caries Index" (the mean DM\*FT in the third of 12-year-olds with the highest DM\*FT values) fell from 13.09 to 2.20, corresponding to a caries reduction of 83%. The observed caries decline was unexpectedly high. The effect of fluorides may explain a caries reduction of roughly 50%. A large part of the decline, however, remains unexplained. Possible causes are discussed in this paper.

## Introduction

Dental prophylaxis was introduced in schools in the Canton of Zurich, in 1963. To record the success of the measures introduced, children in 16 rural communities were dentally examined at intervals of 4 years, using a standardised method. The original plan for a comparison of test communities with preventive measures and control communities without preventive measures had to be abandoned, given the decision of school authorities in the control communities to join the prophylaxis programme. The investigations in the 16 communities have continued right up to the present day.

This study documents the changes in caries experience in the school-children of these communities over the course of 45 years.

## Materials and methods

### Selection of communities and school-children

At the beginning of the study, 16 communities of the Canton of Zurich with high demographic stability were selected

(MARTHALER 1972). These communities are distributed across the entire area of the Canton of Zurich (Fig. 1). Only in 2000 and 2009, one community (respectively) declined to participate in the survey.

In the smaller communities, all school-children were summoned for examination. In the larger communities, a randomised selection was carried out in each case. Children chosen to participate were again called upon for further examinations after 4 and 8 years, provided they were still of school age.

The present analysis is based on school-children in which both clinical and radiological examinations had been conducted. Absenteeism in the schools and objection to radiological examinations (particularly following the Chernobyl nuclear power plant accident in 1986) negatively impacted on the response rate. On average, it was possible to clinically examine approx. 90% of the children selected. Between 65% and 94% of the clinically examined participants were X-rayed between the years 1984 and 2009. The children excluded on the basis of unavailable X-ray images exhibited a slightly lower caries experience (DFS, pits and fissures) (STEINER ET AL. 1995).

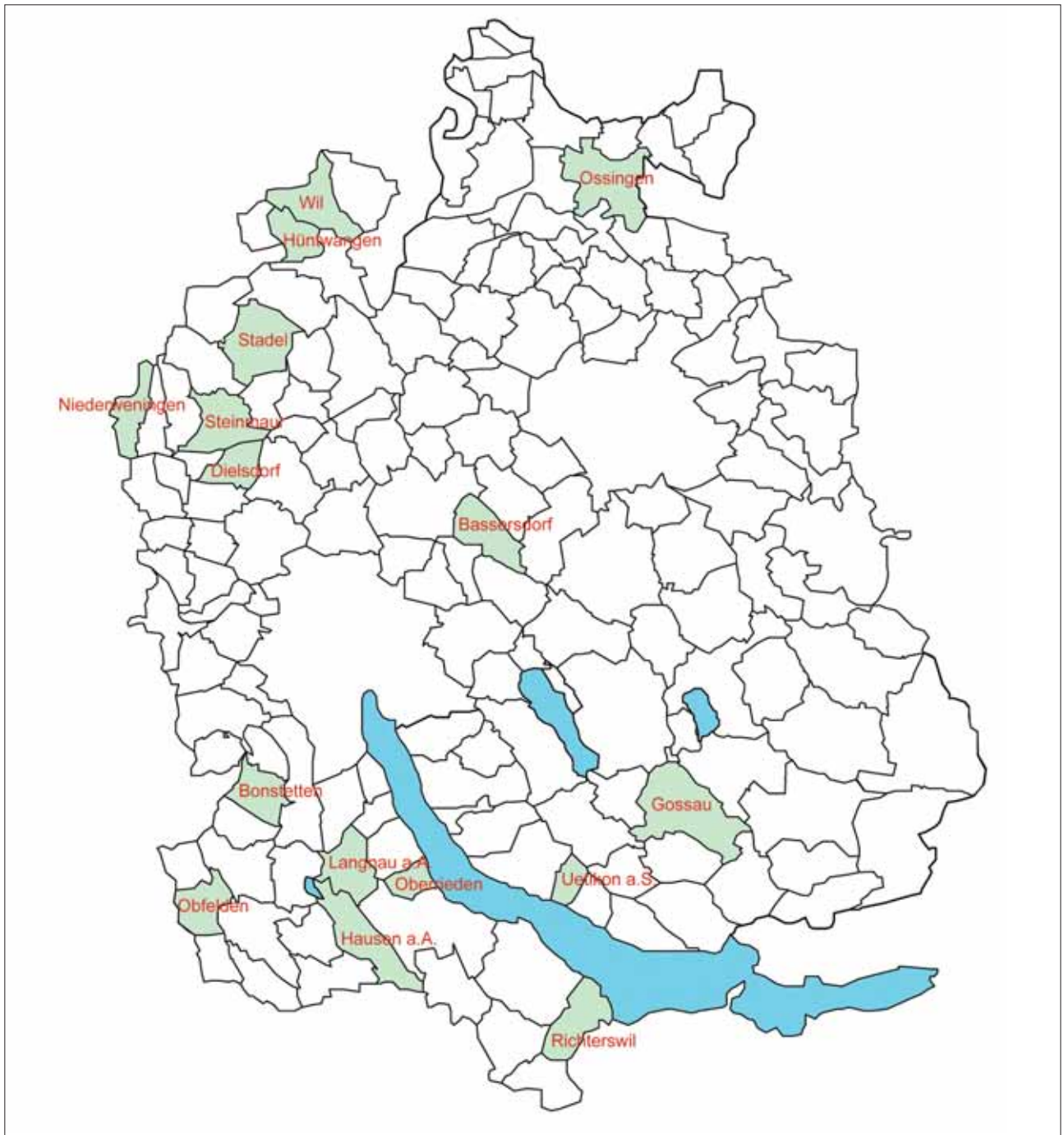


Fig. 1 The 16 communities studied in the Canton of Zurich

The present analysis is based on Swiss and non-Swiss children resident in Switzerland from preschool age (5 years). The small number of children who had arrived as immigrants when they were over the age of 5 years were excluded from the analysis. Those excluded (2% to 4%) exhibited a substantially higher caries experience (MARTHALER ET AL. 1996a).

#### Examination dates

Dental examinations in the individual communities were generally conducted in autumn, at 4-year intervals, on one day. The scheduled examinations for all 16 communities were generally distributed over 2 years. The average examination date was in the second year: 1963/64 (=1964), 1967/68 (=1968),

1971/72 (=1972), 1975/76 (=1976), 1979/80 (=1980), 1983/84 (=1984), 1987/88 (=1988), 1991/92 (=1992), 1995/96 (=1996), 2000 (=2000), 2004/05 (=2005) and 2008/09 (=2009).

#### Standardised examination

The examination methodology has been described on several previous occasions (MARTHALER 1966, MENGHINI ET AL. 1998, MARTHALER ET AL. 2005). Several important points are reiterated here.

From 1964 to 1992, findings concerned one side of the dentition only, i.e. only the right side was examined. Children were examined at a rate of approximately 220 children per day, by two dentists working in parallel. From 1996, both sides of

the dentition were examined. From 1996, children were examined at a rate of approximately 140 children per day. Analyses indicated that one-sided assessments produce almost identical results to assessments of both sides (MARTHALER ET AL. 2005).

