ORIGINAL ARTICLE

Caries status and proximal lesion behaviour during a 6-year period in young adult Danes: an epidemiological investigation

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Abstract Studies have indicated that many initial proximal caries lesions progress and are eventually restored even if the patients have been under comprehensive preventive programmes. The objectives of the study were (1) to describe the 1996-year baseline caries status of male Danish conscripts and (2) to assess their early proximal lesions 6-year behaviour. In 1996, all 20-year-old conscripts at Central Barrack Birkerød (n=115) went through an oral examination, including visual surface-level fillings' recording and a radiographic examination with bitewing radiographs that assessed the proximal-surface caries and restoration patterns. After 6 years, the behaviour of proximal lesions was studied in 73 of these subjects, and oral health habits were assessed through a questionnaire. Mean number of filled surfaces was 7.5, of which 23% were posterior proximal. Radiographically, the mean number of proximal lesions was 5.5. Over the 6-year period, there was progression of

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K. R. EkstrandDepartment of Cariology and Endodontics, Dental Faculty, University of Copenhagen, Norre Alle 20,2200 Copenhagen N, Denmark lesions into deeper radiolucencies or fillings in 57% of cases. The questionnaire showed a poor compliance with regular flossing/tooth-stick use (18%). Based on these results, more efficacious preventive measures seem to be needed for proximal surfaces.

Keywords Proximal lesions · Caries epidemiology · Progression · Radiography · Adults

Introduction

Clinical experience and solid epidemiological data indicate that the major caries problem in the permanent dentition of Danish children and adolescents is caries on the occlusal surface on molar teeth [1]. In young adults, the major problem is caries on proximal surfaces. Thus, in studies of military recruits, the proximal surfaces are highlighted as a caries problem in young adults [1-4]. Mejàre et al. [5] in a cohort of Swedish 12-year-olds followed up for 10 years with annual bitewing radiographs showed that the prevalence of proximal caries lesions increased from 39% at age 12 to 72% at age 20–21, even though the participants were under comprehensive dental care during the study period. Further, the rate of progression of lesions was slow but continuous. It seems therefore that even under very firm preventive measurements, it is difficult to control caries progression on the proximal surfaces in young adults.

The dental health system in Denmark for adults does in principle not differ from that in Sweden, but the very tight preventive programme, which the participants were offered within the above investigation, does not continue after the age of 18–19 years in either Sweden or Denmark. Thus, unfortunately, it is tempting to hypothesise that the prevalence and progression rate of proximal caries on young adults in Denmark and many other countries may be higher than that observed in the Swedish study.

The main aim of the present study was to investigate the behaviour of early proximal lesions in young Danish adults over a period of 6 years after they were detected on radiographs. During the observation period, the participants were cared for within the Danish Dental Health System for adults.

This paper will first describe the baseline caries status of 20-year-old male conscripts in 1996; next, the paper will describe the behaviour of proximal lesions observed at baseline. In order to establish whether the sample was representative of the young male Danish adults, their educational level in 2002 was compared with the national mean for males within the related age group available (25–29 years) in the national database (Statistics Denmark, 2002). A questionnaire, including questions about educational matters and oral health habits after leaving the military service, was included in the study.

recruited from different parts of Denmark for military service in the Central Barrack Birkerød, Denmark, in 1996 (Fig. 1).

According to the military laws, the conscripts must have their health conditions checked during the first day of their training by dentists from the Danish Defence Forces, and this involved (1) a clinical examination, carried out in the dental clinic, and (2) bitewing radiographs taken following a standardised procedure. As far as possible, the film holder Kwik-Bite (Hawe-Neos, Switzerland) was positioned identically in each case in a sagittal position in relation to the permanent first molars; the focus-to-skin distance from the X-ray machine was 5 cm; exposure conditions were 6.5 kV, 7.5 mA and 0.6 s; films speed group E (Eastman Kodak Co., New York, USA) were used; and automatic processing was conducted.

Based on the clinical and radiographic findings, a treatment plan was offered to the conscripts, which more than 95% accepted to have during the training.

