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Caries prevalence and distribution in individuals aged 3–20 years in Jönköping, Sweden, over a 30-year period (1973–2003)

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Background. Oral health status of individuals aged 3–80 years in the city of Jönköping, Sweden, has been assessed in a series of epidemiological studies over a 30-year period.

Aim. To analyse the changes in caries prevalence and caries distribution in child population sample groups, based on studies performed in 1973, 1978, 1983, 1993, and 2003.

Design. Each time point included 500 randomly sampled individuals, divided into age groups of 3, 5, 10, 15, and 20 years.

Results. Thirty-five per cent of 3-year-olds were caries free in 1973, compared with 69% 30 years later. Decayed and filled primary (dfs) and permanent surfaces (DFS) were reduced by 50–80% between 1973 and 2003. Adolescents aged 10 and 15 years exhibited the most pronounced reduction in DFS on the occlusal surfaces. By 2003, 90% of the proximal carious lesions in 15-year-olds were initial carious lesions. In 2003, about 60% of 15-year-olds had a DFS of ≤ 5, while about 7% exhibited a DFS of ≥ 26.

Conclusions. Despite the dramatic decline in the prevalence of caries, caries remains a health problem among children, particularly those of preschool age. Continuous epidemiological studies are recommended to evaluate preventive measures.

Introduction

In the 1950s to the 1960s, the high prevalence of caries was a major health problem in Sweden, particularly among children and adolescents[1–3]. Notably, caries progression was rapid in the occlusal surfaces of the first permanent molars[4]. At that time, no preventive dental care system was in place and, furthermore, restorative treatment was almost non-existent in primary teeth and inconsistent in young permanent teeth.

In 1973, a cross-sectional epidemiological study of random sample groups from the child and adolescent populations of Jönköping, Sweden, was conducted to portray the oral health status of these populations. Concurrently with this study, a preventive dental care system for children aged 0–16 years was introduced. This system adapted to the needs of this population by providing both basic preventive care to all individuals (population-directed), and additional preventive care (individualized) to individuals who did develop severe disease[5]. The introduction of the preventive dental care system was accompanied by the implementation of continuing education and training of dental care professionals in diagnostics and preventive dental care[6].

To further evaluate the dental health changes in the child and adolescent populations, a series of epidemiological studies was carried out in Jönköping in 1978[7], 1983[8,9], and 1993[8,9], followed by a new cross-sectional study in 2003[8,9]. In these studies, an overview of changes in dental care habits and knowledge of oral health as well as clinical findings were presented covering the 30-year period, in individuals aged 3–80 years.

The present study's aim was to present a detailed analysis of caries prevalence and caries distribution in individuals aged 3–20 years over a 30-year period, from 1973 to 2003.

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Table 1. Age and gender distribution of subjects examined in 1973, 1978, 1983, 1993, and 2003.

Age group (years)	Number examined														
	1973			1978			1983			1993			2003		
	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male
3	100	49	51	100	53	47	101	59	42	100	47	53	96	59	37
5	100	47	53	100	48	52	108	42	66	107	58	49	96	45	51
10	100	48	52	100	47	53	111	46	65	114	67	47	110	58	52
15	100	55	45	100	45	55	107	55	52	102	51	51	96	51	45
20	100	60	40	100	58	42	100	55	45	100	50	50	84	38	46

Materials and methods

In 1973, 1978, 1983, 1993, and 2003, a random sample of the age groups 3, 5, 10, 15, and 20 years was selected from four parishes within Jönköping. The randomization process was conducted by the County Council. In 1973 and 1978, the participants were listed in respective age group in chronological order according to date of birth. Each of these lists contained 140–170 individuals and the first 100 individuals who accepted to participate were included in the study. In 1983, 1993, and 2003, 130 individuals were randomly selected in each age group. All of these individuals were invited to participate in a clinical and radiographic investigation. For various reasons 12–30% of those invited, depending on age group and year, declined to participate. The numbers of participating individuals are presented in Table 1.

All participants were personally invited to take part in the study, and were informed about the examination procedures. If recent radiographs were available, they were obtained from the individual's regular dentist.

All examinations were carried out by dentists from the Institute for Postgraduate Dental Education in Jönköping, Sweden. The dentists were calibrated prior to the study, according to the diagnostic criteria below. Further information about the sampling procedure and routines, reasons for not taking part in the study, and numbers of nonrespondents are reported by Hugoson *et al.*[8].