A total of 34 (one-sided) and 68 (both sides) caries predilection sites were clinically assessed in the permanent dentition. A further 12 or 24 approximal surfaces (7 mesial to 4 distal), respectively, were assessed radiologically using bitewing X-ray images.

In the deciduous dentition, 10 (one-sided) or 20 (both sides) deciduous teeth, respectively, were clinically assessed and 6 or 12 approximal surfaces on deciduous molars (V distal to IV distal), respectively, were assessed radiologically.

The examinations were conducted within the school buildings using portable chairs. The chairs were equipped with compressed air equipment and simple dental lamps (1964 and 1968), and later fibre optic lamps (from 1972). Clinical assessment was largely visual, with the aid of a dental flat mirror. Sickie probes were used only in cases of doubt to confirm cavitation or to remove plaque and food residues.

From 1964 to 1992, a conventional bitewing X-ray image (film) was taken of the right side of the dentition. From 1996, digital bitewing X-ray images (Digora) were taken of both sides of the dentition.

From 1996, the bitewing X-ray images were also used to correct obvious errors in clinical evaluation (overlooked tooth-coloured fillings, fillings assessed as sealings in the fissures of permanent molars and premolars, overlooked tooth-coloured fillings in deciduous molars).

Prior to the examination, children brushed their teeth in groups under the guidance of an oral health instructor.

### Caries indices

To characterise caries experience, the following counts were made:

- MT, first molars = number of first molars missing/MT, other teeth = number of other teeth missing/DT = number of carious teeth/FT = number of filled teeth/DMFT = number of carious, missing and filled teeth/DM\*FT = number of carious, missing (first molars only) and filled teeth
- DS = number of carious predilection sites/FS = number of filled predilection sites/DFS = number of carious and filled predilection sites
- D<sub>1-2</sub>S on pits and fissures of molars and premolars = number of discoloured pits and fissures/D<sub>1-2</sub>S on approximal surfaces of molars and premolars = number of surfaces with radiolucencies in the enamel only/D<sub>1-2</sub>S on free smooth surfaces of molars = number of surfaces with white spots/D<sub>1-2</sub>S on anterior tooth surfaces = number of surfaces with white spots
- m\*t = number of missing deciduous molars/dft = number of carious and filled deciduous teeth/dm\*ft = number of carious, missing (deciduous molars only) and filled deciduous teeth
- ms = number of missing approximal surfaces on deciduous molars/ds = number of carious approximal surfaces on deciduous molars/fs = number of filled approximal surfaces on deciduous molars/dmfs = number of carious, missing and filled approximal surfaces on deciduous molars/d<sub>1-2</sub>s = number of carious approximal surfaces on deciduous molars (radiolucencies in the enamel only)
- The "D" and "d" components comprise lesions with cavitation (clinical evaluation) and radiolucencies in the dentin (radiological evaluation). The "D<sub>1-2</sub>" and "d<sub>1-2</sub>" components

comprise only initial lesions without cavitation and radiolucencies in the enamel.

### Examiners

The clinical examinations were performed by the authors TM, MS and GM, together with 23 other specially trained dentists. The radiological assessments were performed by three examiners.

### Reliability

The reliability (reproducibility) of the clinical measurements was determined since 1996 by means of the intraclass correlation coefficient (KINGMAN 1997), comparing the findings of several pairs of examiners. The mean intraclass correlation coefficient (ICC) for four pairs of examiners in 7-year-olds was 0.97 for dm\*ft. The mean ICC for eight pairs of examiners in 12-year-olds was 0.92 for DM\*FT and 0.93 for DFS.

It was also possible to determine the intraclass coefficient for the radiological assessment by repeating the assessment. The mean ICC (over several observation years) for dmfs on approximal surfaces of deciduous molars in 7-year-olds was 0.99. The mean ICC for DFS on approximal surfaces of molars and premolars in 12-year-olds was 0.95, and the ICC for D<sub>1-2</sub>S was 0.81.

### Statistical analysis

Mean values per child were calculated for the caries indices specified above. The mean values for the findings from one side of the dentition (1964 to 1992) were duplicated to make the values directly comparable with the findings from both sides of the dentition (1996 to 2009).

The mean caries experience in the permanent dentition was calculated as for 8-year-olds (7.50 to 9.49), 10-year-olds (9.50 to 11.49), 12-year-olds (11.50 to 13.49) and 14-year-olds (13.50 to 15.49). The caries experience in the deciduous dentition was calculated for 7-year-olds (7.00 to 7.99).

The "Significant Caries Index" (SiC) was calculated for 12-year-olds (11.50 to 13.49) (BRATTHALL 2000). For this purpose the sample was ordered according to DM\*FT values. The mean DM\*FT was then calculated in the third of participants with the highest values.

## Results

### Changes in dental caries in the permanent dentition

Changes in caries experience in the permanent dentition are shown in Tables I, II, III and IV for 8-, 10-, 12- and 14-year-olds. The means are based on 241 to 988 children, depending on age and examination year. The mean ages were close to 8.5, 10.5, 12.5 and 14.5 respectively in all examination years.

Changes in caries experience (DM\*FT) are depicted in Figure 2. A steady caries decline was observed in all age groups up to about 1996. Thereafter, the caries experience stabilised at a low level.

From 1964 to 2009, the DM\*FT index per 14-year-old child fell from 12.50 to 1.31 (Tab. IV), corresponding to a caries reduction of 90%. The caries reduction in 8-, 10- and 12-year-olds was 90% to 92% (Tab. I, II and III).

The number of missing first molars in 14-year-olds fell from 0.86 to 0.01 (Tab. IV).

From 1964 to 2009, the DFS (all predilection sites) per 14-year-old child fell from 22.69 to 1.63. This corresponds to a caries reduction of 93%. The caries reduction in 8-, 10- and 12-year-olds was 93% to 94%.

Tab. I Caries experience (mean values) in the permanent dentition of 8-year-old Zurich school-children (1964 to 2009)