The location of fillings related to the surface(s) involved was recorded on tooth diagrams by the dentist. The

radiographic examination of the proximal caries pattern on

posterior teeth was done by one of the authors (SM) with

Baseline recordings relevant for this study

Materials and methods

The sample for the baseline status of caries and fillings consisted of all (n=115) 20-year-old Danish male conscripts

Fig. 1 Description of study: parts 1 and 2

1st PART: Caries and fillings patterns of 20-year old male conscripts - year 1996 Central Barrack Birkerød, Denmark n=115 Clinical examination: Radiographic examination: Recording of fillings by surface level Recording of proximal primary and secondary caries and of fillings 2nd PART: 6-year behaviour of proximal lesions - year 2002 Subjects with ≥ 1 proximal lesions (yr. 1996): n=73 (out of n=109) Random selection of 1 proximal lesion / person 2 letters sent to subjects 1. Permission to contact their dentist to assess selected proximal 2. 8-question oral health surface on radiograph habits questionnaire 89 complete answers (82%) Letters to dentists (n=89) requesting to score the selected proximal surface If filling present: If caries lesion present: scored with scoring system scored with equivalent scoring system Final sample: n=73 (67%) 25 dentists were asked to rescore surfaces 2 months later to obtain intra-reproducibility of scoring

the aid of a Mattson's magnifying glass (Dental X-ray, Copenhagen, Denmark), including the mesial of the first premolar to the distal of the second molar teeth. Proximal lesions were scored according to the following system: (1) radiolucency restricted to the outer half of the enamel, (2) radiolucency involving the inner part of the enamel up to the enamel–dentine junction (EDJ), (3) radiolucency in the outer dentine but does not exceed one third of the dentine, (4) radiolucency in the inner two thirds of the dentine, and (5) missing surface or no possible radiographic analysis due to overlapping of the proximal surfaces.

Sample for the behaviour of proximal lesions and the questionnaire investigation

From the 1996 baseline sample (n=115), the subjects with at least one radiographic proximal lesion (n=109) were selected in 2002 (Fig. 1). At this stage, one proximal lesion was randomly selected from each person. This was done in a random way using a random numbers table [6]. After obtaining permission from The Danish Data Protection Agency (J.nr. 2003-54-1304), contact with the former conscripts was established by mail. Two letters with a stamp-addressed reply envelope were sent to each of the subjects.

The first letter included an explanation, reminding him that he had been through a dental examination in 1996, when he was a military conscript and at that time he had one or more initial proximal lesions identified from the radiographs. Consent was requested to contact his dentist, in order to assess from his most recent bitewing radiograph, the status of the selected proximal lesion.

The second letter was an eight-question questionnaire, including two educational-level questions and six oral health-habits questions. Twenty envelopes were returned uncompleted: seven due to unknown address, five individuals were not living in Denmark, four individuals did not wish to participate, and four did not answer (after having received envelopes twice). Thus, questionnaires and consent forms to contact their dentists were obtained from 89 individuals, corresponding to 82% of original sample (n=109).

A letter, with a stamp-addressed reply envelope, was prepared for the 89 individuals' dentists, explaining the aim of the study and asking them to score on a recent bitewing radiograph the status of the selected proximal surface. If the radiograph was dated before 2001, the dentist was asked to take a new one, for which the project offered to cover the costs. The dentist was not informed about the status of the lesion in 1996 and was asked to score the radiographic status of the surface on a viewing box. When there was a lesion still present, the dentist was asked to state the lesion depth using the same system as described above. If the lesion had been restored, the dentist was asked to state the depth of the filling according to the following classification system: (1) filling restricted to the outer half of the enamel, (2) filling involving the inner part of the enamel up to the EDJ, (3) filling in the dentine but does not exceed one third of the dentine, and (4) filling in the inner two thirds of the dentine.

From the 89 envelopes prepared for the dentists, it was not possible to get data from 16, even though contact was attempted for a second time. Thus, a total of 73 forms were collected from the dentists, corresponding to 67% of original sample of conscripts (n=109). The final sample for the second part of this paper will therefore consist of 73 subjects.

Two months later, 25 dentists were asked to re-score the proximal surface with the same system in order to get the intra-examiner reproducibility of the assessment of the selected proximal surface.

Statistics

Baseline caries data

For the epidemiology study (n=115), descriptive analyses were used to describe the mean number of filled surfaces (FS), the percentage distribution of absolute number of fillings in this group, the frequency of fillings and sealants on occlusal molar surfaces, the frequency of fillings on proximal molar surfaces, and the percentage distribution of radiographic scores assigned to proximal surfaces.