Diagnostic criteria

Number of teeth

Primary teeth were recorded in the 3- and 5-year age groups. In the 10-, 15-, and 20-year age groups only permanent teeth, excluding third molars, were recorded.

Caries

Clinical caries. All tooth surfaces available for clinical evaluation were examined for caries according to the criteria described by Koch[10], as follows: Initial caries: loss of mineral in the enamel causing a chalky appearance but not clinically classified as a cavity. Manifest caries: carious lesions on previously unrestored surfaces that could be verified as cavities by probing and in which, on probing in fissures using light pressure, the probe stuck.

Radiographic caries. Lesions seen on the proximal tooth surfaces as clearly defined reductions in mineral content. Initial caries: (i) the lesion was not deeper than two-thirds of the enamel and (ii) the lesion was deeper than two-thirds of the enamel but did not involve the dentine. Manifest caries: the lesion extended into the dentine.

Hereafter, *caries* means the sum of initial and manifest lesions, unless otherwise stated.

Fissure sealings

Fissure sealings were recorded for each participant.

Restorations

For each tooth surface, the presence of any of the following materials was also recorded: amalgam, silicate, glass ionomer, cement or composite material, gold inlays, or metal or porcelain crowns. Several oral health variables were also recorded, such as plaque, gingivitis, and endodontic treatment.

Decayed and filled primary and permanent surfaces

The number of decayed and filled primary (dfs) and permanent surfaces (DFS) were calculated on existing teeth. As there were almost no teeth extracted (other than by orthodontic reasons) m/M was not counted.

Ethical considerations

Throughout the study, the ethical rules for research described in the Helsinki Declaration were followed[11]. The study was approved in 2003 by the Ethical Committee at the University of Linköping, Linköping, Sweden.

Data processing and methodological analysis

A computerized dental record system was used to compile a database for the study. The data were analysed using SPSS (version 13.0, SPSS Inc., Chicago, IL, USA), and frequencies, mean values, and distributions were calculated. Before the 2003 study commenced, the examiners were calibrated for the diagnostic criteria by the two senior examiners, who had been involved in the earlier studies. Radiographs of 140 individuals from the 1983, 1993, and 2003 examinations were selected from the database by a statistician, representing 7840 proximal tooth surfaces that were healthy, carious, or filled. The radiographs from these individuals were taken by about 10 different examiners and were re-examined by the two senior examiners. The tooth surfaces were diagnosed according to the criteria listed above. Agreement between the two examinations was statistically significant with a Cohen's kappa value of 0.57 for 2003 and 0.79 for 1983 and 1993.[12]

Comparisons of differences between the years for the respective age groups are expressed as mean values and 95% confidence intervals ($P < 0.05$) for number of teeth and number of DFS/dfs.

Results

Number of teeth

There were no statistically significant differences in the mean numbers of teeth between the 1973, 1978, 1983, 1993, and 2003 studies in any of the age groups, and almost no tooth loss was observed (Table 2). The 15- and 20-year age-groups had a mean of 27.0–27.4 teeth.

Caries-free individuals

Table 3 shows the percentage of caries-free individuals and the total mean number of decayed and filled surfaces (dfs/DFS). The percentage of caries-free 3-year-olds had increased markedly by 1978, compared to the 1973 value. Minor changes occurred thereafter, between 1983 and 2003. The number of caries-free 5-year-olds increased successively from 9% in 1973 to 48% in 1993. There were no further significant changes among this age group between 1993 and 2003. The number of caries-free 10- and 15-year-olds also increased steadily over the study period, reaching 52% and 20%, respectively, by 2003. Caries-free 20-year-olds were first seen in 1993 (3%); this percentage increased to 12% by 2003.

Caries and restorations

In all age groups, the mean dfs/DFS in 2003 was 20–50% of 1973 levels. Most of this decrease took place during the first 5 years, that is, between 1973 and 1978, among 3- and 5-year-olds. After that only statistically nonsignificant

Table 2. Mean numbers of erupted teeth in 1973, 1978, 1983, 1993, and 2003. The 95% confidence interval is shown for the age groups in 1983, 1993, and 2003.