Year N	1964 486	1968 768	1972 974	1976 988	1980 734	1984 562	1988 502	1992 522	1996 437	2000 430	2005 422	2009 428	Caries Decline
Teeth (28)													
MT, first molars	0.09	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	
MT, other teeth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	
DT	1.22	0.73	0.60	0.78	0.47	0.25	0.15	0.12	0.07	0.07	0.04	0.05	
FT	1.28	1.27	0.96	0.61	0.52	0.36	0.33	0.26	0.20	0.21	0.16	0.16	
DMFT	2.59	2.03	1.57	1.39	0.99	0.61	0.48	0.39	0.28	0.28	0.21	0.21	
DM*FT	2.59	2.03	1.57	1.39	0.99	0.61	0.48	0.39	0.28	0.28	0.20	0.21	92%
Predilection sites (92)													
DS	1.79	0.90	0.73	0.89	0.53	0.27	0.17	0.15	0.09	0.08	0.05	0.06	
FS	2.25	1.99	1.54	1.03	0.79	0.51	0.41	0.35	0.26	0.25	0.22	0.21	
DFS	4.04	2.88	2.28	1.93	1.32	0.78	0.58	0.50	0.36	0.33	0.26	0.27	93%
FS/DFS	56%	69%	68%	53%	60%	65%	71%	70%	72%	76%	85%	78%	
Pits and fissures of molars and premolars (22)													
DS	1.05	0.57	0.39	0.38	0.25	0.18	0.14	0.13	0.07	0.07	0.03	0.05	
FS	1.88	1.82	1.45	0.96	0.75	0.49	0.40	0.32	0.24	0.24	0.20	0.20	
DFS	2.93	2.39	1.84	1.34	1.00	0.67	0.54	0.46	0.31	0.30	0.23	0.25	91%
D <sub>1-2</sub> S	2.92	3.09	2.37	2.40	1.95	1.41	1.35	1.19	1.16	1.10	0.93	0.93	68%
Sealed	0.00	0.00	0.01	0.01	0.20	0.15	0.32	0.62	0.96	0.73	0.68	0.59	
Approximal surfaces of molars and premolars (24)													
DS	0.27	0.24	0.30	0.49	0.26	0.08	0.02	0.01	0.02	0.02	0.01	0.00	
FS	0.18	0.11	0.06	0.05	0.02	0.01	0.00	0.01	0.02	0.01	0.00	0.00	
DFS	0.45	0.36	0.37	0.54	0.28	0.09	0.02	0.02	0.04	0.02	0.02	0.01	98%
D <sub>1-2</sub> S	2.18	1.92	1.44	1.21	0.94	0.63	0.47	0.22	0.20	0.29	0.15	0.15	93%
Free smooth surfaces of molars (16)													
DS	0.27	0.05	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	
FS	0.13	0.04	0.03	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.01	
DFS	0.40	0.09	0.06	0.04	0.04	0.01	0.01	0.02	0.01	0.00	0.02	0.01	98%
D <sub>1-2</sub> S	2.49	2.19	1.02	0.97	0.57	0.37	0.25	0.25	0.12	0.10	0.07	0.04	98%
Anterior tooth surfaces (30)													
DS	0.19	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
FS	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	
DFS	0.26	0.05	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	100%
D <sub>1-2</sub> S	0.72	0.41	0.14	0.14	0.07	0.02	0.03	0.03	0.01	0.02	0.01	0.02	97%

FS/DFS expresses the level of dental care.

From 1964 to 2009, the DFS in pits and fissures fell by 87% to 91%, depending on the age group.

The DFS on other predilection sites (approximal surfaces of molars and premolars, free smooth surfaces of molars, anterior tooth surfaces) fell by 96% to 100%, depending on predilection site and age group.

From 1964 to 2009, the D<sub>1-2</sub>S in pits and fissures fell by 40% to 68%, depending on age group.

The D<sub>1-2</sub>S on other predilection sites fell by 81% to 99%, depending on predilection site and age group.

#### Changes of the "Significant Caries Index"

The changes of the SiC are shown in Table V. From 1964 to 2009, the SiC fell from 13.09 to 2.20, corresponding to a caries reduction of 83%.

#### Changes in dental caries in the deciduous dentition

Changes in caries experience (dm\*ft) in the deciduous dentition are depicted in Figure 3 for 7-year-olds. A steady caries

decline was observed up until 1988. A slight increase was then observed between 1988 and 2000, followed by a subsequent decrease to the level of 1988 once again.

From 1964 to 2009, the dm\*ft per 7-year-old child fell from 7.60 to 1.57 (Tab. VI), corresponding to a caries reduction of 79%.

The number of missing deciduous molars fell from 0.75 to 0.07.

From 1964 to 2009, the dmfs on approximal surfaces of deciduous molars fell from 8.37 to 1.71, corresponding to a caries reduction of 80%.

#### Sealings in the permanent dentition

From 1996 on, 1 to 2 pits/fissures (of 22) were sealed (Tab. I, II, III and IV).

#### Level of care in the permanent dentition

More than two thirds of the carious lesions had been filled in practically all examination years and age groups. (See level of dental care, FS/DFS in Tab. I, II, III, IV.)

Tab. II Caries experience (mean values) in the permanent dentition of 10-year-old Zurich school-children (1964 to 2009)

Year N	1964 487	1968 712	1972 823	1976 950	1980 742	1984 508	1988 476	1992 501	1996 395	2000 399	2005 372	2009 390	Caries Decline
Teeth (28)													
MT, first molars	0.18	0.12	0.06	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	
MT, other teeth	0.04	0.04	0.09	0.03	0.05	0.07	0.03	0.02	0.03	0.01	0.00	0.02	
DT	1.76	1.02	0.94	0.97	0.73	0.42	0.17	0.10	0.13	0.08	0.06	0.07	
FT	2.86	2.31	1.93	1.34	1.04	0.76	0.67	0.53	0.46	0.45	0.39	0.38	
DMFT	4.84	3.49	3.02	2.36	1.82	1.26	0.87	0.65	0.61	0.54	0.45	0.49	
DM*FT	4.80	3.45	2.93	2.33	1.77	1.19	0.84	0.63	0.58	0.53	0.45	0.47	90%
Predilection sites (92)													
DS	2.49	1.23	1.15	1.12	0.82	0.45	0.17	0.12	0.16	0.09	0.07	0.08	
FS	5.88	4.10	3.48	2.30	1.73	1.09	0.96	0.69	0.56	0.56	0.48	0.46	
DFS	8.37	5.33	4.64	3.42	2.56	1.54	1.13	0.82	0.72	0.65	0.55	0.55	93%
FS/DFS	70%	77%	75%	67%	68%	71%	85%	84%	78%	86%	87%	84%	
Pits and fissures of molars and premolars (22)													
DS	1.07	0.54	0.39	0.36	0.33	0.19	0.07	0.09	0.10	0.05	0.05	0.05	
FS	3.64	3.31	3.07	2.12	1.59	1.01	0.88	0.62	0.51	0.53	0.45	0.42	
DFS	4.71	3.86	3.46	2.48	1.93	1.20	0.95	0.71	0.61	0.57	0.50	0.47	90%
D <sub>1-2</sub> S	2.99	3.37	2.68	2.99	2.61	2.52	2.05	1.58	1.75	1.55	1.32	1.19	60%
Sealed	0.00	0.01	0.01	0.05	0.13	0.30	0.42	0.94	1.18	1.20	1.15	1.01	
Approximal surfaces of molars and premolars (24)													
DS	0.63	0.47	0.67	0.71	0.46	0.23	0.09	0.02	0.05	0.03	0.02	0.03	
FS	1.13	0.54	0.28	0.12	0.09	0.06	0.06	0.05	0.03	0.03	0.01	0.03	
DFS	1.76	1.02	0.95	0.82	0.54	0.28	0.16	0.08	0.08	0.06	0.03	0.05	97%
D <sub>1-2</sub> S	3.22	3.06	2.66	2.60	2.26	1.20	0.72	0.55	0.61	0.55	0.45	0.29	91%
Free smooth surfaces of molars (16)													
DS	0.28	0.07	0.03	0.02	0.03	0.01	0.00	0.00	0.01	0.01	0.00	0.00	
FS	0.39	0.12	0.07	0.03	0.04	0.01	0.01	0.02	0.02	0.01	0.01	0.01	
DFS	0.67	0.18	0.10	0.05	0.07	0.02	0.01	0.02	0.03	0.01	0.01	0.01	99%
D <sub>1-2</sub> S	3.19	2.94	1.55	1.26	0.74	0.59	0.37	0.35	0.29	0.19	0.09	0.04	99%
Anterior tooth surfaces (30)													
DS	0.52	0.14	0.06	0.04	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.00	
FS	0.71	0.13	0.06	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	
DFS	1.23	0.27	0.13	0.07	0.02	0.03	0.01	0.02	0.01	0.01	0.01	0.02	98%
D <sub>1-2</sub> S	1.54	0.84	0.43	0.39	0.20	0.20	0.07	0.05	0.06	0.06	0.02	0.01	99%

FS/DFS expresses the level of dental care.

