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Use of the Significant Caries Index in quantifying the changes in caries in Switzerland from 1964 to 2000

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Abstract – *Objectives:* To follow the changes in the Significant Caries Index (SiC) and the DMFT during the period 1964–2000 in children aged 12 and 15 in the Canton of Zurich. *Methods:* Examinations of random samples of children in 16 communities of the Canton were repeated every 4 years from 1964 onwards using the same standards for diagnosing caries. *Results:* In the 12-year-olds, the children in the low tertile had virtually no DMF-experience from 1980 on. On the contrary, the SiC, based on the children in the highest tertile, decreased until 1996. At the age of 15, the zero-average in the low tertile was reached in 1992 but the SiC continued to decrease until 2000. In the 12-year age group the reduction of the SiC from 1964 to 1996 was 81.3% and for the overall DMFT it was 89.7%. The corresponding reductions for the 15-year-olds, in this case from 1964 to 2000, were 77.0 and 88.4%, respectively. The DMFT-counts in the total samples had substantially higher coefficients of variation than those in the highest tertile. As a consequence, the SiC had relatively smaller confidence intervals than the average DMFT. *Conclusions:* The SiC is a very useful measure of dental caries experience. On the basis of the results in the 15-year-old group, the target of an SiC below 5.0 is proposed. The decline of the SiC demonstrates that even in the high-risk children caries experience has been reduced substantially.

In 1979, the World Health Assembly accepted an important goal for oral health in children: the global average for dental caries experience in 12-year-old children should not be higher than 3.0 in the year 2000. When this limit was established in the late 1970s, only few countries had presented reports on a decline of caries prevalence. While many hoped that this goal might be achieved for their country, no solid evidence was available at that time to demonstrate if this goal was realistic.

By 1995, the average DMFT in six industrialized Western European countries (Denmark, Finland, Ireland, the Netherlands, Sweden, UK) had fallen below 2.0 (1). Some detailed scientific papers and abstracts have since shown that the DMFT still shows a tendency to decrease whereas in other papers the DMFT seems to be 'bottoming out'. Whatever the future may be, for the countries of Western Europe, North America and several countries beyond, most of them English speaking, the original WHO-requirement of less than 3.0 DMFT has ceased to be a useful yardstick.

Parallel to the decline in caries prevalence, the majority of children has little or no decay, say 0, 1 or 2 DMFT whereas a minority of them still has considerable DMF-experience. Bratthall (2) suggested the 'Significant Caries Index' (SiC) as an epidemiologic statistic, which would focus on those most affected by caries. 'Individuals are sorted according to their DMFT values. The one-third of the population [or rather: of the sample] with the highest caries score is selected and the

mean DMFT for this subgroup is calculated'. This index was presented in addition to the overall average DMFT in several recent papers on caries epidemiology (3–5).

The purpose of this paper is to follow the changes through 36 years of the SiC in the Canton of Zurich where samples of schoolchildren from 16 communities were examined in 1964 and subsequently every 4 years until the year 2000.

Materials and methods

Selection of children
In the smaller communities, all children present on the examination day were examined. In the larger communities, less than 100% of the children were included. Random selection was made according to their day of birth within any month.

Absenteeism in the schools in the Canton has been consistently around 10% for decades. Refusal of examination was less than 2% until 1976, the participation was high because the examinations were recognized as part of the mandatory school dental service, serving for quality control. In 1984, after the introduction of a new law on radiation protection, 14% of the parents did not allow their children to have radiographs taken. After the Chernobyl accident in 1986, this percentage increased to 32% in 1988. In 1992, 1996 and 2000, the percentages of the clinically examined children who refused to be radiographed were 35, 25 and 19%, respectively. Their clinical DFS-counts in pits and fissures of molars and premolars were generally similar to those who had radiographs taken (6).

The results of this study are based exclusively on permanent residents, whether Swiss or non-Swiss. The latter group included those immigrants who were not older than 5 years when they arrived in Switzerland; they had benefited from the six supervised tooth brushing exercises per year at kindergarten and school like those born in Switzerland. The recent immigrants in Switzerland had on average a substantially higher caries experience than the permanent residents (7, 8).

