

Outcomes of a Non-Operative Caries Treatment Programme for Children and Adolescents

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Key Words

Caries prevention · Children · Non-operative caries treatment programme · Risk assessment

Abstract

This study assessed the effectiveness and performance of a non-operative caries treatment programme (NOCTP) used since 1987 in the municipality of Nexö in Denmark. The NOCTP emphasizes mechanical plaque control and considers the eruption period of molar teeth as a risk factor. The mean DMF-S among 18-year-olds in 1999 and 2000 in Nexö was 1.23 ± 2.26 and 1.25 ± 2.01 (medians 0); 55 and 56% had DMF-S = 0. The mean numbers of sealed surfaces were 4.6 ± 3.25 and 4.0 ± 3.22 , respectively. The cost per child per year was marginally and significantly reduced in the years with the NOCTP compared to that before 1988 ($p = 0.05$). In 4 comparison municipalities with very low caries experience, mean DMF-S scores among 18-year-olds in 1999 were 2.73–3.25 (medians 1–2) and were significantly higher than in Nexö ($p < 0.001$). The NOCTP differed from the preventive programmes used in the comparison municipalities in the period 1988–1999 in emphasising care for the erupting molars, the use of a firm guideline and stated goals to be achieved, but with less emphasis on diet. The effectiveness and performance of the NOCTP were both considered high, as very low DMF-S and high %DMF-S = 0 had been achieved by 1999, and 18-year-olds in Nexö had significantly less caries than in the

comparison municipalities. The latter difference could not be explained by difference in caries-related background variables.

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The Public Dental Health Service for Children (PDHSC) was instituted in Denmark by the Child Dental Health Care Act of 1971 [Friis-Hasché, 1994]. The Act required that all 275 municipalities in Denmark establish oral health clinics for the management of school children. A later amendment included preschool children and 16- to 18-year-olds [Friis-Hasché, 1994].

With the implementation of the PDHSC in 1972, a compulsory system for recording the oral health of the individual child was introduced [Helm, 1973]. Today the registrations are compulsory only for children aged 5, 7, 12 and 15, but each municipality can choose to do registrations in all age cohorts. The registrations are done on standardized optical readable forms (OCR forms). The municipalities send copies of these forms to The Danish National Board of Health, which treats the data and, on a yearly basis, reports the results back to each municipality. Thus, data are not directly open to the public, but it is possible for researchers to get access to data and publish them, although only after application. Based on such data, a number of studies [Helm, 1973; Schwartz et al., 1994; Poulsen and Scheutz, 1999] have disclosed a dramatic reduction in D_3 DMF-S among children and adolescents from the mid 1970s to the mid 1990s. Since then,

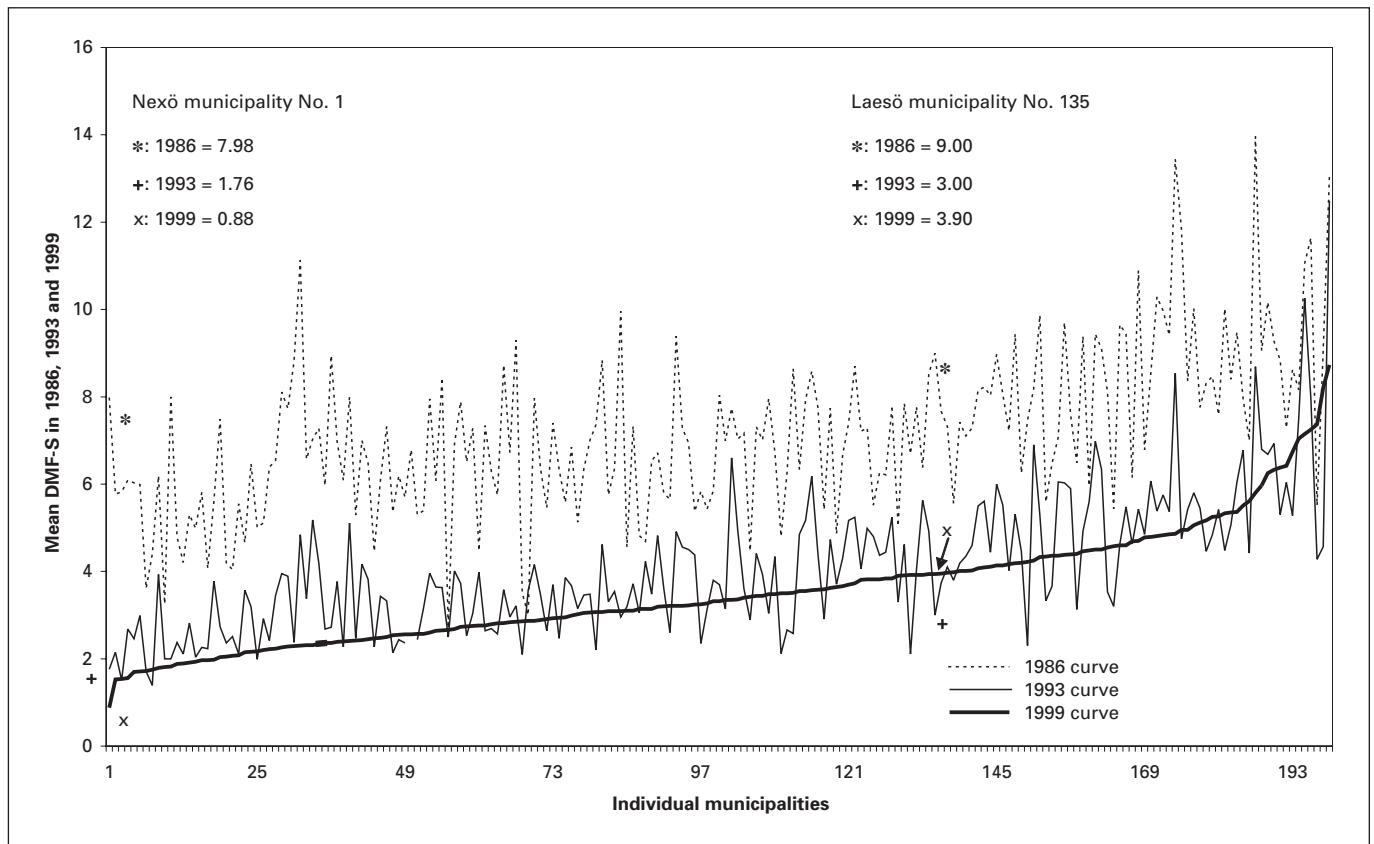


Fig. 1. Mean DMF-S among 15-year-olds in 1986 (upper curve), 1993 and 1999 (bold line) in 200 municipalities in Denmark. The municipalities are arranged according to DMF-S in 1999 (bold line). Nexö, with the lowest mean DMF-S in 1999, is thus the left-hand municipality. Laesö is an example of a municipality which faced an increase in DMF-S from 1993 to 1999.

