

ORIGINAL ARTICLE

Dental caries in relation to smoking and the use of Swedish snus: epidemiological studies covering 20 years (1983–2003)

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Abstract

Objective. The aim of this study was to evaluate some intra-oral caries-associated variables and tobacco use on dental caries. **Materials and methods.** The participants were randomly recruited from three cross-sectional studies in Jönköping, Sweden, in 1983, 1993 and 2003. Each study consisted of 130 individuals in each of the 20, 30, 40, 50, 60 and 70-year age groups. Of these, 550, 552 and 523 dentate individuals attended respective year of examination. They were all examined both clinically and radiographically. A questionnaire was completed in conjunction with the examination. In the studies, 345 were smokers, 104 snus users and 1142 non-tobacco users, in total 1591 individuals. **Results.** In 1983 and 1993, there were no significant differences in mean DFS between non-users and smokers, but a statistically significantly higher mean DFS in comparison with snus users. In 2003, there was no statistically significant difference in mean DFS between the groups. Multiple regressions showed that, after adjusting for age, gender and socio-demographic variables, there was a statistically significant association between DFS and smoking in 1983 (smoking excluded in favour of lactobacilli when further analysed) and DFS and plaque index (PLI) in 1993. In 2003, there was no association, apart from buffer capacity (Power rising) between DFS and the examined intra-oral caries-associated variables and tobacco use. **Conclusions.** The results of these epidemiological studies, performed in 1993 and 2003, indicate that daily smoking or snus use does not increase the risk of dental caries.

Key Words: caries, salivary factors, smoking, snuff, Swedish snus, tobacco

Introduction

In 2009, ~ 13% of the adult Swedish population were smokers and 11% used Swedish moist snuff (so-called 'snus'). The trend in Sweden shows a decreasing number of smokers, whilst the regular use of snus is increasing [1]. There are several studies showing an association between dental caries and smoking habits [2–5]. On a population basis, smoking appears to go hand-in-hand with both poor oral hygiene and food habits, which may promote a high prevalence of caries [2,6–8]. Axelsson et al. [9] found an association between caries and smoking, even though oral hygiene was similar in non-smokers and smokers. In some studies, smoking is associated with fewer remaining teeth and root caries in the elderly [10–13], but there are also studies of younger age groups showing

no such correlation. Aguilar-Zinser et al. [8] found that, among professional truck drivers in Mexico, older age, poorer oral hygiene, higher education and greater tobacco exposure were associated with higher caries experience (DMFT). An interaction was also observed between oral hygiene and the use of tobacco. It has been suggested in several other studies that the caries experience is higher in smokers than non-smokers [2,6,9], but there is no consistent pattern in other reports [14]. Smoking may modify the plaque flora [15] and the amount of plaque [16], but it is unclear how this affects the caries process.

There are few epidemiological studies of the relationship between dental caries and the use of snuff/snus. In a public health report [17], it was shown that American smokeless tobacco might increase the risk of dental caries, but most studies show no correlation

[4]. The contradictory results may be because the ingredients and the composition of smokeless tobacco vary considerably between different countries, for example regarding sugar content, pH, as well as substances added during the manufacturing process [18–20].

Recently, the results of three cross-sectional epidemiological studies, carried out in 1983–2003 regarding tobacco habits among Swedish adults of 15–70 years of age, have been presented [21]. The aim in these studies was to provide an overall picture of the tobacco users in relation to social factors and dental care habits. There was a difference between users and non-users in terms of dental visits and oral hygiene habits. Non-users visited the dentist more regularly and brushed their teeth more frequently than users. The present investigation should be regarded as a further evaluation of some intra-oral caries-associated variables and the effect of smoking and snus use on dental caries. The hypothesis was that smoking or the use of snus will not significantly increase the risk of dental caries compared to non-tobacco users.

Materials and methods

Study population

The participants consisted of three stratified random samples of inhabitants from the city of Jönköping, Sweden. In 1983, 1993 and 2003, a number of individuals received a written invitation to take part in a dental health examination. They were informed of the purpose of the investigation and that clinical and radiographic examinations would be performed (for details, see Hugoson et al. [22]). A questionnaire was also completed at the time of the examination. Each sample consisted of 130 randomly selected individuals from each of the 20, 30, 40, 50, 60 and 70-year age groups [22]. Non-respondents were contacted by telephone and asked about their reasons for not participating; the numbers of drop-outs in 1983 and 1993 were similar (12–28%), whilst they were somewhat higher in 2003 (26–36%). Detailed information about the number of non-respondents has been published elsewhere [22].