In order to investigate reproducibility, the baseline radiographs were examined for a second time by the same examiner after a period of 1 month. The kappa value for the intra-examiner reproducibility of the examiner concerning scores on baseline radiographs was 0.8.

Behaviour of proximal lesions

The 6-year behaviour of the selected lesions (n=73) was obtained by comparing the status of the lesion in the baseline radiograph with that of year 2002 in terms of progression, no changes or regression. Further internal analyses were made to investigate if depth of baseline lesion influenced the progression rate. Due to low numbers, this was only reported at the descriptive level.

The intra-examiner reproducibility concerning the dentists' score was substantial (kappa value of 0.78).

Questionnaire examination

Educational status was divided into three levels according to the years of education beyond primary and secondary school: level 1, 1 year of further education; 2, more than 1 year of moderate-level education; and 3, more than 3 years of highest-level education. Frequency distributions were calculated regarding the educational level, and these were compared with national data. Descriptive statistics were also used to show trends in the reported oral health habits of the sample (n=89).

Results

Baseline information (n=115)

Clinical examination No first or second molars were recorded as missing. The mean number of FS related to tooth surfaces disclosed that more than half of the total number of filled surfaces (52%) corresponded to occlusal fillings (3.9; Table 1). Occlusal fillings in premolars made up only a small fraction (0.5); therefore, most surfaces that were filled were the occlusal surfaces of molar teeth (3.4). These were followed by the posterior proximal surfaces (1.7), corresponding to 23% of filled surfaces.

The percentage distribution of the subjects according to the number of filled surfaces disclosed that 13% of the subjects had no filled surfaces; 31% had from one to four filled surfaces; 12%, 9–12; 12%, 13–16; and about 10% had more than 17 filled surfaces (4%, 17–20; 1%, 21–24; 5%, over 24).

The relative frequency of occlusal fillings in molars showed that around half (45% to 51%) of the first permanent molar teeth and one third of the second permanent molar teeth (33% to 37%) were filled; the percentage of sealed occlusal molar surfaces ranged from 6% to 12%.

The majority of the proximal fillings and lesions were related to the molar teeth, on which the following description will therefore concentrate. The mesial surface of the first permanent molars was the surface most often restored among the proximal surfaces of the posterior teeth

 Table 1
 Mean number of filled surfaces (FS) related to tooth surfaces at baseline

Tooth surface		n=115 Mean (SD)
Occlusal surfaces	Molar teeth	3.4 (2.6)
	Premolar teeth	0.5 (1.0)
	Total	3.9 (2.5)
Buccal/palatal	Buccal	1.0 (1.0)
Pits	Palatal	1.4 (0.7)
Proximal surfaces	Anterior teeth	0.3 (1.0)
	Posterior teeth	1.7 (3.0)
Total		7.5 (7.4)

(in the upper jaw, on an average from 15% to 19%, and in the lower jaw, from around 11% to 14%) followed by the distal surface of same teeth on the upper and lower jaw (11% and 8%, respectively), the mesial surface of second upper and lower permanent molars (around 8% and 4% to 6%, respectively) and the distal surface of the second permanent molar (around 1% to 4%).

Radiographic analysis The radiographic examinations disclosed that, in total, only five teeth were root-treated. Two to six percent of the distal surfaces of the second molar teeth were missing on the radiograph (score 5), and up to 9% of the surfaces were unable to be scored due to overlaps (score 5). The surfaces that most often presented overlaps on the radiographs were as follows: 26D (9%), 36M (7%) and 27M (6%).

A total of 628 proximal lesions were identified on the radiographs, which gives a mean on 5.5 lesions per individual. More than half of the lesions (56.5%) were score 1. More than one third (36.3%) were score 2 and 7.2% were score 3. The percentage distribution of subjects in relation to the number of proximal lesions shows that almost half of the subjects (43.5%) had from one to four lesions, followed by 22.6% having from 5 to 8, 21.7% from 9 to 12 and 7% from 13 to 17 lesions. Around 5% of the subjects were free of proximal lesions.