### Level of care in the deciduous dentition

From 1964 to 2009, the level of care in deciduous dentition increased continuously (Tab. VI). In 1964, only 11% of the carious approximal surfaces had been filled; in 2009, this figure had increased to 44%.

## Discussion

### Changes in caries experience

The changes in caries experience are strictly speaking only representative for the 16 Zurich communities. However, the changes in other regions of Switzerland are similar (MENGHINI & STEINER 2006).

In the permanent dentition, a steady caries decline was observed from 1964 to 1996. The caries experience stabilised at a low level thereafter (Fig. 2). In the deciduous dentition, a steady caries decline was observed only up until 1988 (Fig. 3). No plausible explanation could be found for the slight increase up until 2000 and the subsequent relapse to the level of 1988.

The caries decline in school-children has reached an unexpectedly high level, as shown by the example of the caries experience on the approximal surfaces of permanent molars and premolars of 14-year-olds (Tab. IV). In 1964, 7.2 lesions per child were present, while in 2009, this figure had fallen to only 0.3 lesions. This represents an enormous benefit, since approximal fillings in the posterior teeth in particular have a limited lifespan (SJÖGREN & HALLING 2002) and may promote loss of attachment (BROADBENT ET AL. 2006).

It is noteworthy that the caries experience also declined by 83% (Tab. V) in the group most susceptible to caries (SiC in 12-year-olds). Additional preventive measures for school-children at high caries risk have consequently no priority.

### To what extent can the observed caries decline be explained?

To discuss this question, we will examine the decline of DFS in 14-year-olds (Tab. VII). In 1964, 14-year-olds had 22.7 lesions, while in 2009, this had decreased to just 1.6 lesions.



Tab. III Caries experience (mean values) in the permanent dentition of 12-year-old Zurich school-children (1964 to 2009)

Year N	1964 474	1968 677	1972 736	1976 775	1980 758	1984 542	1988 452	1992 399	1996 292	2000 328	2005 276	2009 295	Caries Decline
Teeth (28)													
MT, first molars	0.52	0.31	0.11	0.04	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.00	
MT, other teeth	0.16	0.25	0.35	0.26	0.23	0.16	0.21	0.11	0.10	0.06	0.05	0.05	
DT	2.97	1.64	1.65	1.42	1.23	0.65	0.31	0.18	0.14	0.15	0.14	0.10	
FT	4.46	3.68	3.20	2.18	1.75	1.56	1.27	0.95	0.69	0.72	0.71	0.66	
DMFT	8.10	5.88	5.30	3.90	3.22	2.39	1.80	1.24	0.93	0.96	0.91	0.82	
DM*FT	7.94	5.64	4.96	3.64	2.99	2.23	1.58	1.13	0.84	0.90	0.86	0.77	90%
Predilection sites (92)													
DS	3.79	1.96	1.87	1.59	1.38	0.74	0.35	0.20	0.16	0.16	0.16	0.12	
FS	9.88	7.10	6.06	4.06	3.05	2.42	1.78	1.30	0.89	0.96	0.93	0.75	
DFS	13.67	9.07	7.93	5.66	4.43	3.16	2.12	1.50	1.05	1.12	1.09	0.87	94%
FS/DFS	72%	78%	76%	72%	69%	77%	84%	87%	85%	86%	85%	86%	
Pits and fissures of molars and premolars (22)													
DS	1.30	0.62	0.60	0.46	0.44	0.35	0.14	0.08	0.07	0.08	0.08	0.05	
FS	5.34	4.97	4.89	3.48	2.72	2.07	1.57	1.15	0.81	0.86	0.83	0.72	
DFS	6.65	5.59	5.49	3.93	3.16	2.42	1.70	1.23	0.87	0.94	0.91	0.77	88%
D <sub>1-2</sub> S	5.05	5.24	4.30	4.81	4.17	4.11	3.26	2.57	2.82	2.95	2.54	2.26	55%
Sealed	0.00	0.01	0.02	0.04	0.12	0.37	0.40	0.87	1.06	1.59	1.12	1.66	
Approximal surfaces of molars and premolars (24)													
DS	1.16	0.94	1.06	1.04	0.89	0.34	0.17	0.09	0.08	0.07	0.06	0.06	
FS	2.21	1.36	0.85	0.45	0.24	0.25	0.17	0.10	0.07	0.08	0.09	0.03	
DFS	3.37	2.30	1.91	1.49	1.13	0.59	0.34	0.19	0.14	0.16	0.15	0.09	97%
D <sub>1-2</sub> S	5.89	5.88	5.30	6.20	5.51	2.63	1.77	0.98	0.68	0.66	0.72	0.58	90%
Free smooth surfaces of molars (16)													
DS	0.48	0.15	0.06	0.05	0.02	0.02	0.02	0.02	0.02	0.00	0.01	0.01	
FS	0.63	0.25	0.13	0.06	0.04	0.06	0.02	0.04	0.02	0.02	0.01	0.00	
DFS	1.11	0.40	0.18	0.11	0.07	0.08	0.04	0.06	0.04	0.02	0.02	0.01	99%
D <sub>1-2</sub> S	4.16	3.63	2.46	1.69	1.23	1.03	0.64	0.42	0.33	0.39	0.13	0.14	97%
Anterior tooth surfaces (30)													
DS	0.85	0.25	0.15	0.05	0.03	0.03	0.02	0.01	0.00	0.01	0.01	0.00	
FS	1.70	0.53	0.20	0.08	0.04	0.05	0.03	0.01	0.00	0.00	0.00	0.00	
DFS	2.54	0.78	0.35	0.13	0.07	0.08	0.04	0.03	0.00	0.01	0.01	0.00	100%
D <sub>1-2</sub> S	2.21	1.07	0.62	0.58	0.34	0.35	0.21	0.11	0.12	0.11	0.06	0.12	95%

FS/DFS expresses the level of dental care.

### Fluorides as a reason for the caries decline

The children examined in 1964 had scarcely come into contact with fluoride as a prophylactic measure compared with children examined in 2009. The use of fluoride as a caries prophylaxis began only in the early 1960s.

In the years 1960–63, three fluoride toothpastes whose effectiveness had been verified were launched on the market (MARTHALER 1975). From 1963, fluoride salt with a low fluoride content (90 ppm F) was used by the majority of the population in the 16 communities (MARTHALER 1972). Around 13% of the families used fluoride tablets in 1963/64 (MARTHALER & SCHRÖDER 1966). Since 1962–1964, toothbrushing exercises using fluoride preparations have been carried out four to six times a year in the schools of the 16 communities (MARTHALER 1972).