The three samples comprised 550, 552, 523 dentate individuals, respectively. From this population, 34 mixed tobacco users (those who both smoked and used snus) were excluded. Thus, the final populations in the present study were 539, 543 and 509 non-tobacco users, smokers and snus users, respectively. Among the 1591 participants, 345 were smokers (156 males, 189 females), 104 snus users (99 males, five females) and 1142 non-tobacco users (526 males, 616 females). The distribution of dentate non-users, smokers and snus users in 1983, 1993 and 2003, divided into females, males and age groups, is shown in Figure 1.

Questionnaire

The questionnaire was completed in conjunction with the clinical examination. Respondents were asked to detail their tobacco habits and these were verified during the clinical examination; the data collected refer to the time of the examination. Smokers and snus users were defined as daily smokers (number of cigarettes per day noted) and daily snus users. Pipe and cigar tobacco was recalculated in terms of cigarettes. Non-users did not use tobacco in any form. Participants who had been smoking earlier but quit (former smokers; $n = 105$) were analysed in the 1993 examination. In 1983 and 2003, no information about former smokers was available. As regards tobacco habits, the same basic information was collected in each year of examination. Smoking (yes/no) and use of snus (yes/no) were used as explanatory variables. Other questions included information on medical and oral health history, dental and dietary habits and socio-demographic status. Occupational status was divided into employed (blue- and white-collar workers) and not employed (student, unemployed, pensioners and housewife/househusband). Educational level was described as low education (9-year compulsory school, practical upper secondary school) or higher education (upper secondary school, college of higher education). Marital status was listed as single or partner. The question on diet was 'How often do you eat snacks and drinks between meals?', scored 0, 1, 2, up to more than 10-times a day and dichotomized to ≤ 3 times/day ≥ 4 times/day.

Clinical examination

The examinations were carried out at modern public dental health clinics. Each clinical and radiographic examination took 60–90 min.

Salivary factors. A whole saliva sample was collected by asking the respondents to chew on a piece of paraffin wax for 5 min. The secretion rate was expressed as ml/min. Buffer capacity was estimated by means of a chair-side test (Dentobuff Strip, Orion Diagnostica, Esbo, Finland). In 1983, the numbers of *mutans streptococci* and *lactobacilli* were also analysed, using Dentocult SM-Strip mutans and Dentocult-LB, respectively (Orion Diagnostica).

Oral hygiene. Oral hygiene was registered as the presence of visible plaque on four tooth surfaces per tooth (after drying with compressed air) according to the criteria described by Löe [23] for Plaque Indices (PLI) 2 and 3.

Number of teeth and dental caries. The number of teeth was recorded, but third molars were excluded. All