Age classification
The age of the schoolchildren was recorded in years and quarter of years. Customarily, 'age 12' comprises children in the age bracket 12.00–12.99 years. In accordance with earlier reports on caries in the Canton of Zurich (6), the age bracket 11.50–13.49 was also used in order to increase the

number of children. The adequacy of the broader age group will be shown in 'Results'. In the children aged 15, there were regularly slightly larger numbers being 15.0–15.49 years old and less being 15.5–15.99 years old. Therefore, the limited number of children being 16.0–16.24 years old was included in the age class '15 years'. The average ages of these slightly broader age groups were between 15.40 and 15.55. The labeling '15-years-old' is therefore justified.

Recording of caries
Before the examination, all children brushed their teeth under supervision and guidance of dental health educators. They were used to this procedure within the preventive program comprising six tooth-brushing exercises per year in groups with a concentrated fluoride preparation (mostly gel with 1.25% F). The children were subsequently seated on portable chairs, all examinations took place in the schools. In 1964 and 1968, a small dental lamp provided focused light on the teeth, and the teeth had to be dried with the aid of syringes. From 1972 on, fiber optic illumination and compressed air were available at each examination chair, which facilitated a more thorough inspection of the teeth. The examination of the individual tooth surfaces (except for approximal surfaces in the buccal segment which were scored exclusively on radiographic examination) was based primarily on visual examination aided by plane mirrors (9). Use of probes was only allowed in connection with fissures and pits in cases of doubt, and to remove plaque, which had remained, in spite of tooth brushing. From 1964 to 1992, 220 children were examined per day unilaterally (right side) by two examiners working in parallel. In 1996 and 2000, both sides were included in the scoring, and the number of children examined per day varied around 140.

Lesions due to caries were categorized according to the scheme published by Marthaler (9), which distinguishes two precavity stages. In this publication, only cavitated lesions are considered as D as it is usual in epidemiology. Restored teeth with fillings but otherwise sound were counted as FT. Only first molars were counted as MT. In accordance with guidelines for school dental services, it was justified to assume that missing premolars were due to extractions for orthodontic reasons. Loss of other teeth was very rare and due to accidents. The state of the approximal surfaces from the second molar mesially to the first premolar distally was assessed

on radiographs. When radiolucencies were discernible in the dentine, the surface was scored as D.

The status of 46 sites (92 in full mouth recording) was recorded whereas a small number of sites which very rarely became carious, e.g., the lingual surfaces of the premolars and anterior teeth, were not examined. The validity of the system was demonstrated by Marthaler (10) and Rugg-Gunn et al. (11).

Examiners

In the surveys conducted from 1964 to 1992, the author TMM was one of the two examiners working in parallel in at least half of the 16 communities, or he was present taking the radiographs. The second examiners were former students or assistants of the Clinic for Cariology, Periodontology and Preventive Dentistry who were trained in a 1-day course to follow exactly the diagnostic procedures and standards (9). The number of the external examiners was reduced over the years. From 1980 onward, the author MS was always one of the examiners, working often in parallel with TMM. In 1996 there were still eight examiners, but in 2000 all examinations were done by authors GM and MS. In 1996 and 2000 the intraclass correlation coefficients for the DMFT-counts per subject assessing the inter-examiner reliability ranged between 0.91 and 0.98. The radiographs were scored by TMM and an experienced assistant until 1980. All later radiographs were assessed by MS.

Statistical evaluation

In the 1960s and 1970s, the state of each predilection site was recorded on punch cards. Later, all data were transferred to magnetic tape and thoroughly tested for inconsistencies (12) and finally stored electronically. Individual DMFT counts were all made using appropriate programs (developed by Marthaler in 1966; they were later enlarged and modernized). The averages and standard deviations derived from unilateral examinations (1964–1992) were doubled to make them directly comparable with those from the full mouth examinations. Further details have been reported in earlier papers dealing with the examinations repeated every 4 years in the Canton of Zurich (13, 14).

Results

Caries experience at age 12

Figure 1 compares the average SiC obtained from children in the age bracket 11.50–13.49 with those obtained from the subsample of children at age 12.00–12.99. The SiC averages were almost equal in most of the examination courses. The two largest differences were 0.52 (1976) and 0.27 (1988) while the remaining differences varied between 0.03 and 0.22. With respect to the DMFT, the differences between the averages were similarly small (data not shown). Subsequent data presentation for 12-year-olds will be based on the larger number of children in the age class 11.50–13.49 years, but will be labeled 'age 12 years' for simplicity. The corresponding number of children is shown on the left in Table 1.