Today (2009), according to information provided by the parents, 96% of the children use fluoride toothpastes and 81% consume fluoridated salt with a high fluoride content (250 ppm F) at home. Around half of the children additionally use a fluoride gel and/or a fluoride mouthwash at home. Ac-

ording to the parents, 13% of the children took fluoride tablets in the first five years of their lives. Some of the children would have received a fluoride varnish application from their dentist. In the schools of the 16 communities, toothbrushing exercises using fluoride preparations continue to be held four to six times a year, as they have been since 1962–1964. From 1980–1984 to 1990–1994, the annual per-head consumption of toothpaste in Switzerland increased from 370 grams to 420 grams (MARTHALER ET AL. 1996b).

In a systematic review (MARINHO ET AL. 2003), the caries-preventive effect of fluoride toothpastes has been estimated at 21% to 28% (Tab. VII). The effect of locally applied fluoride preparations in addition to fluoride toothpastes has been estimated at 2% to 17% (MARINHO ET AL. 2004). MARTHALER (2005) estimates the preventive effect of fluoride salt with 250 ppm fluoride to be 21% to 24%. The cumulated effect of all these fluoridation measures has been calculated using a formula given by MARTHALER (1983), whereby it has been assumed that the applied measures act independently of one another. With

Tab. IV Caries experience (mean values) in the permanent dentition of 14-year-old Zurich school-children (1964 to 2009)

Year N	1964 451	1968 501	1972 685	1976 640	1980 715	1984 569	1988 488	1992 357	1996 241	2000 299	2005 285	2009 271	Caries Decline
Teeth (28)													
MT, first molars	0.86	0.48	0.24	0.10	0.05	0.03	0.02	0.03	0.01	0.01	0.01	0.01	
MT, other teeth	0.34	0.44	0.59	0.47	0.35	0.32	0.31	0.39	0.28	0.25	0.12	0.21	
DT	4.96	2.40	2.46	2.17	1.77	1.21	0.64	0.26	0.27	0.30	0.25	0.23	
FT	6.67	6.82	4.82	3.74	2.94	2.53	2.00	1.61	1.25	0.95	1.26	1.06	
DMFT	12.84	10.14	8.11	6.48	5.11	4.09	2.98	2.29	1.80	1.52	1.64	1.52	
DM*FT	12.50	9.70	7.52	6.01	4.76	3.77	2.67	1.90	1.53	1.27	1.52	1.31	90%
Predilection sites (92)													
DS	6.44	2.92	2.83	2.47	2.03	1.38	0.72	0.28	0.29	0.38	0.28	0.26	
FS	16.25	14.12	9.67	7.27	5.20	4.20	3.01	2.21	1.67	1.28	1.71	1.37	
DFS	22.69	17.04	12.49	9.74	7.23	5.58	3.73	2.49	1.95	1.66	1.99	1.63	93%
FS/DFS	72%	83%	77%	75%	72%	75%	81%	89%	86%	77%	86%	84%	
Pits and fissures of molars and premolars (22)													
DS	1.68	0.61	0.66	0.58	0.62	0.40	0.19	0.15	0.14	0.14	0.08	0.07	
FS	7.77	8.20	6.93	5.83	4.31	3.49	2.52	1.86	1.43	1.14	1.39	1.19	
DFS	9.45	8.81	7.58	6.41	4.93	3.89	2.71	2.01	1.57	1.28	1.47	1.25	87%
D <sub>1-2</sub> S	5.63	5.73	5.27	5.42	5.67	5.93	5.64	4.21	4.41	4.18	3.40	3.40	40%
Sealed	0.00	0.00	0.01	0.01	0.09	0.22	0.42	0.76	1.18	2.01	1.46	1.75	
Approximal surfaces of molars and premolars (24)													
DS	2.76	1.82	1.85	1.71	1.33	0.88	0.49	0.11	0.14	0.19	0.16	0.15	
FS	4.47	3.63	1.92	1.17	0.66	0.54	0.36	0.24	0.19	0.13	0.29	0.16	
DFS	7.23	5.45	3.77	2.88	1.99	1.42	0.85	0.35	0.33	0.32	0.45	0.32	96%
D <sub>1-2</sub> S	7.66	7.76	8.26	9.22	8.30	5.10	4.09	2.15	1.37	1.44	1.52	1.44	81%
Free smooth surfaces of molars (16)													
DS	0.71	0.21	0.10	0.06	0.03	0.03	0.02	0.01	0.00	0.03	0.01	0.01	
FS	1.04	0.55	0.20	0.12	0.09	0.09	0.07	0.05	0.03	0.00	0.02	0.01	
DFS	1.75	0.77	0.30	0.18	0.12	0.12	0.09	0.06	0.03	0.03	0.03	0.02	99%
D <sub>1-2</sub> S	5.56	5.52	3.69	2.52	2.01	1.89	1.28	0.90	0.75	0.59	0.26	0.27	95%
Anterior tooth surfaces (30)													
DS	1.29	0.27	0.23	0.12	0.06	0.08	0.03	0.01	0.01	0.01	0.03	0.03	
FS	2.97	1.74	0.62	0.15	0.14	0.07	0.05	0.06	0.02	0.01	0.01	0.01	
DFS	4.25	2.01	0.85	0.26	0.20	0.15	0.08	0.07	0.02	0.02	0.05	0.04	99%
D <sub>1-2</sub> S	3.19	2.14	0.84	0.89	0.68	0.53	0.43	0.45	0.12	0.36	0.15	0.33	90%

FS/DFS expresses the level of dental care.

a calculated overall (rounded) preventive effect of 39% to 55%, there is a reduction of carious lesions from 22.7 down to 10.3 to 13.9 (Tab. VII).

#### Other possible reasons for the caries decline

What are the possible reasons for the observed further decline from 10.3 to 13.9 down to 1.6 lesions, i.e. a (rounded) reduction of 84% to 88%? Other factors must be responsible for this – accordingly, other possible factors are listed in Table VII. The reasons listed have partly already been discussed in connection with the observed caries reduction in industrialised countries (BRATTHALL ET AL. 1996).

A reduction in plaque levels through improved oral hygiene (Factor 1) in the observation period (1964 to 2009) can be derived from the gingivitis data (results not shown). A reduction of plaque levels per se (without the contribution of fluoride) as a result of normal oral hygiene on the part of the patient would appear to have only a minor influence on caries prevalence. According to BELLINI ET AL. (1981), the effect is

mainly limited to the free smooth surfaces and the anterior teeth.

Changes in the plaque quality (Factor 2) are conceivable: a high level of mutans streptococci (>1 million bacteria per ml of saliva) was found significantly less frequently in Swiss school-children (14%) than in foreign school-children (26%), as indicated by the unpublished results of a caries epidemiological study (MENGHINI ET AL. 1998). In a Swedish study, a significant reduction of mutans counts in saliva was observed in school-children (KLOCK & KRASSE 1987).

In addition to toothbrushing exercises with fluoride preparations four to six times a year, the children of the 16 communities of the Canton of Zurich were also given dietary counseling. It is conceivable that the quantity or frequency of sugar consumption (Factor 3) was reduced, although there is no firm evidence of this. Since 1950, the amount of sugar (sucrose) consumed in Switzerland has remained at a constantly high level (40 to 44 kilograms per head per year [MARTHALER ET AL. 1994, Swiss Federal Statistical Office 2009]).