DMF-S at the national level has been constant [Poulsen and Scheutz, 1999], e.g. around 3.2 DMF-S in 15-year-olds.

Figure 1 documents the reduction in caries in Denmark as well as the inter- and intramunicipality variation in mean DMF-S among 15-year-olds in the public clinics, using the years 1986, 1993 and 1999 for reference. Some municipalities show a continuing drop in mean DMF-S from 1986 to 1993 and further to 1999. In others (28%), the mean DMF-S dropped from 1986 to 1993, but increased in 1999; one example is the municipality of Laesö, as shown. In 1999, 15-year-olds in the Nexö municipality had the lowest mean DMF-S in the country and the third lowest in 1993 (fig. 1). The mean DMF-S in Nexö in 1986 (7.98 DMF-S) was a little higher than the average (7.15 DMF-S) of all the municipalities.

Since 1987, the dental service in Nexö has used a special non-operative caries treatment programme (NOCTP)

for children and adolescents (www.nexodent.com). The scientific rationale of the NOCTP is described below. The aims of this study were: (1) to assess the effectiveness of the NOCTP in relation to pre-stated goals; (2) to assess the performance of the NOCTP by comparing the outcomes achieved in Nexö with those in 4 other dental services, which in 1999 had very low caries rates. Relevant caries background variables, which differ among municipalities, were taken into account.

Description of the NOCTP

Municipality and PDHSC in Nexö

Nexö is situated on Bornholm, an island in the Baltic Sea. It is an area of Denmark with a very low socio-economic status [Statistics Denmark, 1997] and a population during the 1990s of 8,000–9,000 inhabitants. Nexö be-

came a municipality with a public clinic in 1976. From 1976 to 1987, most preventive initiatives were not directly related to the needs of the individual child. Outside the clinical facilities, health education of parents, children and key persons was given as group lectures on the multifactorial concept of caries. At the clinic, regular dental examinations were performed every 6–8 months. Prior to these examinations, groups of schoolchildren were instructed in tooth brushing. Topical applications of fluoride and sealants were used on the majority of the children, but were not based on caries risk assessment or strict indications.

The NOCTP was implemented at the end of 1987. The programme is offered to all children from the time when the permanent first molar teeth begin to emerge. Since 1992, the program has been offered to children from the age of 8 months. It is based on three closely interrelated principles applied according to the individual child's needs: (1) education of parents, children and adolescents in understanding dental caries as a localized disease, (2) intensive training in home-based plaque control and (3) early professional, non-operative intervention, including professional plaque removal, local application of 2% NaF and application of sealants. In the period when the children have erupting permanent first or second molars, the parents and children are instructed in using a tooth brushing technique specially designed for erupting molar teeth [Carvalho et al., 1991].

Goals

In 1987, the objectives stated in Nexö [unpubl. data] were: children and adolescents in Nexö should have the lowest caries experience in Denmark at the end of the 20th century; the expenditure per child per year should not exceed pre-1988 values. The operational goals for the 18-year-olds were: that no permanent tooth should be extracted or root canal treated due to caries, that the mean DMF-S should be less than 2.0 and that more than 50% of the cohorts should have a DMF-S = 0. Fissure sealants should be used only in case of continued occlusal caries progression despite fluoride application and plaque control. The DMF-S target was based on mathematical calculations as suggested by Heidmann and Poulsen [1986].

Scientific Rationale of the NOCTP

One concept of the caries disease among others considers: (1) no or limited functional attrition, (2) microbial deposits, (3) fermentable carbohydrates and (4) time as necessary factors to develop caries [Holmen et al., 1988; Thylstrup et al., 1994]. In accordance with Sögaard

[1986], the clinical experience of the authors has been that it is extremely difficult to control children's consumption of fermentable carbohydrates. Therefore, the overall focus of attention in the NOCTP has been on plaque control – home-based but also professional – in stagnation areas where the limited functional attrition would otherwise allow plaque to develop. Particular emphasis was placed on explaining to parents and their children that mechanical forces, including adequate tooth brushing, control caries progression by disturbing the plaque, whereas fluoride may only slow down progression [Fejerskov et al., 1981]. The professional plaque removal at each visit served three purposes [Koch et al., 1986]: (1) it formed the basis for the assessment of actual caries activity, (2) it favoured the arrest of active subclinical and clinically visible carious lesions and (3) it created a basis for educating the patient. Local fluoride application was only used on the basis of an active caries diagnosis, as suggested by Fejerskov et al. [1981]. It was mandatory to seal only when the occlusal surface had active caries at an early stage, and only after several attempts using plaque control and local application of fluoride had failed to arrest progression; several papers have shown that sealants can arrest ongoing initial lesions [Handelman et al., 1981, 1985]. Lesions were treated operatively when the dentine was considered to be infected, i.e. after cavitation [Thylstrup and Qvist, 1986] or where radiolucency was well into the dentine [Ricketts et al., 2002].