Regarding the distribution of radiographic proximal lesions, there were more lesions in the lower than in the upper teeth (around 60% and 40%, respectively). The surfaces that most often presented lesions were the distal of the first lower molar teeth (17.5%) and the mesial of the second lower molar teeth (15.2%), followed by the distal surfaces of second premolars, both lower (10.1%) and upper (8.9%). Score 1 lesions accounted for almost two thirds of the lesions in the upper posterior teeth (62%) and for around half of the lesions in the lower posterior teeth (52%), while lesions score 2 and 3 were more frequent in the lower (38% and 9%, respectively).

Behaviour study

More than half of the randomly selected lesions (n=73) were score 1 (56%), 40% were score 2 and 4% were score 3 (Table 2). The majority of the lesions were located in the first molar teeth (23%), followed by the second upper premolars (20%) and the second lower molar teeth (19%).

The behaviour of the lesions after 6 years disclosed that 57% of the lesions progressed in terms of a deeper radiolucency or a filling (Fig. 2). Progression of the lesion was observed in all lesions scored 3 at the baseline, in more than two thirds of lesions scored 2 (68%) at baseline and in around half of lesions scored 1 (48%) at baseline. While

Distribution of t	he rand	omly s	elected	lesions ((<i>n</i> =73)												
Tooth surface	14/24		15/25		16/26		17/27		34/44		35/45		36/46		37/47		Total
	М	D	М	D	М	D	М	D	М	D	М	D	М	D	М	D	
Score 1	1	5	2	6	3	5						4	3	5	7		41
Score 2		2		7	2	1		1				3		6	7		29
Score 3													1	2			3
Total	1	7	2	13	5	6		1				7	4	13	14		73

Table 2 Distribution of the randomly selected lesions for the final sample according to surface and radiographic score (n=73)

almost half of lesions scored 2 at baseline were restored (46%), only 9% of the lesions scored 1 at baseline were restored. In 5% of the cases, regression was observed.

The behaviour of the lesions according to the tooth surface showed a tendency towards higher percentages of surfaces showing progression in mesial surfaces of the second lower molar teeth (71%), distal surfaces of the first lower molar teeth (69%), distal surfaces of first upper molar teeth (67%) and distal surfaces of second upper premolar teeth (61%; Table 3).

Questionnaire Regarding the educational level, data from Statistics Denmark showed that on a national basis, 18.1% of males between 25 and 29 years could be classified as having a high-level (professionals), 42.5% as having a medium length education (technical work) and 25.7% as



Fig. 2 Six-year behaviour of approximal lesions according to final radiographic status (unfilled/filled) and score

having a short education (basic 9-year school education); there were no data available on 13.7%. Among the former conscripts, similar figures were 40.4%, 43.8% and 10.1% (Table 4). Thus, they had in general a higher educational level compared to that at the national level. Table 4 further shows the percentage distribution of the questionnaire answers (n=89). Most of the individuals had more than the obligatory 9 years of basic education (94%). As for reported oral health care, two thirds of the individuals visited the dentist yearly and 22% once or twice in the previous 5 years. All reported to brush their teeth from one to three times per day, with fluoridated toothpaste; 17-18% reported that they used tooth-stick/dental floss on a regular basis; 13% eat candy every day; and almost half of them (47%) claim not to have received oral hygiene instructions from their dentist.

Discussion

Sample

Regarding the sample size for the first part of the study, it has to be considered that the age group corresponds to a population group where epidemiologic and even more prospective data are difficult to obtain, especially in Denmark where subjects leave the free system at the age of 18 years [4]. As for the second part of the study, it has been previously described all attempts made to gather as much subjects out of the 109 as possible.