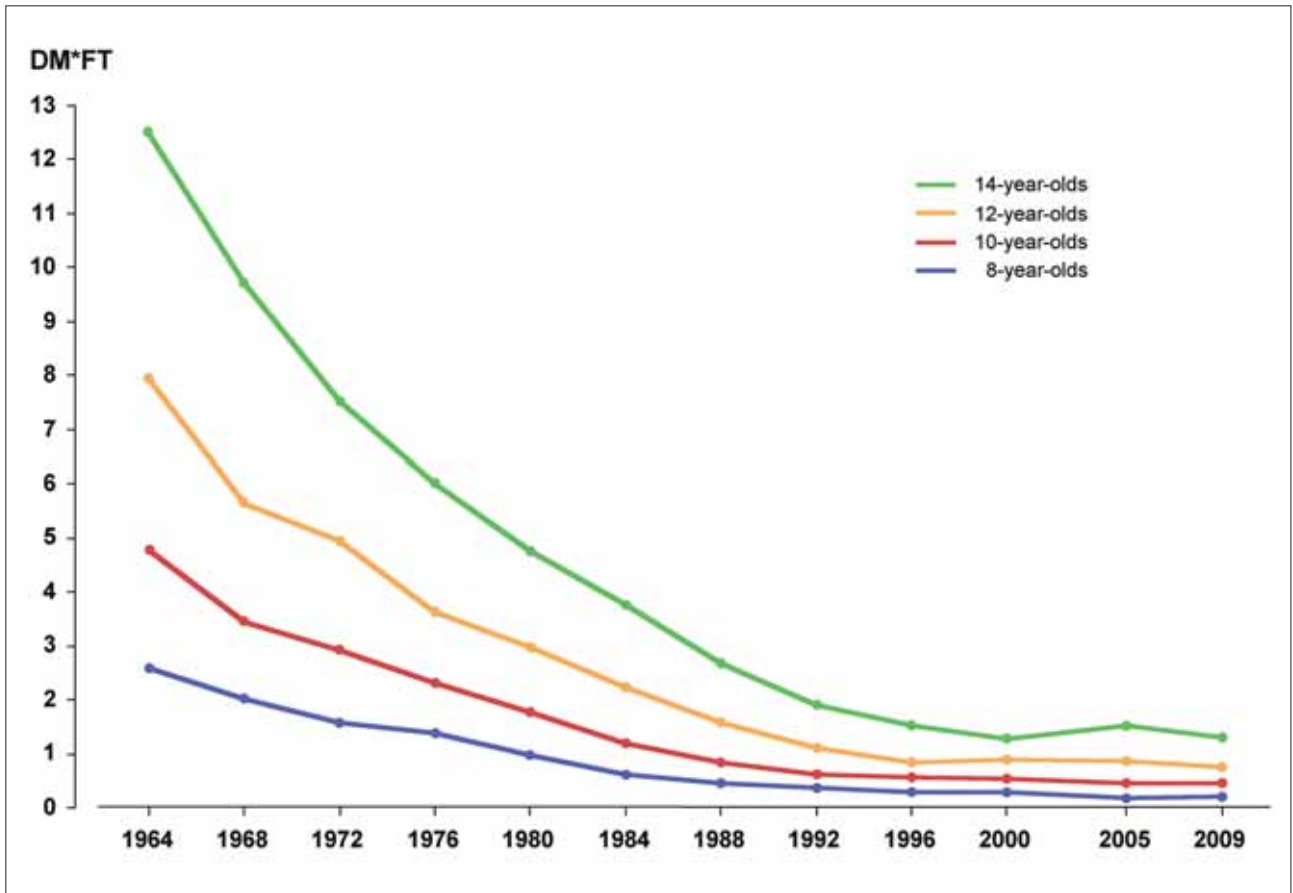


Fig.2 Mean DM\*FT values per school-child

Tab.V "Significant Caries Index" (SiC) in the permanent dentition of 12-year-old Zurich school-children (1964 to 2009)

	Year	1964	1968	1972	1976	1980	1984	1988	1992	1996	2000	2005	2009	Caries Decline
	N	158	226	246	259	253	181	151	133	98	110	92	99	
Teeth (28)	SiC	13.09	9.31	8.30	6.36	5.79	5.06	3.93	3.20	2.38	2.46	2.34	2.20	83%

Tab.VI Caries experience (mean values) in the deciduous dentition of 7-year-old Zurich school-children (1964 to 2009)

	Year	1964	1968	1972	1976	1980	1984	1988	1992	1996	2000	2005	2009	Caries Decline
	N	155	351	529	500	338	261	275	281	216	194	205	173	
Deciduous teeth (20)	m*t	0.75	0.65	0.40	0.17	0.11	0.04	0.03	0.01	0.13	0.18	0.10	0.07	
	dft	6.85	5.77	4.74	3.39	2.18	1.72	1.57	1.54	1.73	2.27	1.50	1.50	
	dm*ft	7.60	6.42	5.14	3.56	2.28	1.75	1.60	1.55	1.87	2.45	1.60	1.57	79%
Approximal surfaces of deciduous molars (12)	ms	1.15	0.96	0.58	0.24	0.15	0.07	0.03	0.01	0.19	0.22	0.15	0.09	
	ds	6.32	5.29	4.13	3.44	2.86	1.88	1.20	1.35	1.31	1.27	0.73	0.86	
	fs	0.90	1.26	1.22	0.96	0.62	0.65	0.61	0.55	0.55	0.79	0.59	0.76	
	dmfs	8.37	7.52	5.93	4.64	3.64	2.60	1.84	1.91	2.04	2.27	1.47	1.71	80%
	d <sub>1-2</sub> s	1.72	2.42	2.26	2.83	2.86	1.52	1.30	1.12	0.81	1.00	0.72	0.80	
	fs/dmfs	11%	17%	21%	21%	17%	25%	33%	29%	27%	35%	40%	44%	

fs/dmfs expresses the level of dental care.