Four variables were used to determine the timing of the next visit (table 1): co-operation; caries in progression; eruption stage of molar teeth, and caries progression on the occlusal surfaces of molar teeth. Co-operation was assessed using the risk indicators plaque accumulation [Holmen et al., 1988; Axelsson 1998] and gingival health [Thylstrup and Birkeland, 1986]. Previous caries experience is a strong predictor for future caries [Demers et al., 1990] also in non-cavitated stages [Klock and Krasse, 1979]. The variable 'caries in progression', whether in general or specifically at the occlusal surfaces on molar teeth, was therefore clearly to be included in the judgment of the duration of the interval until the next visit. A risk factor exposes the host to the causal chain [Beck, 1998] and, as it has been shown that the eruption period favours plaque accumulation on the occlusal surface because of limited attrition from the antagonists [Carvalho et al., 1989, 1991; Ekstrand et al., 2000], the NOCTP assesses the eruption periods of permanent first and second molars as a risk factor. Thus, no child in Nexö with erupting permanent molar teeth had an interval longer than 4 months before the next visit and this was shortened

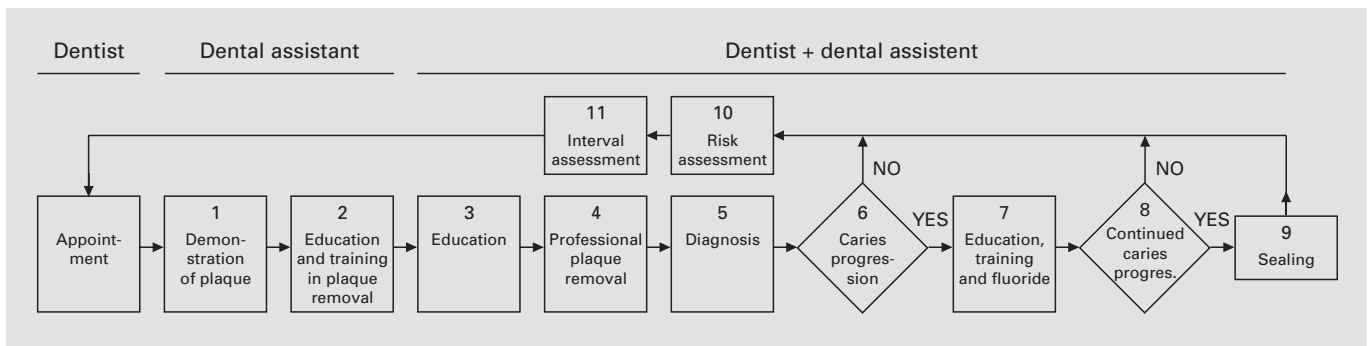


Fig. 2. Flow chart showing the clinical process of the NOCTP, which the child follows at each recall visit.

further if the clinical examination disclosed other risk indicators or evidence of progressing caries. In the worst situation (table 4, last column), the interval was only 1 month. This interval was chosen for two reasons. First, professional cleaning of children's teeth performed at intervals from every fortnight to every second month seems to be sufficient to control caries development [Axelsson and Lindhe, 1974; Bellini et al., 1981]. Second, in vitro studies indicate that calcium fluoride formed by one application of 2% NaF for 1 min will be sufficient to interfere optimally with the active lesion for at least 1 month without being repeated [Bruun and Givskov, 1991].

The Guideline

A fundamental aspect of the NOCTP is that the parents take an active part until the children are at the age of about 10.

Figure 2 describes the clinical process of the NOCTP, which the individual child follows at each visit. Initially, a dental assistant applies disclosing solution to the child's teeth to demonstrate plaque accumulation (point 1). Then training of the child and parents in tooth brushing and/or flossing (point 2) is performed. In the dental chair, the child receives need-related education, based on the observations of plaque accumulation and distribution (point 3), from the dentist together with the dental assistant. Any remaining plaque is then professionally removed (point 4), followed by the diagnostic process (point 5). If active incipient caries is diagnosed (point 6), further education is given related to the location of the active lesion in the dentition, and 2% NaF is applied locally (point 7). If occlusal caries has been recorded as having progressed during several recalls (point 8), the lesion is sealed (point 9). The final step is to assess the interval to the next appointment (points 10 and 11), which

Table 1. Criteria for planning the recall interval in the NOCTP

	1 point	2 points
Co-operation (risk indicators)	adequate	inadequate
Caries in progression on one or more surfaces (diagnosis)	no	yes
Stage of eruption of permanent molar teeth (risk factor) ¹	full occlusion	partial eruption
Occlusal caries progression on erupting molar teeth (diagnosis) ¹	no	yes

¹ When there are no erupting molar teeth, only the co-operation and caries in progression are used to assess the recall interval, and a modified point system is used.

is based on summation of the 4 parameters in table 1. Thus, 8 points are achieved if there is inadequate co-operation (2 points), caries in progression in one or more surfaces (2 points), permanent molars partly erupted (2 points) and caries in progression on the occlusal surface on erupting molar(s) (2 points). This corresponds to a 1-month interval to the next visit. Seven points result in a 2-month interval, 6 points a 3-month interval, 5 points a 4-month interval and 4 points (adequate co-operation, no caries in progression at any surfaces and no permanent teeth partly erupted) a 6- to 14-month interval.

Subjects and Methods

Sample 1

The two cohorts, born in 1981 and 1982, who became 18-year-olds in 1999 and in 2000, were the focus of this part of the study. In 1981 and 1982, 91 and 92 children were born in the municipality (fig. 3). Of these children, 88 and 80 were still in the dental

	Cohorts in Nexö				Comparison cohorts			
	Born in Nexö in 1982 (n = 92)		Born in Nexö in 1981 (n = 91)		Born in 1981 (1) Lyngby-Taarbæk (n = 392) (2) Sölleröd (n = 267) (3) Vaerlöse (n = 176) (4) Bramsnaes (n = 79)			
	Sub-cohort (n)	Total cohort (n)	Sub-cohort (n)	Total cohort (n)	Total cohort (n)			
				(1)	(2)	(3)	(4)	
Age 5	80	99	88	100	420	298	206	86
Age 15	76	107	75	96	436	329	206	98
Age 18	49	80	53	74	293	170	173	56
Year	2000		1999		1999			

Fig. 3. Diagram showing the number of children/adolescents related to different age in the 2000 and 1999 cohorts in Nexö and in the 4 comparison municipalities.

service at the age of 5. In 1999 and 2000, at the age of 18, 53 (58%) and 49 (53%) still participated in the dental service. The children who had left the dental service had moved to other municipalities or had transferred to private practice. The children born and raised in Nexö and who had followed the programme from age about 5 until the age of 18 will be called subcohorts 1981 and 1982, respectively.