In 1964, the 12-year-old children had on average 7.94 DMFT (results from right side doubled, Table 1). The average fell constantly and reached its lowest level of 0.82 (unilateral) in 1996. The
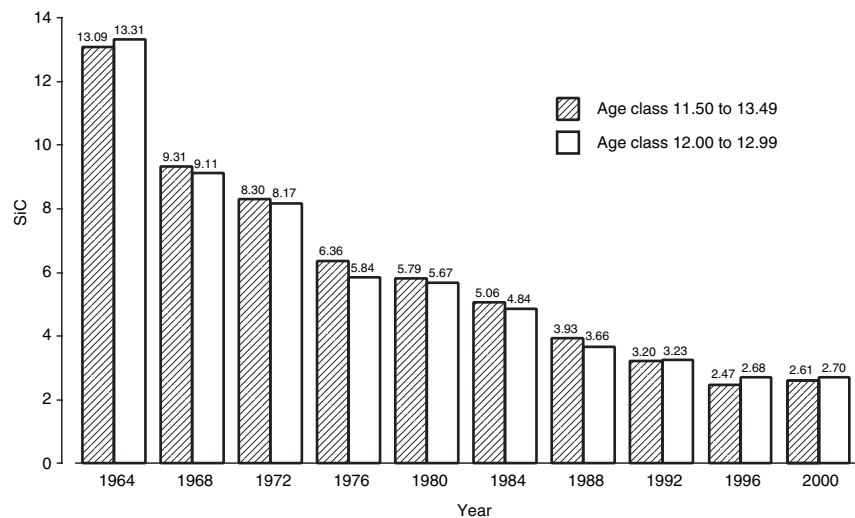
Fig. 1. SiC in the age class 11.50–13.49 versus SiC in the age class 12.00–12.99.

Table 1. Number of 12-year-old children examined, average DMFT and SiC

	Number of children	% with DMFT = 0		Numbers for SiC	Average DMFT		Average SiC		Percent changes in 4 years[a]	
		Unilateral[a]	Both sides		Unilateral[a]	Both sides	Unilateral[a]	Both sides	DMFT	SiC
1964	474	0.8		158	7.94		13.09			
1968	677	5.9		226	5.64		9.31		−29.0	−28.9
1972	736	8.7		246	4.96		8.30		−12.1	−10.8
1976	775	16.8		259	3.64		6.36		−26.6	−23.4
1980	758	29.4		253	2.99		5.79		−17.9	−9.0
1984	542	39.7		181	2.23		5.06		−25.4	−12.6
1988	452	53.1		151	1.58		3.93		−29.1	−22.3
1992	399	63.4		133	1.13		3.20		−28.5	−18.6
1996	292	72.3	62.3	98	0.82	0.84	2.45	2.38	−27.4	−22.8
2000	328	68.9	59.1	110	0.87	0.90	2.58	2.46	6.1	5.3
Total reduction from 1964 to 1996									89.7	81.3
Total reduction from 1964 to 2000									89.0	80.3
Average of the percent reductions in 4-year periods from 1964 to 1996									24.5	18.5

[a]Based on the examination of the right side.

percentage reductions in the 4-year intervals from 1964 to 1996 varied between 12.1 and 29.1, with an average of 24.5%. The reduction from 1964 to 1996 was 89.7%.

The SiC was 13.09 in 1964 but was only 2.45 and 2.58 in 1996 and 2000, respectively. The overall reduction observed until 1996 was 81.3%. The percentage reductions in the 4-year intervals until 1996 ranged from 9.0 to 28.9, with an average of 18.5%. The percentage differences proved to be significantly lower when compared with the reductions of the overall DMFT (sign-test, eight differences in the same direction, $P < 0.01$). Neither the DMFT nor SiC indicated any further decline in caries experience of the permanent residents after 1996.

Figure 2 illustrates the SiC (the upper tertile) and the DMFT averages in the lower two tertiles. Both the SiC and the average DMFT had the strongest reduction from 1964 to 1968. Until 1980, the declines were more or less equal and constant in the three tertiles, but the lowest tertile had by then reached the average of only 0.23, and it was zero from 1984 onward. With respect to SiC and the middle tertile, the decrease continued until 1996.