Age group (years)	1973	1978	1983	1993	2003
3	19.7	19.9	19.8 (19.6–20.0)	19.9 (19.8–20.0)	19.9 (19.9–20.0)
5	19.6	19.0	19.3 (19.1–19.5)	19.7 (19.6–19.9)	19.8 (19.5–20.0)
10	18.1	17.0	16.5 (15.6–17.3)	14.1 (13.4–14.9)	16.8 (15.8–17.8)
15	27.0	27.4	27.2 (26.9–27.5)	27.1 (26.8–27.4)	27.0 (26.7–27.4)
20	27.2	27.3	27.4 (27.2–27.6)	27.3 (27.0–27.6)	27.4 (27.1–27.6)

Table 3. Percentage of caries-free individuals and mean number of decayed and filled tooth surfaces (dfs/DFS) in 1973, 1978, 1983, 1993, and 2003. The 95% confidence interval is given for dfs/DFS in 1983, 1993, and 2003.

Age group (years)	Caries-free individuals (%)					No. of dfs/DFS				
	1973	1978	1983	1993	2003	1973	1978	1983	1993	2003
3	35	62	70	72	69	3.9	2.0	2.3 (1.2–3.4)	1.2 (0.7–1.7)	1.8 (0.8–2.7)
5	9	25	29	48	46	11.2	6.3	5.9 (4.7–7.8)	3.7 (2.5–4.9)	3.5 (2.3–4.8)
10	1	11	17	37	52	9.3	4.4	5.0 (4.3–5.8)	2.6 (2.1–3.3)	1.7 (1.2–2.1)
15	0	2	6	14	20	27.7	13.7	11.2 (9.7–13.0)	11.7 (9.1–14.1)	6.4 (4.8–8.0)
20	0	0	0	3	12	35.1	27.0	21.5 (18.8–24.3)	15.7 (13.5–17.5)	9.7 (7.1–12.4)

Table 4. Mean number of decayed (ds/DS) and filled (fs/FS) tooth surfaces in the different age groups in 1973, 1978, 1983, 1993, and 2003.

Age group (years)	No. of ds/DS					No. of fs/FS				
	1973	1978	1983	1993	2003	1973	1978	1983	1993	2003
3	3.7	1.7	2.1	1.2	1.7	0.2	0.3	0.2	0.0	0.0
5	10.3	4.5	3.5	2.9	3.0	0.9	1.8	2.3	0.8	0.5
10	4.2	0.5	1.6	2.0	1.2	5.1	3.9	3.6	0.6	0.5
15	9.9	2.2	4.8	9.2	4.7	17.8	11.5	6.4	2.6	1.7
20	6.5	2.7	4.5	6.7	5.2	28.6	24.3	17.0	9.0	4.6

changes in dfs were seen. Children and adolescents aged 10–20 years showed a continuous decrease in DFS between 1973 and 2003 (Table 3; Fig. 1), except for a slight DFS increase among 15-year-olds between 1983 and 1993. Statistically significant changes in DFS were seen; for example, 10-year-olds between 1983 and 1993, for 15-year-olds between 1993 and 2003, and for 20-year-olds between 1983 and 1993 and 1993 and 2003.

The number of decayed surfaces decreased for all age groups between 1973 and 1978 (Table 4). Only minor changes in decayed primary surfaces were found between 1978 and 2003, compared to the first 5 years for 3- and 5-year-olds. The number of decayed tooth surfaces among 10-, 15-, and 20-year-olds increased between 1978 and 1993, and decreased thereafter.

Very few filled tooth surfaces were found among children aged 3 and 5 years, at all five examinations. The number of filled tooth surfaces reduced gradually among the other age groups, with a 90% reduction seen among 10- to 15-year-olds, and 84% among 20-year-olds by the end of the 30-year study period.

Table 5 lists the mean numbers of dfs/DFS for the different tooth surfaces in 1973, 1983, 1993, and 2003. Similar decreases in dfs were seen for different tooth surfaces among 3- and

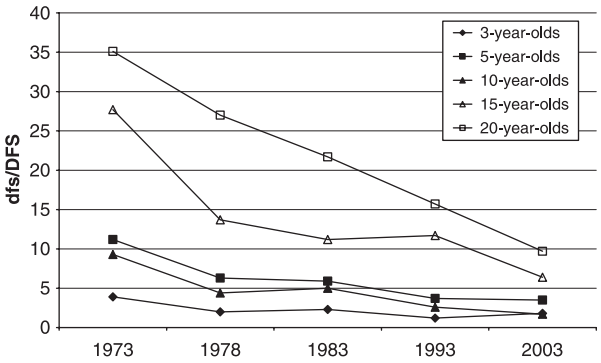

Fig. 1. Number of dfs/DFS in the 3-, 5-, 10-, 15-, and 20-year age groups in 1973, 1978, 1983, 1993, and 2003.