In addition, a number of children born in 1981 and 1982 elsewhere had moved to Nexö during the years (newcomers) and were integrated into the dental service. Thus, the total cohort of children (fig. 3) at any point in time consisted of children born in Nexö as well as newcomers. The total numbers of 18-year-olds in Nexö in 1999 and 2000 were 74 and 80, respectively, of which 53 (72%) and 49 (61%) were born and raised in Nexö.

Caries Experience

DMF-S figures of each individual in the total 1981 and 1982 cohorts were extracted annually from the OCR registration forms from age 5 to age 18. In spite of the fact that it is not compulsory [Danish National Board of Health, 1988], the dentists in Nexö, in accordance with the research protocol, also recorded sealants placed at the surface level on the registration forms.

Bitewing radiographs were taken of the 18-year-olds in the total 1999 and 2000 cohorts. As far as possible, an identical sagittal position of the film holder (Kwik Bite film-holder, Hawe-Neos, Switzerland) in relation to the permanent first molars was obtained. The X-ray machine had a pointed cone, and the focus-to-skin distance was 5 cm. The exposure data were 65 kV, 7.5 mA and 0.6 s. The films used were (extra) speed group E automatically processed under standardized conditions.

All bitewing radiographs were examined for caries by the first author using Mattson's magnifying glass (Dental X-ray, Copenhagen, Denmark) on a light board in a dark room. The following surfaces were examined: occlusal and mesial surfaces on permanent

second molar teeth, distal, occlusal and mesial surfaces on permanent first molars and second premolar teeth and finally the distal and occlusal surfaces on first premolar teeth. For the purpose of this study, only the prevalence of lesions deeper than the outer third of the dentine (D2) will be reported, as these should have been restored.

Calibration

No attempts were made to calibrate the dentists involved, as the clinical recordings followed the routine system used in all PDHSCs in Denmark [Danish National Board of Health, 1988]. As in Denmark more than 90% of the DMF-S are related to the F-component [Poulsen and Scheutz, 1999], the reliability of the DMF-S index was, however, considered to be high.

In order to blind the examiner doing the radiographic readings as much as possible, almost 175 sets of bitewing radiographs were mixed with the radiographs from the total cohorts of 1999 and 2000. The extra radiographs were selected from 18-year-olds, who had also participated in the service, but were born in 1975–1980. A total of 320 sets of bitewing radiographs were examined, of which 15% were re-examined. One week elapsed between the first and second readings.

Costs of Preventive Programmes and Number of Visits in Nexö

The cost per child per year in Nexö in the period from 1980 to 1999 was collected from the municipality office and converted to 1980 costs using conversion factors published by The Organization of the Municipalities in Denmark.

The total number of caries-related visits was counted for those children who had followed the programme from age 5 till age 18 (subcohorts). As a comparison, similar data were obtained from a group of children aged 5 years in 1980 who became 18-year-olds in 1993, but who had not received the NOCTP.

Table 2. The questions asked and the answers received from the chief dental officers in Nexö and the 4 comparison municipalities

Question	Nexö	Lyngby-Taarbaek	Sölleröd	Vaerlöse	Bramsnaes
Has the dental clinic been a clinical municipality for the whole period?	yes	yes	yes	yes	yes
Has the chief dentist been the same during the whole period?	yes	yes	yes	yes	no
What is the percentage of exchanged dentists in the period? 0, 1–25%, 26–50%, 51–75%, >75%?	0	26–50	>75	0	>75
Has the dental clinic had a general objective?	yes	yes	yes: 1996	yes	yes
If the answer to question 4 is yes, has there been a caries objective for the years in question?	yes	yes: 1997	no	yes	no
If the answer to question 5 is yes, was the DMF-S included in the objective?	yes	yes: 1997	no	yes	no
What should the DMF-S be for 18-year-olds at the end of the 20th century?	<2	not stated	not stated	2.8	not stated
Did your dental clinic use a guideline, e.g. like the one in Nexö for non-operative caries treatment of all children?	yes	no	no	no	no
What percentage of children have received individually planned tooth-brushing instructions at their appointments for check-up and control (0–25%, 26–50%, 71–75%, 76–100%)?	100	0–25	51–75	?	?
Did diet advice play an important part in your caries prevention programme?	no	yes	yes	yes	no
Does your dental clinic regard the eruption period of permanent molars as a risk factor?	yes	no	no	yes	?
Does the stage of eruption of permanent molars influence your evaluation of the length of intervals until next visit?	yes	no	no	yes	no
Does your dental clinic use fissure sealing?	yes	yes	yes	yes	yes
The indication of fillings in permanent teeth is in the literature mentioned as caries, which clinically/radiographically is well into the dentine. Did your dental care vary in general from this indication?	no	no	no	no ¹	no

? = Do not know; 1996, 1997 = since that year.

¹ In dentine but not deep into dentine.

Sample 2

The Danish National Board of Health was contacted in 2000 in order to find those municipalities with the second to fifth lowest mean DMF-S among 18-year-olds in 1999, and consent to use the data was obtained. Three of the comparison municipalities (Lyngby-Taarbaek, Sölleröd and Vaerlöse) had >20,000 inhabitants and were among the wealthiest municipalities in Denmark situated on Zealand, close to Copenhagen. The fourth municipality, Bramsnaes, also situated on Zealand, is small but with a lower socio-economic status than the three others [Statistics Denmark, 1997]. Figure 3 also provides an overview of the comparison cohorts involved in this study. The total number of 18-year-olds in 1999 in the comparison municipalities was 293, 170, 143 and 56.