Table 2 compares the results of unilateral examination statistics (right side only, statistics doubled for comparisons) with complete examinations comprising both sides. It is evident that the average results were close to each other. The slight increase from 1996 to 2000 (not significant, t-test: $P > 0.05$) occurred in both the unilateral and full mouth recording. A detailed analysis of the data showed that in both 1996 and 2000, the DMFT in the middle tertile was at zero on the right side whereas full mouth examinations resulted in averages of 0.12
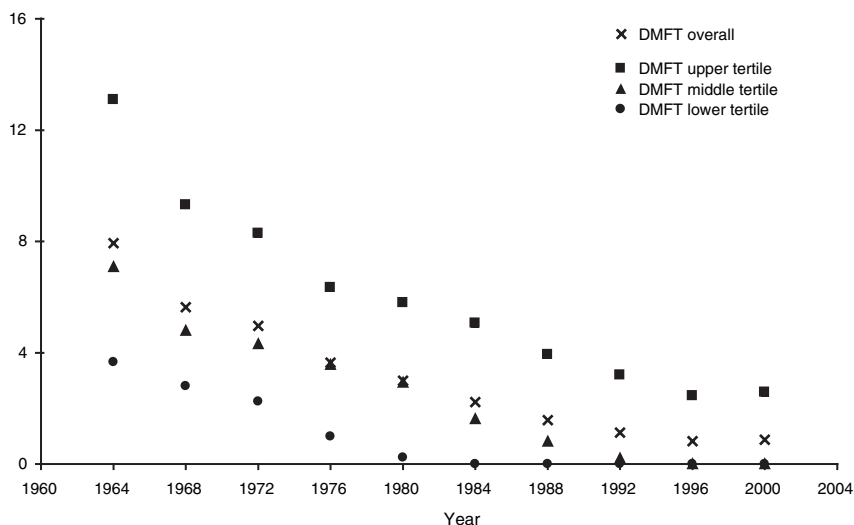

Fig. 2. The SiC (= average DMFT in the upper tertile) and the average DMFT in the middle and lower tertile, age 12.

Table 2. Comparisons of statistics from right side and full mouth examination, age 12

	DMFT statistics			SiC statistics		
	Unilateral[a]	Both sides	Diff. %	Unilateral[a]	Both sides	Diff. %
Averages						
1996	0.82	0.84		2.45	2.38	
2000	0.87	0.90		2.58	2.46	
Standard deviations						
1996	1.50	1.42	−5.3	1.66	1.52	−8.4
2000	1.44	1.34	−6.9	1.34	1.21	−9.7
Coefficients of variation						
1996	183	169	−7.7	68	64	−5.9
2000	166	149	−10.2	52	49	−5.8

[a]The averages and standard deviations obtained from the right side were multiplied by 2 to be directly comparable with the statistics from the full mouth examination (both sides).

DMFT in 1996 (12 of the 97 children in this tertile had one DMFT on the left side) and 0.22 in 2000. The standard deviations and the coefficients of variation of the full mouth counts were between 5 and 10% lower than those of the unilateral examinations. The coefficients of variation of the SiC were approximately one-third of those of the overall DMFT.

Caries experience at age 15

From 1964 to 2000 the SiC decreased from 19.17 to 4.41 and the average DMFT from 13.89 to 1.61 (Table 3). Nevertheless, statistical significance was not reached when comparing the 1996 averages with those of 2000 with respect to both the overall average DMFT and the SiC (t-test: $P > 0.05$). The average reduction in each of the 4-year periods up to 2000 was 14.7% regarding the SiC and 20.7% in the case of the DMFT. The total reduction for the SiC was 77.0% in the

period 1964 to 2000 and 88.4% for the overall DMFT.

The averages pertaining to the three tertiles, shown in Fig. 3, fell constantly until 1984, the differences between the averages of tertiles remaining almost constant. In 1984, the average DMFT of the lower tertile was already down to 0.8 and reductions by 1.1–2.0 as in the earlier 4-year periods were not possible. In the middle tertile, the decreases became minor after 1992, and the final average was only 0.41. The SiC average in 1992 was 5.31. It decreased to 5.14 in 1996 and finally was at 4.41 in 2000 (decrease from 1992 to 2000 not significant, t-test: $P > 0.05$).

Table 4 shows the closeness of the results from unilateral and full mouth examinations. The standard deviations and the coefficients of variation of the full mouth counts were between 8 and 23% lower than those of the unilateral examinations.