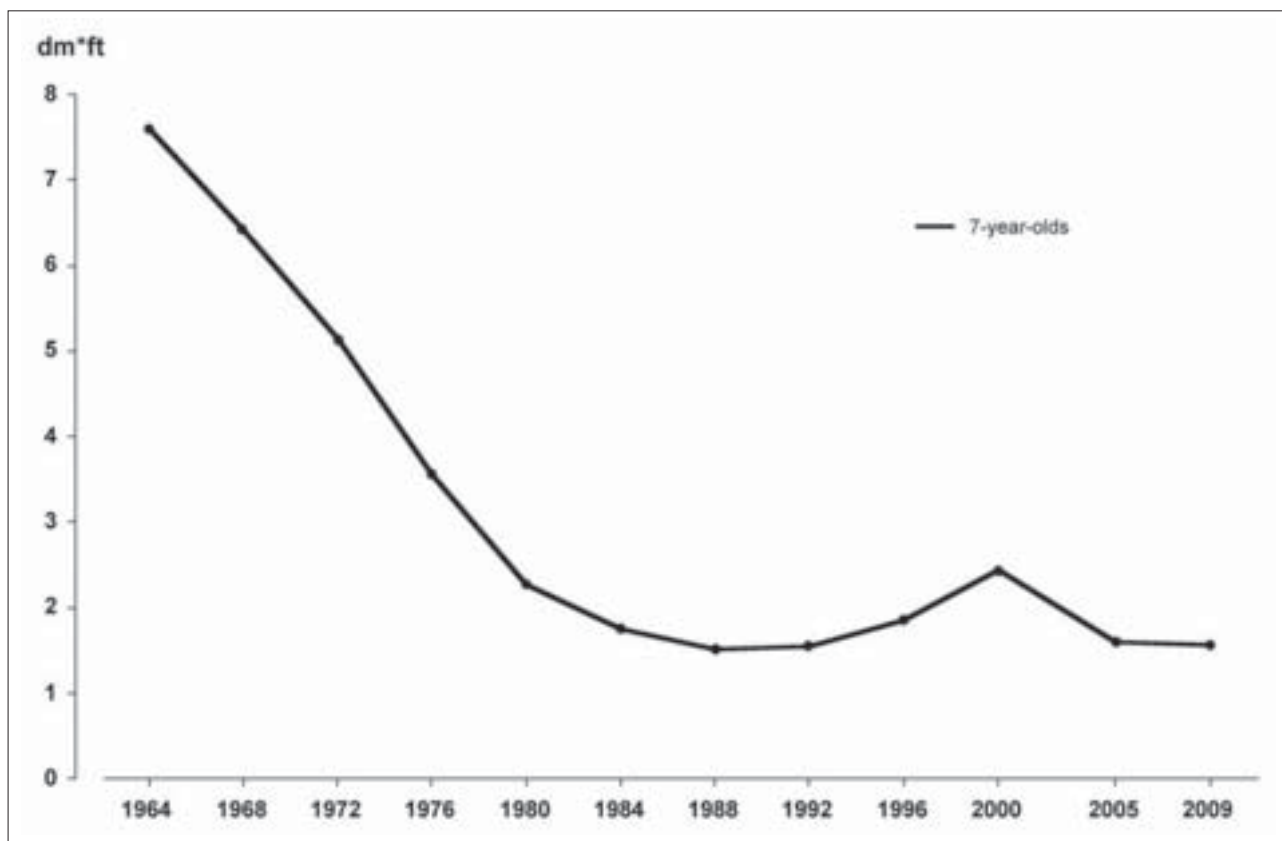


Fig. 3 Mean dm\*ft values per school-child

Tab. VII To what extent can the observed caries decline be explained?

Factors	Reduction	DFS	References
F-toothpastes	21%–28% <sup>b</sup>	22.7 <sup>a</sup>	MARINHO ET AL. 2003
F-gel/F-mouthwash/F-varnish in addition to F-toothpaste	2%–17% <sup>b</sup>		MARINHO ET AL. 2004
F-salt	21%–24% <sup>c</sup>		MARTHALER 2005
F-factors cumulated	39%–55%	10.3–13.9	
Other factors:			
1 Mechanical reduction of plaque quantity	Small		
2 Changes in plaque quality (number and virulence of cariogenic bacteria)	?		
3 Reduction in quantity or frequency of sugar consumption	?		
4 Sugar-free confectionary products	?		
5 Sugar-free chewing gum	Small		
6 Fissure sealants	Small		
7 Antibiotics	?		
8 Preservatives	?		
9 Polyphenols	?		
10 Unidentified factors	?		
11 Synergistic effects	?		
Other factors cumulated	84%–88%	1.6 <sup>a</sup>	

<sup>a</sup> The mean DFS in 14-year-old school-children in the Canton of Zurich decreased from 22.7 in 1964 to 1.6 in 2009.  
<sup>b</sup> 95% confidence interval  
<sup>c</sup> Estimation based on different assumptions

The proportion of sugar-free confectionary products (Factor 4) on the market in Switzerland is around 20% (BISCOUISSE 2010). This can have contributed to a decline in caries only if the consumption of sugar-containing confectionary products has sunk as result; however, there is no firm evidence of the latter.

In Switzerland, the consumption of sugar-free chewing gum (Factor 5) is widespread. In a survey of recruits in 2006, 39% of respondents stated that they chewed two or more pieces of gum daily. Today, over 90% of chewing gums are sweetened with sugar substitutes and/or artificial sweeteners. School chil-

dren who chewed gum sweetened with Sorbitol developed 20% fewer carious lesions than children who chewed no gum at all (DESHPANDE & JADAD 2008). Chewing sugar-free gum may therefore have led to a small caries reduction.

The influence of the sealing of pits and fissures (Factor 6) on caries experience was probably low; only few pits and fissures were sealed (Tab. IV).

The prescription of antibiotics (Factor 7) by paediatricians probably increased during the observation period (1964 to 2009) (FILIPPINI ET AL. 2006). A number of authors referred to a possible influence of antibiotic usage on caries prevalence (LOESCHE ET AL. 1989, KÜNZEL 1997, GIBBONS 1996).

The use of preservative-containing foodstuffs (Factor 8) probably also increased during the observation period, since the use of industrially processed foodstuffs increased. A caries-preventive effect of preservatives was demonstrated in an experimental animal study (DAVIES ET AL. 2001). Antibacterial and plaque-inhibiting properties were shown in an in-situ study (ARWEILER ET AL. 2008).

In-vitro studies showed, that polyphenols (Factor 9) reduce the virulence of mutans streptococci. Clinical studies demonstrated, that polyphenols inhibit the growth of mutans streptococci and dental plaque. In animal studies a caries inhibition was demonstrated (PETTI & SCULLY 2009). Important sources for polyphenols in the human diet are fruit, tea, coffee and chocolate (SCALBERT & WILLIAMSON 2000). It is conceivable that changes in consumption of these foodstuffs could influence caries experience.

It is also possible that unknown factors (10) contributed to the reduction in caries.

Synergistic effects were little studied (11). The effect of two factors in combination can be greater than the sum of the effects of the two factors taken individually. There are indications that good oral hygiene in combination with fluorides may have an increased caries-preventive effect (RÖLLA ET AL. 1991, MATHIESEN ET AL. 1996).

KLEEMOLA-KUJALA & RÄSÄNEN (1982) observed that poor oral hygiene and high sugar consumption in combination have an

increased caries-promoting effect. This means that good oral hygiene has an increased caries-preventive effect in the case of high sugar consumption.

## Conclusion

In summary, it must be said that only the effect of fluorides is at all quantifiable, which means that a caries reduction of around 50% can be explained (Tab. VII); the further reduction of more than 80% remains unexplained.

## Uncertain future development

The caries experience in the permanent dentition appears to have stabilised at a low level. Since the caries decline can be explained only to a (small) degree, a long-term and reliable prognosis of future trends is not possible. The future development should therefore be followed by means of caries-epidemiological surveys.

## Résumé

Dans 16 communes zurichoises, des écoliers de toutes classes d'âge ont été soumis à un examen bucco-dentaire, à intervalles de quatre ans depuis 1963/64. Pendant cette période, la même méthode standardisée a été utilisée. Cette étude documente l'évolution de la carie sur 45 ans.

L'indice CA\*OD moyen des écoliers âgés de 14 ans a diminué, entre 1964 et 2009, de 12,50 à 1,31. Cela correspond à une réduction de la carie de 90%. Chez les élèves âgés de 8, 10 et 12 ans, cette réduction était de 90% à 92%.

Le «Significant Caries Index» (le CA\*OD moyen du tiers des élèves de 12 ans avec les valeurs du CA\*OD les plus élevées) a diminué, entre 1964 et 2009, de 13,09 à 2,20. Cela correspond à une diminution de la carie de 83%.