5-year-olds over the 30-year period (except for occlusal surfaces among 3-year-olds). The most pronounced reduction in DFS among 10- and 15-year-olds during the study period was in the occlusal surfaces of the permanent teeth, with occlusal DFS among 15-year-olds decreasing from 11.9 in 1973, to 1.5 in 2003. Table 6 displays the number of fissure-sealed occlusal surfaces in 2003, at which point 70–78% of the permanent molars among adolescents aged 15 years were sealed.

Overall, the numbers of DFS on the proximal and buccal-lingual surfaces reduced gradually, by about 70% (Table 5). For example, among 20-year-olds the number of DFS proximal was

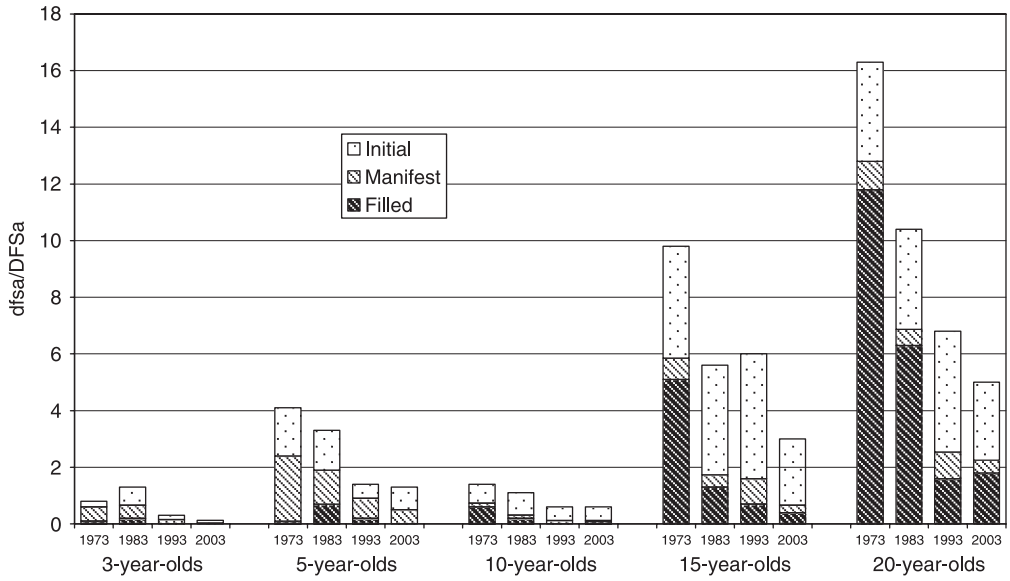

Fig. 2. Number of proximal decayed and filled tooth surfaces (dfs/DFS) categorized by initial carious lesions, manifest carious lesions, and filled surfaces in the 3-, 5-, 10-, 15-, and 20-year age-groups in 1973, 1983, 1993, and 2003.

Table 5. Mean number of decayed and filled tooth surfaces (dfs/DFS) by type of surface in 1973, 1983, 1993, and 2003.

Age group (years)	No. of dfs/DFS											
	Occlusal				Proximal				Buccal-lingual			
	1973	1983	1993	2003	1973	1983	1993	2003	1973	1983	1993	2003
3	0.8	0.7	0.5	0.7	0.8	1.3	0.3	0.1	2.3	0.3	0.5	1.0
5	3.1	2.0	1.1	1.1	4.1	3.3	1.4	1.3	4.0	0.6	1.2	1.1
10	4.6	3.3	0.6	0.5	1.4	1.1	0.6	0.6	3.3	0.6	1.3	0.6
15	11.9	5.2	2.0	1.5	9.8	5.6	6.0	3.0	6.0	0.4	3.7	1.9
20	11.5	9.4	6.0	2.8	16.3	10.4	6.8	5.0	7.3	1.7	2.9	2.0

Table 6. Molars with fissure sealings (%) in 2003.