Table 3. Number of 15-year-old children examined, average DMFT and SiC

|	Number of children	% with DMFT = 0		Numbers for SiC	Average DMFT		Average SiC		Percent changes in 4 years[a]	
		Unilateral[a]	Both sides		Unilateral[a]	Both sides	Unilateral[a]	Both sides	DMFT	SiC
1964	72	0.0		24	13.89		19.17			
1968	202	0.5		67	11.82		17.04		−14.9	−11.1
1972	282	2.1		94	8.88		13.72		−24.9	−19.5
1976	285	4.6		95	7.54		12.11		−15.1	−11.7
1980	303	9.9		101	6.24		10.87		−17.2	−10.2
1984	286	19.9		95	4.79		9.09		−23.2	−16.4
1988	226	23.5		75	3.84		7.79		−19.8	−14.3
1992	147	44.2		49	2.22		5.31		−42.2	−31.8
1996	131	50.4	41.2	44	2.05	2.02	5.14	4.91	−7.7	−3.2
2000	117	59.8	53.0	39	1.61	1.58	4.41	4.31	−21.5	−14.2
Total reduction from 1964 to 1996									85.2	73.2
Total reduction from 1964 to 2000									88.4	77.0
Average of the percent reductions in 4-year periods from 1964 to 2000									20.7	14.7

[a]Based on the examination of the right side.
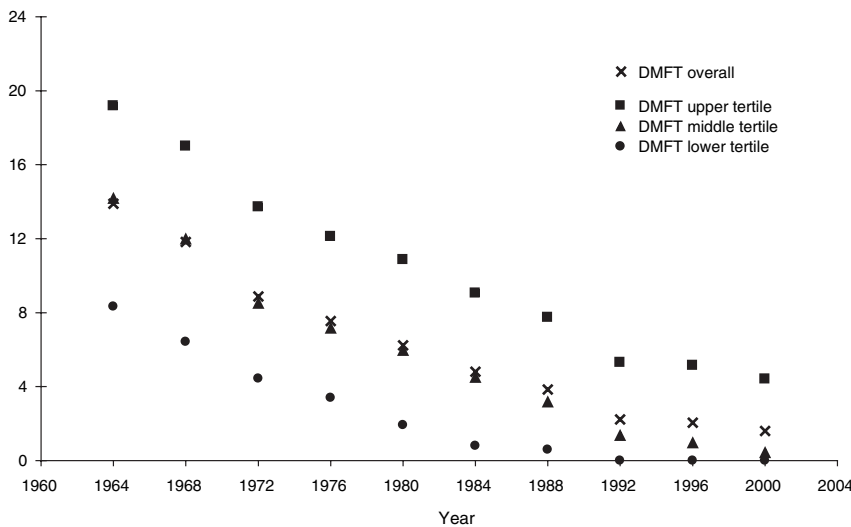
Fig. 3. The SiC (= average DMFT in the upper tertile) and the average DMFT in the middle and lower tertile, age 15.

Table 4. Comparisons of statistics from right side and full mouth examination, age 15

	DMFT statistics			SiC statistics		
	Unilateral[a]	Both sides	Diff. %	Unilateral[a]	Both sides	Diff. %
Averages						
1996	2.05	2.02		5.14	4.91	
2000	1.61	1.58		4.41	4.31	
Standard deviations						
1996	2.68	2.45	−8.6	2.34	2.02	−13.7
2000	2.52	2.27	−9.9	2.56	1.96	−23.4
Coefficients of variation						
1996	131	121	−7.6	46	41	−10.9
2000	157	144	−8.3	58	45	−22.4

[a]The averages and standard deviations obtained from the right side were multiplied by 2 to be directly comparable with the statistics from the full mouth examination (both sides).

The coefficients of variation of the SiC were close to one-third of those of the overall DMFT.

Discussion

Methodology

Throughout the 36 years, the scoring system remained the same and the detailed guidelines were kept unchanged. Nevertheless, there were two technical improvements: instead of the old hand-blowers, compressed air has been available for drying the teeth since 1972; the small lamps were substituted by a fiber optic with a diameter of 5 mm, providing excellent light throughout the oral cavity. These changes facilitated the inspection of the teeth, particularly the posterior ones. This in turn may have increased the number of precavitation changes diagnosed (not considered in this paper) but was unlikely to affect the recording of cavitated lesions. The supervision of

the senior investigator (TMM) continued until 1996, when MS had already 16 years of experience and GM was also familiar with the scoring system. The fact that the averages decreased with remarkable regularity [particularly evident on figures based on the logarithmic scale (13)] supports the hypothesis that variations due to examiner deviations from the diagnostic system were minor.