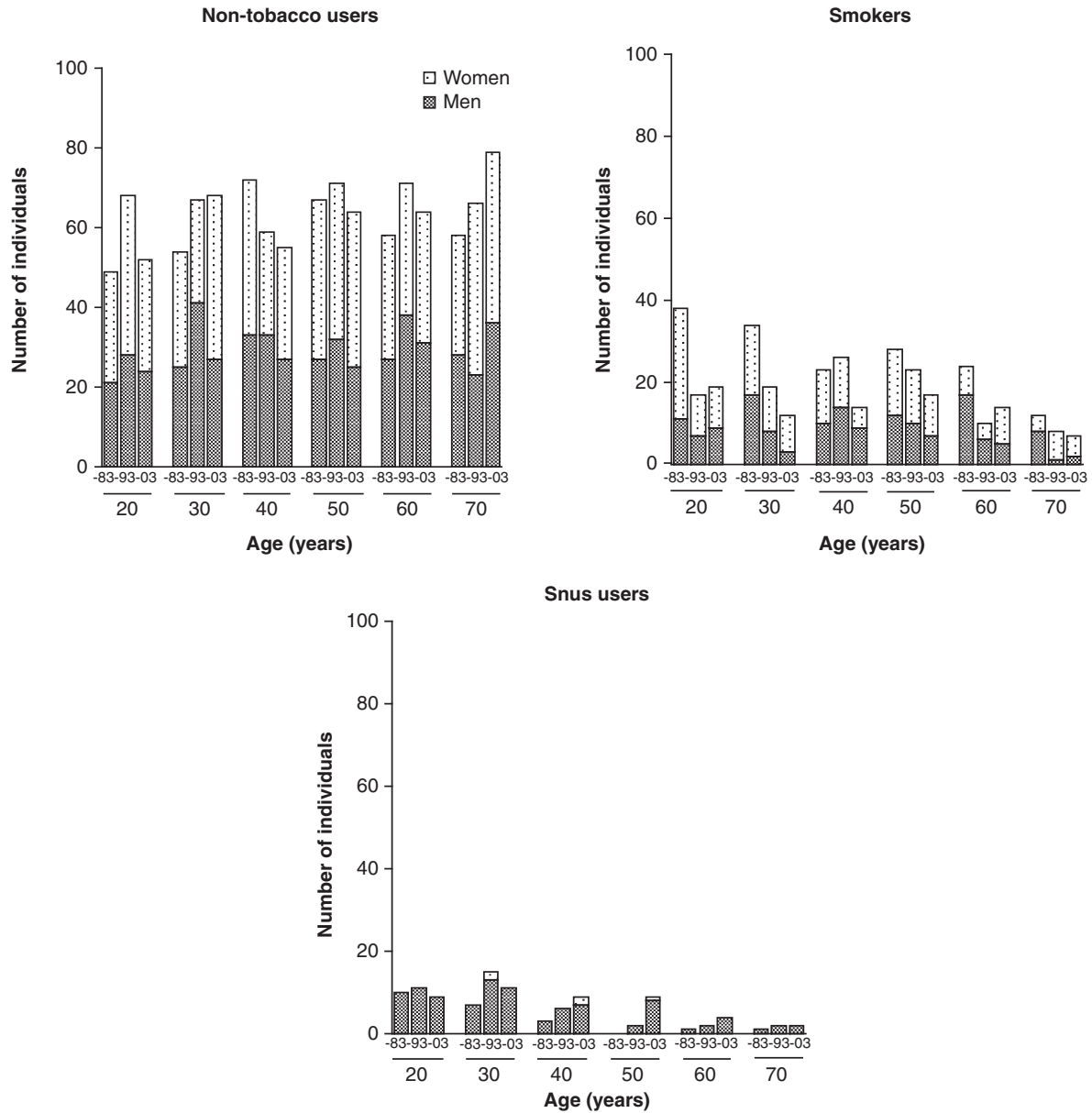


Figure 1. Number of female and male non-tobacco users, smokers and snus users in the different age groups and year of examination.

surfaces available for clinical examination were examined for dental caries according to Koch [24]:

- initial caries = loss of mineral in the enamel, giving a chalky appearance but without any clinical cavitations;
- manifest caries = new carious lesions on surfaces not previously restored and of such an extent that they could be verified as cavities by probing and, when probing fissures using light pressure, the probe became stuck; and
- restored tooth surfaces were recorded.

Measures of tooth surfaces with visible plaque (PLI) and decayed and filled tooth surfaces (DFS) were expressed as the individual percentage of the total number of tooth surfaces (PLI% and DFS%).

Radiographic examination. As part of this epidemiological follow-up of oral health covering many clinical and radiographic variables, both extra- and intra-oral films were taken. If a participant had had a recent radiographic examination, the radiographs were obtained from the records. Due to improved oral health and ethical considerations, the examination changed somewhat during the course of the studies. Thus, in 1983, all age groups underwent a full-mouth intra-oral examination, 16 periapical and four posterior bite-wings and a panoramic radiograph. In 1993 the examinations of the 20–30-year age groups comprised six bite-wing radiographs and a panoramic radiograph. The 40–70-year age groups had a full-mouth intra-oral examination including four posterior bite-wing radiographs and

a panoramic radiograph. In 2003, however, the examination of the 20–40-year age groups comprised six bite-wing radiographs (two in the frontal region and four in the posterior region) and a panoramic radiograph. The 50–70-year age groups had a full-mouth, intra-oral examination, including four posterior bite-wing radiographs and a panoramic radiograph. All tooth surfaces that could not be evaluated clinically were evaluated on the radiographs. Dental caries on the radiographs was recorded as follows: initial caries = lesions were not deeper than 2/3 of the enamel or deeper than 2/3 of the enamel but did not involve the dentine; manifest caries = lesions extended into the dentine [24].