Evaluation

DMF-S data from those 18-year-olds in the 4 comparison municipalities who were still in the dental service in 1999 were obtained from the Danish National Board of Health. The preventive

programmes used in the comparison municipalities and in Nexö were evaluated using a questionnaire (table 2). The interview was conducted by the first author over the telephone. Initially, the chief dental officers were asked whether they would participate, and the aim was explained carefully to them. All agreed. The 14 questions were asked in the order given in table 2 and the answers were noted on paper. The questions and the answers from the individual municipality were then sent to the chief dental officer for correction and returned.

Background Variables

Table 3 shows the 8 background variables used in this study and data are presented from those 143 municipalities (approx. 70% of the total number of municipalities with public clinics) which had forwarded caries data on 18-year-olds in 1999 to the Danish National Board of Health. The background variables (described in more detail by Ekstrand et al. [2003b]) were: cost per child per year (mean for 1995–1999); child/dentist ratio (mean for 1987, 1990,

Table 3. Summary of the independent variables and statistics for all municipalities, Nexö and the 4 comparison municipalities

Variables	Statistics for all municipalities	Nexö	Lyngby-Taarbaek	Sölleröd	Vaerlöse	Bramsnaes
Cost per child per year (mean), DKK	range: 928–1,732 first quartile: 1,155 median: 1,253 third quartile: 1,333	1,172	1,216	1,403	1,128	1,255
Child/dentist ratio (mean)	range: 608–1,230 first quartile: 774 median: 826 third quartile: 912	710	879	912	954	795
Auxiliary personal/dentist ratio (mean)	range: 1.2–3.2 first quartile: 1.8 median: 2.0 third quartile: 2.2	1.2	1.8	1.9	2.1	2.1
Concentration of fluoride in the water supply (mean), ppm	range: 0.0–1.4 first quartile: 0.1 median: 0.3 third quartile: 0.4	0.8	0.4	0.4	0.3	0.4
Personal income (mean), DKK	range: 134,000–235,000 first quartile: 146,000 median: 151,000 third quartile: 159,000	138,000	192,000	235,000	211,000	169,000
Mothers with less than 10 years of education, %	range: 13.8–60.6 first quartile: 33.3 median: 39.0 third quartile: 44.1	46	20	16	15	33
Immigrants (median), %	range: 0.8–19.1 first quartile: 1.6 median: 2.5 third quartile: 4.6	2	6	7	5	2
Size of the municipalities in terms of number of 0- to 18-year-olds (mean)	range: 549–72,901 first quartile: 2,086 median: 3,380 third quartile: 6,076	2,010	9,245	6,572	4,457	2,002

1993, 1996 and 1999); auxiliary personnel/dentist ratio (mean for 1987, 1990, 1993, 1996 and 1999); fluoride concentration in the water supply (F_{water}) (mean for 1989–1998); personal income (mean for 1989–1998); mothers' education (percentage of mothers of 18-year-olds in 1999 with ≤ 10 years of education); proportion of immigrants and their descendants (median for 1989–1999); size of municipality (mean total number of 0- to 18-year-olds in the municipality in 1989 and 1999).

Statistical Analysis Effectiveness

The mean DMF-S, percentage of children with DMF-S = 0 and the number of sealants (S-S) of each child in the 1981 and 1982 cohorts in Nexö were followed annually from the age of 5 to the age

of 18. However, the mean DMF-S data and percentage of children with DMF-S = 0 will only be presented for ages 5, 15 and 18 and the mean number of S-S only at the age of 18.

Because the data were not normally distributed, Wilcoxon-Mann-Whitney tests were used to test whether the mean DMF-S and the mean S-S figures among 18-year-olds in 1999 and 2000 were different.

A Wilcoxon signed rank test (paired samples) was used to test whether the cost per child per year in Nexö during the period with the NOCTP was the same as before the NOCTP had been implemented.

The distributions of children in relation to their total number of caries-related visits at the clinic were positively skewed in all three groups. Any difference concerning the number of visits be-

tween the groups was tested by the Kruskal-Wallis one-way analysis of variance. Spearman's correlation coefficient (r_s) was used to express the correlations between the number of visits and DMF-S in each group.

Performance

Because the DMF-S data were not normally distributed, the Kruskal-Wallis one-way analysis of variance was employed to test whether there was any difference in caries experience between the municipalities studied.

Ekstrand et al. [2003a] assessed the influence of the 8 background variables by multiple regression and calculated the predicted mean DMF-S, the predicted %DMF-S = 0 for 18-year-olds in each municipality, as well as the standardized residuals. In the present study, these values were presented for Nexö and the 4 comparison municipalities. The level of significance was set at 1%, corresponding to a confidence interval of ± 2.58 .

Results

Effectiveness in Relation to Goals

No 18-year-olds in the two total cohorts had had permanent teeth extracted or had been root canal treated due to caries.

Table 4 shows mean DMF-S and the percentage of children with DMF-S = 0 from the age of 5, 15 and 18 for the total cohorts and subcohorts. At the age of 5, the mean DMF-S was 0, increasing to about 1 in the total cohorts and about 0.5 in the subcohorts by the age of 15. At the age of 18, the mean DMF-S in the total cohort/subcohort in 1999 was $1.23 \pm 1.96/1.04 \pm 1.69$. The corresponding figures for the total cohort/subcohort in 2000 were $1.25 \pm 2.01/1.16 \pm 2.09$.

At age 5, all children had DMF-S = 0 (table 4). At age 15, in 1996 and 1997, more than 60% of the children had DMF-S = 0, decreasing to 55–59% at age 18 in 1999 and 2000. Therefore, all the medians were 0 (ranges of DMF-S in 1999 0–8 and in 2000 0–9; $p > 0.8$).

In general, the mean DMF-S and DMF-S = 0 for newcomers at all age groups were higher than for children born and raised in Nexö. However, the difference only became significant in the age groups 14–17 ($p < 0.05$).

More than 90% of the DMF-S consisted of the F-component, both in the total cohorts and in the subcohorts. The occlusal surfaces on permanent first molars were filled in 8–13% of the two total cohorts/subcohorts, and these were the surfaces most often filled.