The way the military service recruits males for military service ensures that those 115 conscripts were born and raised across the country and thus represents all parts of Denmark. Whether the sample represents the filling status of 20-year-olds in 1996 (size of the male cohort in 1996~25,000; information from Statistics Denmark) and behaviour of proximal lesions over a period of 6 years is another matter. According to the National Board of Health, the national mean DMF-S among 15-year-olds in 1991 and 18-year-olds in 1994 was 4.4 and 6.8, respectively, of

Tooth surface	14/24		15/2	15/25		16/26		17/27		34/44		35/45		36/46		37/47	
Behaviour	М	D	М	D	М	D	М	D	М	D	М	D	М	D	М	D	
Regression				1	1								1	1			4
Stabilisation	1	4	2	4	2	2						3	2	3	4		27
Progression		3		8	2	4	1					4	1	9	10		42
Total	1	7	2	13	5	6	1					7	4	13	14		73

Table 3 The behaviour of proximal lesions according to tooth surface and score

which 85% was related to the F-component. An increase of about three filled surfaces from age 15 to age 20 and an increase of about 1.7 surfaces from the age of 18 to 20 seem not to be unrealistic. Further, the mean prevalence of fillings of the 20-year-old conscripts in 1996 was 7.5; in

similar groups of 20-year-old conscripts in 1986 and in 1991, the mean prevalence of fillings was 10.2 and 8.7 [4]. Thus, compared to the 1991 group, there was a 14% reduction, which corresponds to the reduction between the 1986 and 1991 group (15%). The distribution pattern—that

Question	Variables	Answer			
		n	%		
Years of study	Less than 10 years	5	5.56		
	More than 10 years	84	94.44		
Level of education	Short education	9	10.11		
	Medium education	39	43.82		
	Long education	36	40.45		
	No answer	5	5.62		
How often have you visited the	0	1	1.11		
dentist in the last 5 years?	1	8	10.00		
	2	10	11.11		
	3	8	8.89		
	4	1	1.11		
	5	59	65.56		
	No answer	2	2.22		
Tooth-brushing frequency/day	1	11	12.22		
	2	74	83.33		
	More than 2	4	4.44		
Tooth sticks use frequency	1/day	7	7.78		
	1/other day	3	3.33		
	2/week	5	5.56		
	When needed	44	50		
	Never	30	33.33		
Dental floss use frequency	1/day	3	3.33		
	1/other day	2	2.22		
	2/week	11	12.22		
	When needed	26	28.89		
	Never	47	53.33		
Has your dentist instructed	Yes	47	53.33		
you in oral hygiene?	No	42	46.67		
How often do you eat candies?	1/day	12	13.33		
-	2–3/week	41	46.67		
	1/week	36	40.00		

Table 4The educational leveland oral hygiene habitsquestionnaire for young Danishadults and related answers(n=89)

the occlusal surfaces on molar teeth were those surfaces more frequently filled—was the same both in 1986 and 1991 and also in 1996. Finally, the questionnaire disclosed that the education, in terms of length of education, was higher among the conscripts 5 years after they left the military service, compared to the educational level of peer groups in the Danish population. Thus, taking all into consideration, the prevalence of fillings and progression rate of proximal lesions in the involved sample is not expected to be higher than that of its peer population.

The proximal lesions

It is noteworthy that the mean number of proximal lesions among the 20-year-olds in this study was 5.5 and that only six conscripts had no proximal lesions. This is a little higher than in the cohort followed by Mejàre et al. [7] with a mean number of proximal lesions of 4.5 at the age of 21–22 increasing to 5.0 at the age of 26–27 years. Initially, it indicates a huge treatment problem. However, in the present study, more than 56% of the lesions found were restricted to the outer enamel, not initially in need of operative treatment. Another matter is that based on a single radiograph, it is not possible to state if the lesions were active or arrested [8].

The distribution pattern of the proximal lesions in this sample was in principle similar to the distribution pattern in the sample from 1986 and 1991; thus, the distal surface of the first lower molar teeth was the one which most often presented lesions (17%), followed by the mesial surface on the second mandibular molar teeth (15%) and then by the distal surface on the second mandibular premolar teeth (10%). The distal surface of the maxillary second molar teeth showed lesions in 9% of the surfaces. That the distal surfaces of the lower molars presented most lesions in our sample and not the mesial surface as reported by Dummer [9], Lith [10] and Mejàre et al. [11] can be related to the fact that the mesial of first lower molar did not account for the same proportion of lesions because many were already filled at the time of examination. So, the mesial surface of first permanent molars had the highest caries experience of all proximal surfaces.