Many papers have shown that the occurrence of caries is highly symmetrical in children (15, 16) as well as in young adults (17). The data shown in Tables 1–4 confirm this for averages even under conditions of low caries prevalence. However, when caries prevalence is very low, the relative symmetry is bound to diminish. In the extreme case of DMFT = 1 in an individual there is asymmetry, and unilateral examination may result in an individual considered as either free of caries or affected by it depending on which side is examined.

Smaller standard deviations and coefficients of variation were to be expected from theory when using full mouth counts (Tables 2 and 4) instead of unilateral counts because random differences between the two sides level out. When caries prevalence was still high in Switzerland, unilateral examinations were useful and justified because larger numbers of children could be examined, which in turn increased the precision of the averages (9, 18). In view of the low prevalence observed in Switzerland since 1992 (13), full mouth examinations are indicated and have become routine in our working group since 1996.

Findings regarding the decline of the SiC and the DMFT

The SiC of the 12-year-old children in the 16 communities of the Canton of Zurich studied since 1964 (19) has declined by 81.3% (1964–1996, Table 1). Since 1996, the SiC has remained below the upper limit of 3.0 as proposed by Bratthall (2). The total reduction of the average DMFT was higher and amounted to 89.7%.

In the 15-year-olds, the decline continued until 2000 for the SiC and the overall DMFT. Therefore, the total period considered was 1964–2000. Accordingly, the total reductions were 77.0% for the SiC and 88.4% for the DMFT.

Multiple use of fluorides are considered to have been the main reason for the decline (13) and the conclusions reached in the project run by Bratthall (20) are assumed to be still up to date. The widespread use of fluoridated domestic salt (250 ppm since 1983, market share above 74% since the late 1980s) can be assumed to have contributed to the decline. This hypothesis is supported by the low DMFT average of 4.8 DMFT in 20-year-old military recruits in 1996 (17).

The decline of the SiC demonstrates that even in the children with the highest caries experience, nowadays often labeled as 'high risk' group, caries experience has been reduced substantially. The widely held belief that part of the child population does not benefit from general preventive measures is clearly disproved by the decrease of the SiC. It should be kept in mind that within the school-based dental health program the high-risk children had taken part in toothbrushing exercises with a concentrated fluoride gel (1.25% F) four to six times a year for at least 7 years, and some for up to 10 years.

Repeated surveys in France resulted in an overall DMFT of 4.2 and an SiC of 7.4 in 1987; the corresponding figures were 2.0 and 4.7 in 1998, respectively (4). Accordingly, the DMFT was reduced by 52%, the SiC by 36%. As in the present material, the decline of the DMFT was moderately stronger than that of the SiC.

Suggestion of a goal for the SiC of the 15-year-olds

Bratthall (2) suggested an SiC of less than 3.0 in 12-year-old children as a global oral health goal, to be reached by the year 2015. With a view to the decreasing caries prevalence in many countries, surveys in older children or adolescents are becoming more important. Accordingly, the 4th edition of 'Oral Health Surveys. Basic Methods' (21) recommends studies in 15-year-old children in addition to the traditional age groups 5 and 12. Bratthall's goal of 3.0 is 22% higher than the SiC of 2.46 reported in this study. Data for the 15-year-olds presented here show that the final and lowest SiC was 4.31. Accordingly we suggest that the global goal to be attained is an SiC of less than 5.0, which is 16% higher than 4.31 reported here for the 15-year-olds.

Observations regarding the reliability of the SiC

The standard deviations of the SiC had about the same range as the corresponding ones of the DMFT at both ages. In fact, the large numbers of zero DMFT-counts add to the dispersion in the total sample whereas such 'caries-free' subjects are not at all or rarely included in the upper tertile, that is in the SiC. The relative variation, or coefficients of variation (CV, standard deviation in percent of the average) of the SiC were accordingly much smaller than that of the DMFT because SiC was much higher than the mean DMFT. Even in the case of the confidence limits, the higher relative precision of the SiC is maintained despite the fact that the number of children on which the SiC is based is by definition only one-third of the number of children available for the overall DMFT (data not shown). These findings show that the SiC is a fairly precise statistic for assessing caries in the most caries-prone third of children.

Practical experience in epidemiological fieldwork suggests another advantage of the SiC. In children with low caries experience, who constitute the lower and middle tertile, minute white fillings are frequently placed in pits and fissures. Part of these small restorations are likely to be overlooked.

On the contrary, the upper tertile (providing the SiC) will contain many children with extensive restorations and cavities, which are rarely overlooked. This means that in situations of low caries prevalence the overall DMFT has a higher risk of underestimation than the SiC.

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