The mean number of sealed surfaces among 18-year-olds in 1999 was 4.62 ± 3.25 (total cohort) and 4.72 ± 3.25 (subcohort). Similar figures for the 18-year-olds in 2000 (total cohort/subcohort) were $4.01 \pm 3.22/3.92 \pm$

Table 4. Mean DMF-S and %DMF-S = 0 in the different cohorts at different ages in Nexö

	Total cohort 1981	Sub-cohort 1981	Total cohort 1982	Sub-cohort 1982
Age 5				
Mean DMF-S	0.00	0.00	0.00	0.00
%DMF-S = 0	100	100	100	100
Age 15				
Mean DMF-S	1.34	0.66	0.98	0.53
%DMF-S = 0	60.4	66.0	60.8	71.4
Age 18				
Mean DMF-S	1.23	1.04	1.25	1.16
%DMF-S = 0	55.4	54.7	56.3	59.2

3.33. The medians were 5 and 5 (range 0–14) in 1999 and 5 and 4 (range 0–15) in 2000 ($p > 0.1$).

Only 3 18-year-olds in 1999 had D2 lesions. Two had 1 lesion each. The third had 2 lesions. Also 3 18-year-olds in 2000 had D2 lesions, one each.

The average cost per child per year in Nexö in the period from 1980 to 1988 (before NOCTP) was DKK 622 (SD = 79.8), while during the period from 1988 to 1999 it was DKK 526 (SD = 46.7). The medians were DKK 613 (range 521–760) and DKK 552 (range 445–607), corresponding to a significant marginal reduction in cost per child per year of about DKK 100 ($p = 0.05$) in those years when the NOCTP had been in effect.

The lowest number of visits during the 13-year period (age 5–18) was 24, both in the 1999 and 2000 groups. The highest numbers of visits were 61 and 65. The first quartiles were 30 and 29, the medians were 35 and 33 and the third quartiles were 42 and 39. In the comparison group (1993) from Nexö ($n = 88$), similar figures were observed: range 20–66, first quartile 27, median 33 and third quartile 38 ($p = 0.3$).

Weak or moderate correlation was noted between the number of visits and the number of DMF-S in the 1999 group ($r_s = 0.30$) and the 2000 group ($r_s = 0.49$). The mean DMF-S in the 1993 group was 3.73 ± 4.16 and r_s was 0.75.

For those children in the third quartiles (14 children in the 1999 group and 13 in the 2000 group), the ranges of DF-S were 0–8 and 0–9 (medians 1 and 2). In the comparison group ($n = 22$), the range of DF-S was 0–19 (median 8).

Table 5. DMF-S data for 18-year-olds in Nexö and in the comparison municipalities

	Nexö 1999	Lyngby- Taarbæk	Sölleröd	Vaerlöse	Bramsnaes	Nexö 1993
Age 18						
n	74	293	170	134	56	89
Mean DMF-S (SD)	1.23 (2.26)	2.73 (3.94)	3.11 (4.48)	3.25 (4.80)	3.09 (5.11)	3.93 (3.77)
%DMF-S = 0	55	36	24	28	39	28
>8 DMF-S, %	3	7	9	7	11	13
>12 DMS-F, %	0	3	4	5	11	11
Median DMS-F	0	1	2	2	1	2
Mean S-S (SD)	4.6 (3.2)	3.1 (2.9)	3.3 (2.8)	3.0 (2.6)	no data	4.6 (2.2)

Performance

Table 5 presents DMF-S data for 18-year-olds in 1999 in Nexö and the 4 comparison municipalities. The mean DMF-S in the comparison municipalities varied between 2.73 and 3.25, versus 1.23 in Nexö. In all municipalities, the F-component accounted for >90% of the DMF-S.

Fifty-five per cent of 18-year-olds in Nexö in 1999 had a DMF-S = 0 (median 0). In the comparison municipalities, %DMF-S = 0 ranged from 24 to 39% (medians 1 or 2). The DMF-S level in Nexö in 1999 was significantly lower than in the external comparison municipalities ($p < 0.001$) and in the municipality with the second lowest DMF-S (Lyngby-Taarbæk; $p < 0.001$). DMF-S in the 4 comparison municipalities did not differ significantly ($p = 0.11$). Only 3% of the 18-year-olds in 1999 in Nexö had more than 8 DMF-S, while the same figure for the comparison municipalities ranged between 10 and 22%.

In all cohorts, the occlusal surfaces on permanent first molars were the ones most often filled, varying from 10% in Nexö in 1999, to between 24 and 28% in the comparison municipalities. On average, 18-year-olds had around 3 sealed surfaces in 3 municipalities and in Nexö 4.6 (table 5). As one comparison municipality did not report on sealants, no statistical test was made.

It appears from table 2 that there were some differences within the 4 comparison municipalities concerning: stability of the staff (question 3); description of operational DMF-S goals for 18-year-olds (questions 5–7), and the effort put into different preventive methods (questions 9, 11, 12).

The general differences from Nexö were that the dentists in Nexö had been the same in the period in question (strong stability), that Nexö had had an operational DMF-S goal for 18-year-olds, that all the children received in-

dividualized tooth brushing instructions each time they attended the clinic, that the dentists in Nexö used a guideline (flow chart, fig. 2) for all children and that the eruption period of molar teeth was considered a risk factor. Only Vaerlöse also considered the eruption period as a risk factor. On the other hand, the NOCTP did not put much emphasis on diet, which was the case in the external comparison municipalities. All the involved municipalities used sealants, and no difference was seen with respect to indications for the use of fillings.

The Influence of Background Variables

Ekstrand et al. [2003b] showed that the intermunicipality variation in mean DMF-S among 18-year-olds in 1999 in Denmark was from 1.23 to 15.54 (mean 6.5), and in %DMF-S = 0, it was 3–55% (mean 18%). They also found that only two background variables, F_{water} and the average personal income, played significant roles, explaining 53 and 30% of the intermunicipality variation in mean DMF-S and %DMF-S = 0 among 18-year-olds in Denmark in 1999. Nexö differed from the comparison municipalities in these 2 variables. Compared to the average for the country, all 5 municipalities had high F_{water} (second to third quartile), but F_{water} was higher in Nexö than in the comparison municipalities (table 3). On the other hand, the Nexö municipality was among the poorest in the country (personal income: first quartile), while the 4 comparison municipalities were all among the third richest in Denmark (third quartile).