Age group (year)	Fissure-sealed teeth (%)			
	17 + 27	16 + 26	36 + 46	37 + 47
10		89	87	
15	78	76	70	73
20	67	61	54	63

16.3 in 1973 compared to 5.0 in 2003. Figure 2 presents a more detailed analysis of proximal dfs/DFS for all age groups and time points. Manifest carious lesions were more prevalent than initial carious lesions in the primary teeth apart from 5-year-olds in 2003. The number of filled surfaces in the permanent teeth decreased among all age groups between 1973 and 2003, in particular during the first 20 years. Notably, the decrease in filled proximal surfaces among 15-year-olds was > 90%. Initial lesions were more frequent than manifest lesions, representing 80–90% of all carious lesions.

Figures 3 and 4 present the frequency distributions of children in 1973, 1983, 1993, and 2003 for the number of dfs/DFS among 5- and 15-year-olds. The distribution in both age-groups shows a continuously increasing skewness over time. In 2003, most of the individuals in both groups had low or moderate caries prevalence, while a small group had high caries prevalence. Among children aged 5 years, the high caries group (dfs > 15) was about 4% in 2003 compared to > 30% in 1973. In 2003, about 60% of 15-year-olds had a DFS of ≤ 5 compared to none in 1973. About 7% had a DFS

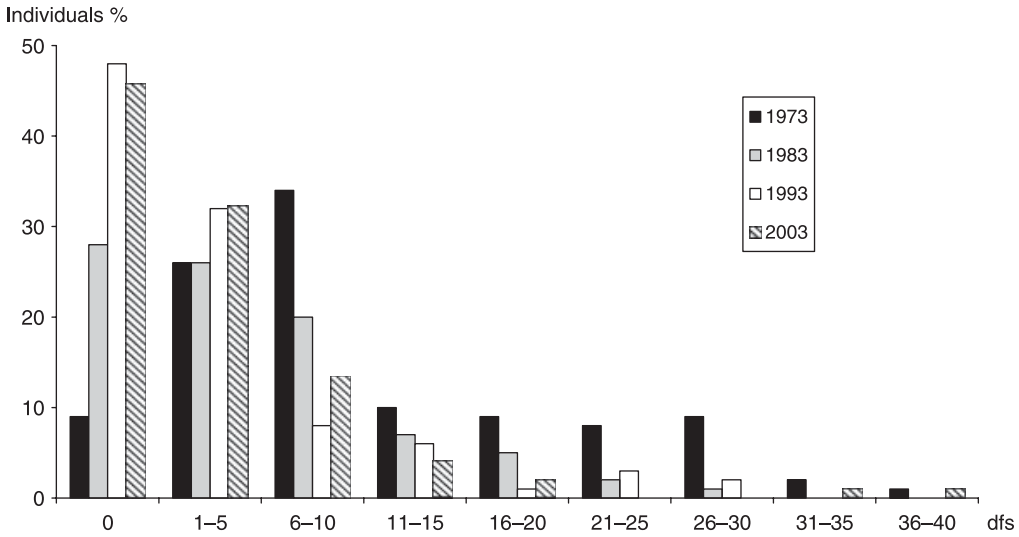

Fig. 3. Percentage distribution of children aged 5 years according to number of decayed and filled primary tooth surfaces (dfs).