Ethical considerations

The ethical regulations for research specified in the Declaration of Helsinki [25] were followed. The Ethics Committee at the University of Linköping (Linköping, Sweden) approved the 2003 study.

Statistical analysis

The data were described by means of ordinary descriptive statistics and analysed using the Statistical Package for Social Sciences (SPSS). ANOVA was used to study differences between non-tobacco users, smokers and snus users for the variables studied, including the *post hoc* test according to Sheffé. ANOVA was also used when studying differences over time, 1983, 1993 and 2003, for each separate variable.

Multivariable logistic regressions were used in some analyses and odds ratios (OR) were calculated. Dental caries (DFS%) was dichotomized when used as an outcome variable (median value). The explanatory variables from the clinical examinations that were used were salivary secretion rate (ml/min), buffer capacity (final pH) and PLI% primarily analysed for the 3 years of examination. In 1983, *mutans streptococci* and *lactobacilli* (CFU/ml; CFU = colony forming units) were also included but in a second analyses.

Some continuous explanatory variables were also grouped, when needed, to make the interpretation of the results clearer. In 1983 and 2003, no information about former smokers was collected. In 1993, former smokers were recorded. There were no statistically significant differences between non-smokers and former smokers as regards DFS (total $p = 0.41$, for men $p = 0.40$ and for women $p = 0.64$). In all 3 years of examination, former smokers were included with non-users in the analyses. As there were few female snus users (five individuals), the multivariate logistic regression analyses were restricted to male snus users (99 individuals). The significance was set as $p < 0.05$.

Results

The mean age of non-tobacco users was 45.9 years (SD = 16.9), for smokers it was 40.9 years (SD = 15.8) and for snus users 34.9 years (SD = 14.3). The differences in mean age between non-tobacco users, smokers and snus users were statistically significant (95% CI = 44.9–46.9, 37.3–42.6 and 32.1–37.7 respectively). There was an age gradient for tobacco use as well as a time trend; thus, as age increased, the use of tobacco decreased. In 1983, there were 33% tobacco users, whilst the figure for 2003 was 24%. The proportion of smokers was almost halved from 29% to 15%, whilst the use of snus rose from 4% to 9%. There were more female than male smokers and most of the snus users were males. Among the daily smokers, the percentage of individuals smoking 1–5, 6–9 or ≥ 10 cigarettes a day in 1983 was 28, 10 and 62%, respectively. The corresponding figures in 1993 and 2003 were 20, 12 and 68% and 29, 10 and 61%, respectively.

Comparison between groups (non-tobacco users, smokers and snus users)

For each year of examination (1983, 1993 and 2003), the mean, 95% confidence interval (CI) and p -value are presented for non-tobacco users, smokers and snus users for each of the variables studied: number of teeth, salivary secretion rate, buffer capacity, PLI and DFS, as well as counts of *mutans streptococci* and *lactobacilli* registered in 1983 (Table I).

As regards number of teeth, non-users as well as smokers had statistically significantly fewer teeth in 1983 than snus users ($p = 0.010$ and $p = 0.016$, respectively). In 1993, there was no significant difference in mean number of teeth between non-users, smokers and snus users. Regarding saliva secretion rate, there were no significant difference between non-users, smokers and snus users in the different years of examination.

In 1983, there were statistically significant differences between non-users and smokers as well as smokers and snus users as regards buffer capacity ($p < 0.001$ and $p = 0.004$, respectively). In 1993, a statistically significant difference in buffer capacity was found between smokers and snus users ($p = 0.047$). No significant difference in buffer capacity between non-users and tobacco users was found in 2003. Regarding PLI, there were no statistically significant differences between non-users, smokers or snus users either in 1983 or in 1993 or 2003.