Behaviour of the proximal lesions over 6 years In order to avoid a statistical problem with dependent observations, it was chosen to select only one proximal lesion from each individual in case they had more than one. The lesion was selected by means of a random numbers table as suggested by Kramer [6]. Eventually, the selected lesions were distributed quite similarly, in terms of depth and location, to the distribution of lesions observed at the baseline examination, apart from that 13 lesions were selected from the distal surface of the maxillary second premolars. The radiographs of the second examination were scored by different dentists because this was the way in which this second study could be logistically conducted. Even though this might lead to inaccuracies in the findings, all dentists received clear written instructions on how to score the lesion/restoration depth of the selected approximal surface, including a diagram showing the described radiographic scoring system. Further, to gain information concerning the intra-reproducibility of dentists in scoring these approximal surfaces, over one randomly selected third (n=25) of the dentists was asked to re-score same surface again after 2 months, showing kappa values for their intra-reliability of 0.78 and perfect agreement of 82%, considered as substantial.

During the 6-year observation period, the proximal lesions that most often progressed were the mesial of second permanent molars, followed by distal surfaces of first permanent molars and the distal of second maxillary premolars. All these surfaces are similar in that they have a wide contact area, which favours the stagnation of bacterial plaque and thus caries development or progression [12].

Data indicate that more baseline proximal lesions scored 2 progressed (68%) than baseline proximal lesions scored 1 (48%) and the related treatment of choice was a filling when a score 2 proximal lesion progressed. There were too few score 3 proximal baseline lesion in this sample to indicate trends of this particular score.

When comparing this study with Hintze et al. [13], it can be seen that in both their and our study, all lesions with a radiographic score 3 (n=27 and n=3, respectively) were restored at the end of the study. Concerning enamel lesions, corresponding figures were 4% (n=1) and 25% (n=15), respectively. As we can presume that dentists in our study decided to treat operatively based on radiographic progression of the lesion and/or pain, Hintze et al. [13] had chosen this treatment based on the presence of a clinical cavity after a 3-day elective temporary separation, even though only in seven cases there was a radiographic progression of the lesion. It is also important to take into consideration the difference in times of both studies, namely 2.5 and 6 years, respectively. Regarding progression of enamel lesions, Hintze et al. [13] only found radiographic progression from score 2 to 3 in four lesions (7%), while we found progression in 29% (n=8). This could be explained by the difference in time evaluation or other factors such as a high caries risk, etc.

With the current understanding of caries etiopathology, the ICDAS Committee recommends taking an operative treatment decision when the lesion visually presents a breakdown plus a radiographic correspondent location deeper then the outer third of the dentine [14]. Thus, it can be wise to make a temporary elective separation in order to combine both visual and radiographic methods for selecting the best individual treatment option.

Questionnaire examination

Concerning oral health behaviour of these young adults, the questionnaire indicated that about two thirds of the conscripts had visited their dentist once a year from 1996 to 2002, and all claimed that they did brush their teeth at least once a day with a fluoridated toothpaste. However, only a few used floss (18%) on a regular basis, a key factor for preventing/controlling proximal caries [15, 16]. This indicates a poor compliance with this behaviour, which agrees with what Frandsen [17] reported about oral health behaviours. Forty-seven percent reported not to have received any instructions in flossing, which is a disappointing reflection on the oral health system since dentists should recommend and teach flossing at an individual level [18]. Unfortunately, the number of conscripts in this study using floss on a regular basis is too low to compare with those who had caries progression or who had no progression. Finally, the high educational level of the subjects would expect a higher compliance to oral hygiene habits [2, 19], but taking into account the age of the subjects, it is known that after the population leaves the free Danish Health System, at the age of 18, some behaviours such as dental visits decrease among young adults [2].

In summary, the prevalence of fillings in 20-year-old Danish males are decreasing by about 15% each 5 year; the molar occlusal surfaces are those most often filled; the mean number of proximal primary lesions on 20-year-olds in Denmark is about 5.5, and the majority of the lesions were restricted to the enamel (scores 1 and 2). During a 6-year period, it was observed that 60% of proximal lesions progressed, which might be related to the fact that few of the participants used dental floss on a regular basis. Score 2 lesions progressed more often than score 1 lesions. Based on these results, it could be argued that there is a need for alternative preventive measures to stop further progression in Danish young adults, such as sealing early active proximal lesions close to the EDJ (score 2 lesions), as suggested by Gomez et al. [20], Martignon et al. [21] and Alkizi et al. [22].

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