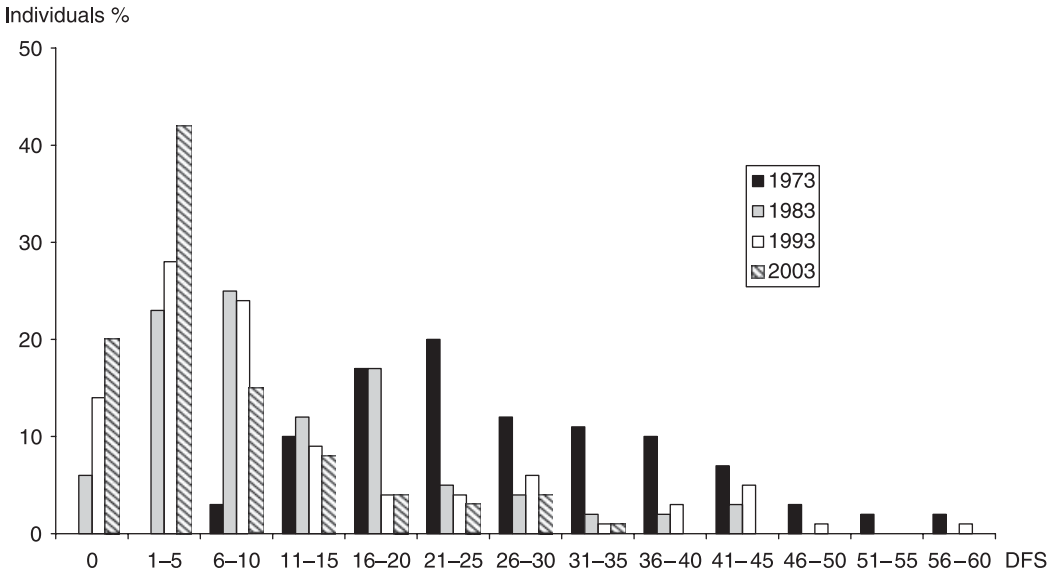

Fig. 4. Percentage distribution of adolescents aged 15 years according to number of decayed and filled permanent tooth surfaces (DFS).

of ≥ 26 in 2003, compared to more than 45% in 1973. Figure 5 illustrates the skewness in caries distribution within the 5- and 15-year age-groups. Mean values of dfs/DFS in 1993 and 2003 for the 5- and 15-year age groups as a whole and for the subgroups with the highest dfs/DFS values (30% and 10%, respectively) are shown. DFS reduced during the last 10-year period for the entire 15-year age group as well as for the groups with high DFS values. A less pronounced reduction was observed among 5-year-olds, however. In 2003, the mean value of dfs/DFS in the 10% of individuals with the highest dfs/DFS in the 5- and 15-year age-groups was about four times the mean value for the age group concerned as a whole.

Discussion

When this series of studies began in 1973, oral health in children and adolescents in Sweden was poor. Restorative treatment available for the primary dentition was limited, and there

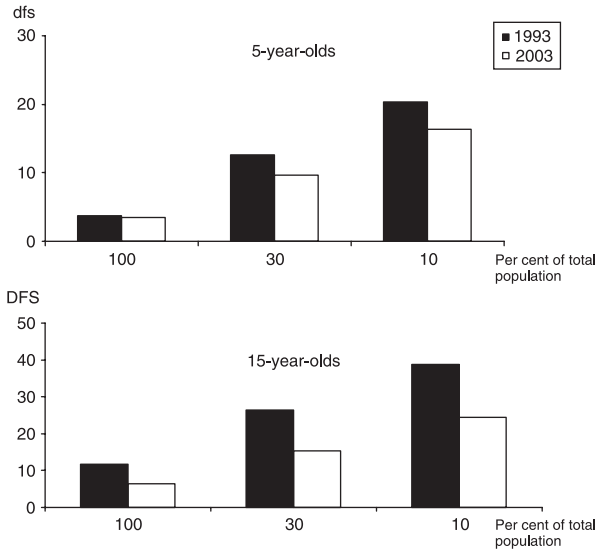

Fig. 5. Mean caries prevalence in 5- and 15-year-olds for the whole age-group and for 30% and 10%, respectively, of children with highest dfs/DFS values.

was no organized preventive dental care system. Systemized preventive dental care for children aged 0–16 years was first implemented in Sweden in 1974–1976[5]. This system was gradually adapted to the needs of the child and adolescent populations, from an initially population-directed approach to a more individualized one. The oral health changes observed in this series of studies should be analysed against this background.

It is also important to point out that the definition of carious lesions used in this study series includes both initial caries (caries restricted to enamel) and manifest caries (caries in the enamel and dentine), contrary to most epidemiological studies on caries prevalence (including the definition recommended by the World Health Organization)[13]. This study series therefore describes more accurately the total caries disease compared to most other studies, which underestimate caries prevalence. The identification of initial carious lesions is of utmost importance for the prevention of caries disease[14].

All clinical and radiographic studies on caries involve a methodological error in the diagnosis of caries. This error can increase depending on the diagnostic criteria, if several examiners are involved, and if the studies span several years. All examiners were therefore calibrated for the diagnostic criteria against two senior examiners, to minimize interexaminer variability. The re-examinations by the two senior examiners of a sample of radiographs from different ages and time points revealed an acceptable inter-examiner agreement.