La forte réduction de la carie observée était inattendue. L'effet des fluorures peut expliquer une réduction de la carie environ 50%. Une grande partie de la réduction reste inexpliquée. Des possibles causes sont discutées.

## References

- ARWEILER N B, LENZ R, SCULEAN A, AL-AHMED A, HELLWIG E: Effect of food preservatives on in situ biofilm formation. *Clin Oral Invest* 12: 203–208 (2008)
- BELLINI H T, ARNEBERG P, VON DER FEHR F R: Oral hygiene and caries: A review. *Act Odont Scand* 39: 257–265 (1981)
- BISCOUISSE: Facts & Figures Zuckerwaren. [www.biscosuisse.ch](http://www.biscosuisse.ch) (2010)
- BRATHALL D, HÄNSEL-PETERSSON G, SUNDBERG H: Reasons for the caries decline: What do the experts believe? *Eur J Oral Sci* 104: 416–422 (1996)
- BRATHALL D: Introducing the Significant Caries Index together with a proposal for a new global oral health goal for 12-year-olds. *Int Dent J* 50: 378–384 (2000)
- BROADBENT J M, WILLIAMS K B, THOMSON W M, WILLIAMS S M: Dental restorations: a risk factor for periodontal attachment loss? *J Clin Periodontol* 33: 803–810 (2006)
- BUNDESAMT FÜR STATISTIK: Statistisches Lexikon der Schweiz. Entwicklung des Nahrungsmittelverbrauchs in der Schweiz. [www.bfs.admin.ch](http://www.bfs.admin.ch) (2009)
- DAVIES B A, RAUBERTAS R F, PEARSON S K, BOWEN W H: The effects of benzoate and fluoride on dental caries in intact and desalivated rats. *Caries Res* 35: 331–337 (2001)
- DESHPANDE A, JADAD A R: The impact of polyol-containing chewing gums on dental caries. A systematic review of original randomized controlled trials and observational studies. *JADA* 139: 1602–1614 (2008)
- FILIPPINI M, MASIERO G, MOSCHETTI K: Socioeconomic determinants of regional differences in outpatient antibiotic consumption: Evidence from Switzerland. *Health Policy* 78: 77–92 (2006)
- GIBBONS R: The caries decline. A comment. *Eur J Oral Sci* 104: 424–425 (1996)
- KINGMAN A: Statistics in community oral health. In: Pine CM: *Community Oral Health*. Wright, Oxford, pp 147–162 (1997)
- KLEEMOLA-KUJALA E, RÄSÄNEN L: Relationship of oral hygiene and sugar consumption to risk of caries in children. *Community Dent Oral Epidemiol* 10: 224–233 (1982)
- KLOCK B, KRASSE B: Caries status and microbial conditions in children in 1973 and 1984. *Scand J Dent Res* 95: 13–17 (1987)
- KÜNZEL W: Caries decline in Deutschland. Eine Studie zur Entwicklung der Mundgesundheits. Hüthig, Heidelberg, 269–276 (1997)
- LOESCHE W J, EKLUND S A, MEHLISCH D F, BURT B: Possible effect of medically administered antibiotics on the mutans streptococci: Implications for reduction in decay. *Oral Microbiol Immunol* 4: 77–81 (1989)
- MARINHO V C C, HIGGINS J P T, LOGAN S, SHEIHAM A: Fluoride toothpastes for preventing dental caries in children and adolescents. *Cochrane Database of Systematic Reviews* 2003, Issue 1. Art. No.: CD002278. DOI: 10.1002/14651858.CD002278

- MARINHO V C C, HIGGINS J P T, SHEIHAM A, LOGAN S: Combinations of topical fluoride (toothpastes, mouthrinses, gels, varnishes) versus single topical fluoride for preventing dental caries in children and adolescents. *Cochrane Database of Systematic Reviews* 2004, Issue 1. Art. No.: CD002781. DOI: 10.1002/14651858.CD002781.pub2.
- MARTHALER T M: A standardized system of recording dental conditions. *Helv Odont Acta* 10: 1–18 (1966)
- MARTHALER T M, SCHRÖDER H E: DMF-experience in children with and without supragingival calculus on lower front teeth. *Helv odont Acta* 10: 120–130 (1966)
- MARTHALER T M: Decrease of DMF-levels 4 years after the introduction of a caries-preventive program, observations in 5819 schoolchildren of 20 communities. *Helv Odont Acta* 16: 45–68 (1972)
- MARTHALER T M: Die kariesprophylaktische Aktion im Kanton Zürich 1962 bis 1974 samt statistischem Erfolgsbericht über die ersten 8 Jahre. *Schweiz Mschr Zahnheilk* 85: 1147–1172 (1975)
- MARTHALER T M: Resultate nach 16 Jahren prophylaxeorientierter Schulzahnpflege: Welche Faktoren waren wirksam? *Stomatol. DDR* 33: 267–273 (1983)
- MARTHALER T M, STEINER M, MENGHINI G, BANDI A: Caries prevalence in Switzerland. *Int Dent J* 44: 393–401 (1994)
- MARTHALER T M, MENGHINI G, STEINER M: Trends in coronal caries prevalence in Southwestern Europe. *Int Dent J* 46: 193–197 (1996a)
- MARTHALER T M, O'MULLANE D M, VRBIC V: The prevalence of dental caries in Europe 1990–1995. *Car Res* 30: 237–255 (1996b)
- MARTHALER T M, MENGHINI G, STEINER M: Use of the Significant Caries Index in quantifying the changes in caries in Switzerland from 1964 to 2000. *Community Dent Oral Epidemiol* 33: 159–166 (2005)
- MARTHALER T M: Increasing the public health effectiveness of fluoridated salt. *Schweiz Monatschr Zahnmed* 115: 785–792 (2005)
- MATHIESEN A T, ØGAARD B, RÖLLA G: Oral hygiene as a variable in dental caries experience in 14-year-olds exposed to fluoride. *Caries Res* 30: 29–33 (1996)
- MENGHINI G, STEINER M, MARTHALER T M: Zahngesundheit und weitere orale Befunde bei Schülern in 16 Landgemeinden des Kantons Zürich 1996. *Acta Med Dent Helv* 3: 87–92 (1998) in *Schweiz Monatschr Zahnmed* 108: 87–92 (1998)
- MENGHINI G, STEINER M: Orale Gesundheit in der Schweiz. Stand 2006. Schweizerisches Gesundheitsobservatorium, Arbeitsdokument 26 (2007) [www.obsan.ch](http://www.obsan.ch)
- PETTI S, SCULLY C: Polyphenols, oral health and disease: A review. *J Dent* 37: 413–423 (2009)
- RÖLLA G, ØGAARD B, CRUZ R: Clinical effect and mechanism of cariostatic action of fluoride-containing toothpastes: a review. *Int Dent J* 41: 171–174 (1991)
- SCALBERT A, WILLIAMSON G: Dietary intake and bioavailability of polyphenols. *J Nutr* 130: 2073S–2085S (2000)
- SJÖGREN P, HALLING A: Survival time of class II molar restorations in relation to patient and dental health insurance costs for treatment. *Swed Dent J* 26: 59–66 (2002)
- STEINER M, MENGHINI G, MARTHALER T, BANDI A: Zahngesundheit von daueransässigen Schülern im Jahre 1992. *Schweiz Monatschr Zahnmed* 105: 1403–1411 (1995)