Table 6 shows the relationship between the observed and predicted mean DMF-S and %DMF-S = 0 among 18-year-olds in Nexö and in the comparison municipalities. According to the regression model, 18-year-olds in Nexö should have had 4.5 times higher mean DMF-S (5.53 vs. 1.23) than those actually observed (standardized

Table 6. Observed and predicted DMF-S and %DMF-S = 0 among 18-year-olds in 1999 in Nexö and the 4 comparison municipalities, together with the standardized residuals

Municipalities	Observed DMF-S	Predicted DMF-S	Standardized residuals	Observed %DMF-S = 0	Predicted %DMF-S = 0	Standardized residuals
Nexö	1.23	5.53	-2.72	55.41	23.46	4.67
Lyngby-Taarbaek	2.73	4.31	-1.00	35.84	25.64	1.49
Sölleröd	3.11	2.81	0.11	24.12	29.72	-0.82
Vaerlöse	3.25	4.25	-0.63	28.36	24.81	0.52
Bramsnaes	3.09	5.56	-1.56	39.29	21.29	2.49

A standardized residual interval between -2.58 and +2.58 corresponds to a confidence interval of 99%.

residual = -2.72, $p < 0.01$). Similarly, a considerable difference was noted between observed and predicted %DMF-S = 0 in Nexö (standardized residual = 4.67, $p < 0.01$). None of the other municipalities were even close to that level, and the differences between observed and predicted values were not significant ($p > 0.01$).

Discussion

Effectiveness in Relation to Stated Goals

The analyses disclosed that the goals as stated in 1987 were largely achieved. Thus, in 1999, 18-year-olds in Nexö had the lowest mean DMF-S and the highest percentage of 18-year-olds with DMF-S = 0 among all municipalities in Denmark [Ekstrand et al., 2003b]. The mean DMF-S among 18-year-olds (both at the total cohort and subcohort levels) was less than 2, and more than 50% of the 18-year-olds in the total cohorts/subcohorts had a DMF-S = 0 (medians 0) as stated as operational goals. No teeth had been root canal treated or extracted due to caries. The clinical data in Nexö were supported by the radiographic data, as very few D2 lesions were observed. According to the protocol, such lesions needed operative treatment if they were considered active. The same low mean DMF-S and high proportion of 18-year-olds with DMF-S = 0 were obtained in two consecutive cohorts (1999 and 2000), and the most recent data from 2004 ($n = 75$) show that the mean DMF-S among 18-year-olds in Nexö is 1.21 ± 2.27 , the proportion of 18-year-olds with DMF-S = 0 is 57% and the mean number of sealants is 4.29 ± 3.03 . So, it can be concluded that the results are not restricted to one episode.

The results were obtained even though, of the children in the total cohorts, 29% in 1999 and 39% in 2000 (fig. 3)

were newcomers. As a group, the newcomers had a significantly higher DMF-S at around 15 years of age than children born in Nexö. Whether this was because newcomers had a higher DMF-S when they arrived in Nexö or a higher caries incidence during their time in the service cannot be investigated because these newcomers came to Nexö at varying times and did not join groups of the same age. The full effect of the NOCTP can only be revealed in the subcohorts, as these children have had the NOCTP from the age of about 5 to 18, and these children had a mean DMF-S at the age of 18 close to 1. However, as all PDHSCs in Denmark serve children born and raised in the municipality as well as newcomers, it was found of relevance for comparison reasons to present data on the total cohorts as well.

The cost of running the dental service in Nexö during the time with the NOCTP was significantly lower than the cost before the NOCTP had been implemented. It is important to note that the cost considerations in this study were only included to see whether in connection with the implementation of the NOCTP, the cost per child per year increased compared to the previous level in Nexö. As shown, it did not. It dropped. As it is not possible to separate the direct cost for the preventive caries programmes in the individual dental services in Denmark or in Nexö, because preventive care is an integral part of the total care, the statistics used (cost per child per year) are inadequate for economic comparisons between other preventive programmes implemented and tested outside Denmark. Finally, it must be emphasized that about 80% of the expenditures for running the PDHSC in each municipality in Denmark relate to salary [Friis-Hasché, 1994].

In analysing the number of visits and time considerations, children in the subcohorts were used, as they had

followed the service from the age of 5 to the age of 18. The results showed that there was no difference in the number of visits between the groups which had received the NOCTP and those which had followed the previous programme.

Further, children who had followed the NOCTP and had to come many times during the 13-year period (belonging to the third quartile) because of high risk ended up with low DMF-S or even with a DMF-S = 0. This explains the weak or moderate correlations between the number of visits and DMF-S in the 1999 and 2000 groups. In other words, with huge efforts children with high risk can end up with very low DMF-S with the NOCTP. This was not the trend in the 1993 group in Nexö.

Thylstrup et al. [1997], in a detailed study of the dental service of Nexö in 1992, found that the average total treatment time needed by children aged 1–17 was 40 min per year. However, the mean time varied greatly with age, ranging between 11 min for 1- to 2-year-olds to 58 min for 13- to 14-year-olds. Sixty percent of the total treatment time was related to the NOCTP, which corresponds to 24 min per year. This does not differ greatly from the average time spent on prevention in other dental services in Denmark, which Wang et al. [1998] estimated at 21 min.