The 30-year series of epidemiological studies presented here shows a dramatic decrease in caries prevalence over time among children and adolescents aged 3–20 years. A similar decrease in caries prevalence was found among 4-year-old children in a separate series of epidemiological studies covering a 35-year period[15]. Concurrent with the period covered in this paper, systemized preventive dental care was implemented and developed in Sweden[16]. This preventive population-directed system, and individualized measures for at-risk individuals or those with high caries activity, are based on the repeated epidemiological studies.

Although the number of individuals in the present surveys might be looked upon as rather small, it has been large enough to describe trends in the change in caries prevalence over time in different age groups.

An interesting finding was that the most important improvement in caries levels occurred within the first 5 years, namely between 1973 and 1978. During this period, the mean number of dfs/DFS decreased by about 50%. This was most evident in the number of carious surfaces. The introduction of a systematic use of fissure sealant in the 1980s resulted in a marked drop in the number of decayed occlusal surfaces[16]. In fact, most of the improvement seen in DFS among 10- and 15-year-olds can be explained by the reduction of occlusal caries. This underlines the importance of fissure sealants in any preventive care programme. Eliminating bacterial deposits in the fissures may also result in fewer proximal caries lesions[17].

The increase in dfs in 3-year-olds between 1993 and 2003, however nonsignificant, was found mostly on occlusal and buccal-lingual tooth surfaces and thus did not correspond to the caries prevalence of the proximal tooth surfaces where dfs decreased.

The study series shows a considerable decrease in the numbers of restored proximal tooth surfaces on a group level over the observation period, especially within the permanent dentition. But the numbers of carious proximal

surfaces showed less reduction and variation over time. Among 15-year-olds, the numbers of carious proximal surfaces were 4.7 (1973), 4.3 (1983), 5.3 (1993), and 2.6 (2003). The number of initial carious lesions as a proportion of the total number of carious lesions increased (at the cost of manifest lesions). Caries disease progression may therefore be restricted, implying that initial carious lesions will not develop into manifest carious lesions that require restoration. This is most evident in the permanent dentition, while caries progression in the primary teeth does not display the same level of reduction. It is important to remember that there is always a number of manifest carious lesions that are not restored, depending on subjective judgements of lesion progression and treatment strategy. The overall improvement in oral health, though, is clearly due to preventive dental care, both on a population and an individual level.

Despite the encouraging reduction in caries disease on a population level, the frequency distributions clearly indicate several individuals with high disease activity. Compared to the earlier time points, the 2003 frequency distribution for 15-year-olds shows more individuals to the left of the distribution curve. Importantly, no significant change in the distribution of caries was seen among 5-year-olds. Furthermore, the distribution also plainly shows that several children and adolescents have high disease activity and require extra attention. These results have been used for both local planning of dental care resources in the long term and to evaluate introduced preventive measures. For example, the 1993 study showed that adolescents aged 15 years had increased caries disease compared to 1983[18]. Consequently, additional preventive measures were applied to this and younger age groups.

A general discussion of the most effective preventive strategies might be based on an analysis of mean values of dfs/DFS in all age groups as a whole and for the subgroups with the highest dfs/DFS values (e.g. 30% and 10%, see also Fig. 5); for example, should preventive measures be population directed or individualized, targeting at-risk individuals only[19]. In summary, only minor differences between the entire group and the subgroups may indicate that a population-directed strategy is appropriate. Large differences between the entire group and the subgroups may in turn indicate that implementation of a high-risk individualized strategy would be more effective.

To conclude, this study shows improved dental health among most adolescents in Jönköping in 2003 compared with previous years. This improvement was not seen in the primary dentition, however, during the last 10 years of the study series. This aligns with other studies that found no further decrease in caries prevalence in the primary dentition[20]. Indeed, increasing caries prevalence in the primary dentition has been reported[15]. This requires immediate attention as recent studies show that caries in the primary dentition are highly correlated with later caries development in the permanent dentition[21–24]. Because caries disease is ever-present, it is important to continually follow changes in oral health with repeated epidemiological studies to be able to institute necessary preventive measures.

What this paper adds

This paper provides new information and in-depth analysis of:

- Caries prevalence and distribution among children and adolescents over a 30-year period
- The relation between initial and manifest carious lesions on proximal tooth surfaces in the permanent dentition at different ages and years of examination

Why this paper is important to paediatric dentists

It highlights the importance of repeated local epidemiological studies to:

- Analyse changes in caries prevalence
- Evaluate the effects of preventive measures, such as fissure sealing
- Plan for future preventive dental care needs

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