In 1983, there was no significant difference in mean DFS between non-users (41.3 ± 2.8) and smokers (41.3 ± 3.5), but a statistically significantly higher DFS in non-users and smokers compared to snus users (20.2 ± 4.4 ($p < 0.001$)). In 1993, although not statistically significant, non-users had fewer DFS than

Table I. Number of individuals examined, mean values, 95% CI and *p*-values for non-tobacco users, smokers and snus users for the different variables studied.

	1983			1993			2003		
	<i>n</i>	Mean	<i>p</i> -value	<i>n</i>	Mean	<i>p</i> -value	<i>n</i>	Mean	<i>p</i> -value
<i>Number of teeth</i>									
Non-user	358	23.0 ± 0.6	<i>0.010</i>	402	24.5 ± 0.5		382	25.4 ± 0.4	0.001
Smoker	159	23.1 ± 1.0	0.016	103	24.0 ± 1.2		83	23.3 ± 1.4	0.001
Snus user	22	27.1 ± 0.7		38	26.0 ± 1.3		44	26.8 ± 0.6	
<i>Secretion rate (ml/min)</i>									
Non-user	352	1.5 ± 0.1		392	1.9 ± 0.1		374	1.6 ± 0.1	
Smoker	157	1.4 ± 0.1		103	1.8 ± 0.1		82	1.5 ± 0.2	
Snus user	22	1.8 ± 0.3		37	2.1 ± 0.3		44	1.9 ± 0.3	
<i>Buffer capacity</i>									
Non-user	352	4.9 ± 0.1	0.001	392	4.4 ± 0.1		343	5.7 ± 0.1	
Smoker	156	4.4 ± 0.2	0.004	103	4.2 ± 0.2	0.047	75	5.6 ± 0.2	
Snus user	22	5.2 ± 0.4		37	4.6 ± 0.2		40	5.8 ± 0.1	
<i>PLI(% sites)</i>									
Non-user	358	31.3 ± 3.0		402	32.7 ± 2.4		382	18.3 ± 2.0	
Smoker	159	33.8 ± 4.3		103	33.6 ± 4.8		83	24.4 ± 5.5	
Snus user	22	31.2 ± 11.6		38	35.8 ± 8.4		44	17.1 ± 6.0	
<i>DFS(% surfaces)</i>									
Non-user	358	41.3 ± 2.8	<i>0.001</i>	402	35.8 ± 2.4	<i>0.003</i>	382	27.8 ± 2.3	
Smoker	159	41.3 ± 3.5	0.001	103	37.1 ± 5.1	0.004	83	28.8 ± 5.8	
Snus user	22	20.2 ± 4.4		38	21.8 ± 5.9		44	19.3 ± 5.0	
<i>Mutans strept (log CFU/ml)</i>									
Non-user	340	5.9 ± 0.1	0.001						
Smoker	152	6.2 ± 0.2							
Snus user	22	5.9 ± 2.0							
<i>Lactobacilli (log CFU ml)</i>									
Non-user	300	5.0 ± 0.1	0.001						
Smoker	142	5.7 ± 0.2	0.044						
Snus user	18	4.9 ± 0.5							

p-values for statistically significant differences between non-tobacco users and smokers are indicated in regular text style, for those between non-users and snus users in italics and for those between smokers and snus users in bold.

smokers (35.8 ± 2.4 and 37.1 ± 5.1, respectively) and both non-users and smokers had a statistically significantly higher number of DFS than snus users (21.8 ± 5.9; *p* = 0.003 and *p* = 0.004, respectively). In 2003, there was no statistically significant difference between the three groups.

In 1983, the number of *mutans streptococci* and *lactobacilli* were analysed. Compared to non-users, smokers had a statistically significantly higher mean number of *mutans streptococci* (*p* < 0.001). Smokers had also a significantly higher number of *lactobacilli* than both non-users and snus users (*p* < 0.001 and *p* = 0.044, respectively). Between non-users and snus users, there were no significant differences as regards the two types of cariogenic micro-organisms.

Time trends (2003, 1993 and 1983)

In 2003, non-users and snus users had statistically significantly more teeth than smokers (*p* < 0.001). Non-users had statistically significantly more teeth in 2003 compared to 1983 (*p* < 0.001).