Performance

Because of the low caries progression rate in Denmark, it was decided in 1987 that this study should evaluate the result of preventive programmes over the longest time possible in the PDHSC, i.e. between the ages of 5 and 18, as by law children/adolescents are leaving the PDHSC at the age of 18. Such a time frame makes it extremely difficult to carry out the study as a randomized clinical trial, which is the design offering the best possibility to control internal as well as external validity [Scheutz, 1997]. The randomized clinical trial principle of testing a new treatment (programme) against the best existing treatment (programmes) was simulated in the present design by comparing the results in Nexö to caries data in 4 other municipalities which according to the Danish National Board of Health were among those with the lowest caries experience in the country, in both 18-year-olds or 15-year-olds. In figure 1, the comparison municipalities are placed 2nd, 7th, 9th and 12th on the curve representing 1999 data on 15-year-olds. All were below 2 DMF-S in 1999 and all were characterized by having moderate to low caries experience, in relation to national figures, both in 1986 and 1993. The drop in DMF-S from 1986 to 1993 and in particular from 1993 to 1999,

which Nexö and the comparison municipalities have achieved, can thus be characterized as marginal reductions obtained from levels which were already low. Marginal reductions are much more difficult to achieve than huge reductions, when the latter are based on high baseline DMF-S values, as actually was the case in many Danish municipalities in 1986 (25% >8 DMF-S) and in 1993 (20% >5 DMF-S) (fig. 1). So, in terms of DMF-S levels in the late 1980s and in the beginning of the 1990s, Nexö and the comparison municipalities were similar, which further stresses that those municipalities were adequate for comparisons.

The reason for including a number of comparison municipalities was that the preventive programmes used varied slightly between the municipalities [Wang et al., 1998], and also between the 4 selected comparison municipalities (table 2). In that way, a number of different programmes were covered. When the study was planned in 1987, it was obviously not known which municipalities would be used for comparison. Consequently, the same detailed information as in Nexö about the preventive programmes was not available. However, by interviewing the chief dental officers in the involved municipalities and by collecting data from different national data banks, it was possible to obtain relevant information about background variables and elements in the preventive programmes used during 1988–1999.

It is important to note that the background for running the PDHSC for all municipalities with public clinics has been the same over the years; the municipalities make dental clinics available, staff the clinics and pay all the running costs. Ekstrand et al. [2003b] confirmed that three structural variables – cost per child per year, number of children per dentist and number of staff per dentist in the municipalities – did not play any role in explaining the observed intermunicipality variation in caries experience, which was 1.2–15.5 DMF-S among 18-year-olds in 1999.

Apart from the size of the municipality, the 7 other background variables have previously been used as explanatory variables in relation to the caries experience under Danish conditions [Heidmann and Christensen, 1985; Sigmund, 1991; Petersen 1992; Thylstrup et al., 1982]. Statistics Denmark provided the data for 7 of the variables, while the level of F_{water} came from the Geological Survey of Denmark and Greenland [Ekstrand et al., 2003b]. This guaranteed that the data characterizing each background variable were collected in a uniform manner. The validity of data collection is therefore considered to be strong. However, it has to be stressed that

only the length of the mother's education is strictly related to the conditions for the 18-year-olds, while the other variables can be considered as proxy variables in this context. This reduces the sensitivity of the findings.

Ekstrand et al. [2003b] found that, of the 8 background variables, only F_{water} and the average personal income had a significant influence on the variation in the mean DMF-S and %DMF-S = 0 among 18-year-olds in Denmark. Thus, it is only relevant to comment on these latter two for the purpose of the present study.

Ekstrand et al. [2003b] showed that under Danish conditions caries in 15- and 18-year-olds was not reduced further by increases in F_{water} beyond 0.3 ppm, a much lower concentration than the 0.7–1.0 ppm, which has previously been described as optimal for caries reduction. However, it fits observations in Finland, where the effect of F_{water} on caries is declining compared to the past [Sepä et al., 2002]. Like Denmark, Finland has a free Public Dental Health Service, focusing on preventive care, and almost everybody uses fluoridated toothpaste. As all the comparison municipalities had an F_{water} level ≥ 0.3 ppm, it is unlikely that the 0.8 ppm F_{water} in Nexö was the reason for the difference from the 4 comparison municipalities. The poorer socio-economic conditions in Nexö would be expected to have resulted in a higher caries experience among children in Nexö compared to the other municipalities [Petersen, 1992]. In the analyses, Nexö was characterized as an outlier (the model could not explain the low mean DMF-S and high %DMF-S = 0), while the model fitted quite well the outcomes obtained in the comparison municipalities (table 6).

Each PDHSC has to provide oral care for children and this must include individual preventive measures, including guidance for each child and their parents, instruction to each child in oral health care and regular clinical examinations [Friis-Hasché, 1994] and all PDHSCs comply with this obligation [Wang et al., 1998].

The interviews identified some differences between the NOCTP and the other programmes (table 2). These include: the systematic use of a guideline (fig. 2) in Nexö for all children; individualized tooth-brushing instruction every time children came to a clinical examination; instruction in a special technique for brushing erupting molar teeth [Carvalho et al., 1991]. Yet another important difference is that the NOCTP considers the eruption period of molar teeth as a risk factor for developing caries, as explained by Carvalho et al. [1989, 1991]. Consequently, no child in Nexö with erupting permanent molar teeth had an interval longer than 4 months between recall appointments. If the clinical examination disclosed other

risk indicators or evidence of progressing caries, the recall interval was further shortened.

For permanent first molars, the duration of eruption (from emergence to full occlusion on both pairs) varies from 5 to 32 months (average 15.2 months) and for permanent second molars from 9 to 45 months (average 27.5 months) [Ekstrand et al., 2003a]. Consequently, some children visit the clinic only very few times during the eruption of their molar teeth, while others need to come many times as the longest possible recall interval in the NOCTP in these dental stages was only 4 months. Such an individualized approach was in general not made in the comparison municipalities. In contrast, they seem to have put more emphasis on diet than the NOCTP.

In the 18-year-olds involved in this study, the occlusal surfaces on permanent first molar teeth were the ones most often filled, ranging from about 10% of the surfaces in Nexö in 1999 to about 25% in the comparison municipalities. This indicates that the NOCTP is particularly effective in preventing occlusal caries from developing into stages where fillings are required. This agrees very well with the high level of attention paid to erupting molar teeth in the NOCTP.

In conclusion, the internal goals stated in Nexö were reached. The results indicate that the caries-controlling performance of the NOCTP is high because 18-year-olds in Nexö had the lowest DMF-S in the country in 1999 and the level of DMF-S was significantly lower than in those 4 municipalities having the second to the fifth lowest DMF-S in Denmark that year. Furthermore, relevant caries background variables could not explain the results in Nexö.

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