The secretion rate for non-users was statistically significantly lower in 2003 compared with 1993 (*p* < 0.001). The buffer capacity was statistically significantly higher in 2003 compared with 1983 and 1993 for both non-users, smokers (*p* < 0.001) and snus users 1983 (*p* = 0.005) and 1993 (*p* < 0.001).

A comparison of PLI in 2003 with PLI in 1983 and 1993 revealed statistically significant lower mean plaque values for non-users (*p* < 0.001) in 2003 and for

Table II. Results of the multiple logistic regression analysis of the association between the outcome variable (DFS %, low/high) and various explanatory variables, adjusted for age, gender and socio-demographic variables in the different years of examination 1983, 1993 and 2003.

Explanatory variables	OR	95% CI	p-value
<i>1983, n = 518</i>			
Gender	2.81	1.76–4.49	0.001
Age	1.10	1.07–1.12	0.001
Education (low)			n.s
Employed	1.56	1.25–1.95	0.001
Marital status			n.s
Non-user	1		
Smoker	2.32	1.41–3.81	0.001
Snus user			n.s
<i>1993, n = 507</i>			
Gender	1.89	1.10–3.22	0.020
Age	1.13	1.10–1.17	0.001
Education (low)	2.57	1.35–4.87	0.004
Employed	3.14	1.59–6.19	0.001
Marital status			n.s.
PLI	1.02	1.01–1.03	0.002
<i>2003, n = 451</i>			
Gender			n.s
Age	1.12	1.078–1.17	0.001
Education (low)			n.s
Employed			n.s
Marital status			n.s
Buffer capacity	0.45	0.26–0.77	0.004

snus users compared to 1993 ($p = 0.002$), but no significant difference for smokers.

In 2003 the number of DFS was numerically lower among both non-users, smokers and snus users compared to 1983 and 1993.

Multivariate analysis

The results from the multiple logistic regression (Table II) showed that, after adjusting for age, gender and socio-demographic variables, there was in 1983 a statistically significantly higher risk for men vs women and for employed vs not employed individuals to have more DFS (OR = 2.81; $p < 0.001$ and OR = 1.56; $p < 0.001$, respectively) and there was also a significant association between DFS and smoking (OR = 2.32; $p < 0.001$). In 1993, there was a statistically significantly higher risk for men vs women (OR = 1.89; $p < 0.020$), for individuals with low education vs high education and employed vs not employed individuals to have more DFS (OR = 2.57; $p = 0.004$ and OR = 3.14; $p < 0.001$ respectively) as well as an

association between DFS and PLI (OR = 1.02; $p = 0.002$). In 2003, there was no statistically significant association between DFS and gender or DFS and socio-demographic variables, but an association between DFS and buffer capacity (lower risk) (OR = 0.45; $p = 0.004$). In none of the years of examination was there an association between DFS and marital status, frequency of snacks and drinks between main meals, saliva secretion rate smoking and snus use. The proposed hypothesis, that smoking or the use of snus will not significantly increase the risk of dental caries compared to non-tobacco users, was thus verified.

Discussion

The use of tobacco and certain food products, as well as oral hygiene, are examples of habits associated with lifestyle. In an earlier study conducted by the authors [21], the aim was to provide an overall picture of the tobacco users in terms of socio-economic conditions, personality aspects and some dental care habits. The main result from that study was that there were only minor differences between tobacco users and non-users, apart from the fact that a larger percentage of tobacco users did not visit a dentist as regularly as non-users. According to Mucci and Brooks [26], smokers may have a lifestyle that modifies their oral health behaviour. The different use of the health service suggests that smokers may have different attitudes to dental health compared to non-smokers and this could be translated as neglecting the prevention and treatment of dental caries [8,26].

The aim of the present report was to continue to study the effect of tobacco use on dental caries and some caries-associated variables, such as saliva secretion rate, buffer capacity and oral hygiene, *mutans streptococci* and *lactobacilli*. It is based on three cohorts of randomly selected individuals from the city of Jönköping, Sweden in 1983, 1993 and 2003. The results regarding the use of tobacco in Sweden are consistent with national studies [1]. The clear-cut time trend is mirrored by the decreasing total number of tobacco users, i.e. the number of smokers is decreasing over time. When it comes to the use of Swedish snus, the opposite trend is apparent, with an increase in certain age groups, particularly among men, but also to some extent among young women. This could be due to the fact that some individuals are starting to use snus instead of cigarettes. From having previously been a male habit, the use of snus has now also increased among women [1].

Cross-sectional studies will only provide a snapshot of lifestyle and oral status. The present study therefore has a limitation in that there is a lack of information about the length of time the different individuals have used tobacco and the age at which they started their tobacco habits. Smokers and snus users were daily

users of tobacco and most of the smokers, 62, 68 and 61% depending on year of examination, smoked more than 10 cigarettes per day. Snus users used snus both as loose snus and as snus in portion bags. Daily use of snus was, therefore, a better way of describing the consumption of snus than the number of boxes.

Giving up smoking may decrease the risk of different general diseases [27]. However, it will take differing lengths of time for former smokers to approach non-smokers [28]. As regards dental disease, tooth loss in subjects who have stopped smoking has been studied by Krall et al. [29] and Yanagisawa et al. [28,30]. Individuals who had stopped smoking had about the same number of teeth, after ~ 13 years of non-smoking, as those who had never smoked, and current smokers had on average about two fewer teeth, after 11 years, than those who had never smoked. In the present study, no information was available on former smokers in 1983 and 2003. In 1993, there was an attempt to get information about former smokers. The participants had difficulties in presenting clear data about when they quit smoking. However, they claimed that they were not smoking anymore and had not been doing so for a relatively long time. Regarding smokeless tobacco, oral mucosal changes are reversible both clinically and histological following cessation of snus use [31].

The prevalence of oral diseases, and in particular dental caries, has changed markedly during the last 40–50 years. This decrease is very impressive in children and adolescents, but also the adult population has shown a considerable improvement in oral health [32,33]. Thus, the present series of epidemiological studies, 1983, 1993 and 2003, from Jönköping, of which this report is part of, has demonstrated a decreasing number of edentulous individuals, an increasing number of natural teeth, better oral hygiene and caries status. These results are also mirrored in the present description of non-tobacco users and tobacco users for the number of teeth, PLI and DFS. Further, saliva secretion rate and buffer capacity seem also to have changed in a significant way, with a lower secretion rate and a higher buffer capacity in 2003 compared to 1993. However, differences between non-users and snus users regarding, for instance, number of teeth and DFS in any separate year of examination may be explained by differences in age.

Dental caries is dependent on age and gender, but also on socio-demographic variables [34]. The possible confounding effect of these variables has therefore been taken into account in the statistical analyses. The results of the multiple regression analyses showed that, after adjusting for background variables, the outcome variable (DFS) in 1983 was explained by gender, age, socio-demographic (apart from marital status) and smoking variables and, thus, other explanatory variables such as saliva secretion rate, buffer capacity and snus use were not statistically

significantly associated with DFS. In 1993, PLI was significantly associated with a higher risk for DFS. In 2003, the only background variable associated with DFS was age. It may be speculated that social and structural changes in society, together with an increasingly better health and oral hygiene, will reduce the importance of background variables like gender and socio-demographic factors for explaining the frequency of dental caries. The reason why buffer capacity in 2003 became an explanatory variable for DFS may be the result of different habits associated with lifestyle changes (better oral hygiene, changing dietary habits, other tobacco habits and products, etc.) compared to 1983 and 1993.

When it comes to dental caries in relation to the use of snus, only a few studies have so far been published. Swedish snus is different from smokeless tobacco in other countries. Thus, Swedish nicotine-containing snus products generally contain neglectable amounts of fermentable carbohydrates and have a high pH value and low level of tobacco-specific nitrosamines (TSNA) [18,20,35]. One interesting observation in the present study was that snus users had a higher buffer capacity than smokers. Thus, when snus is used for many hours a day, as is the case for most snus users, the pH in the oral cavity can be expected to be elevated. This may favour the remineralization of the tooth surfaces and the inhibition of the cariogenic, acid microflora. However, before drawing any further conclusions about the relationship between Swedish snus and caries, further studies are needed.

To conclude, the results of this cross-sectional study of three cohorts in 1983, 1993 and 2003 showed that daily smoking or snus use does not increase the risk of dental caries in the studies carried out in 1993 and 2003.

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