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ORIGINAL ARTICLE

Is caries equally distributed in adults? A population-based cross-sectional study in Norway – the TOHNN-study

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ABSTRACT

Objectives: The aim of the study was to examine the prevalence and distribution of dental caries in an adult population and identify factors associated with being caries free.
Material and methods: Data were collected from a randomized population sample in Northern Norway ($N = 1932$; 988 women; mean age 47.0 years, SD 15.3). The study included a structured questionnaire and a clinical examination. The sum of enamel and dentine caries, $DS_{1\text{-}5}$, formed the main outcome measures for caries prevalence.
Results: Mean DMFT was 15.1 (95% CI 14.8, 15.4), mean DFT was 12.0 (CI 11.7, 12.2), and mean DT was 1.1 (CI 1.0, 1.2). The mean value for dentine caries ($DS_{3–5}$) was 0.8 (CI 0.7, 0.9), and mean $DS_{1–5}$ was 3.8 (CI 3.6, 4.1). Mean $DS_{1–5}$ was highest in the youngest age group (mean 6.9, 95% CI 6.3, 7.6) and in rural areas (mean 5.0, CI 4.4, 5.6). The most caries-prone 20% in the youngest age group had 52% of the total number of carious lesions compared with 80% in the two oldest age groups. Tooth brushing twice daily ($p = .005$), drinking sugar containing soft drink ($p = .029$), and attending dental services every year ($p < .001$), were associated with being caries free.
Conclusion: Dental caries is still a common condition, particularly in the youngest age group. Living in a rural area, low socioeconomic status, less frequent tooth cleaning and sugar containing soft drinks were associated with a higher prevalence of dental caries. The different caries distribution among adults calls for different preventive strategies at both population and individual levels.

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Introduction

The burden of dental caries is usually skewed in the population. No single variable explains the variation among individuals. Factors that have been explored include diet [1,2], genetics [3,4] and socioeconomic status [5,6]. Sheiham and James [2] concluded that dental caries is a diet-mediated disease and that there is extensive scientific evidence that free sugars are the primary necessary factor. Shaffer et al. [4] suggested that genetics account for up to 65% of inter-individual variation in dental caries experience. Costa et al. [6] reviewed the evidence for an association between socioeconomic indicators and dental caries and found that lower income and lower educational levels were both associated with higher caries prevalence. The WHO emphasised that caries still has a substantial impact on individuals in terms of pain, impairment of function and economics with respect to personal and societal costs and a reduced quality of life [5]. For these reasons, caries epidemiology remains of interest and is an indispensable part of dental public health actions [7].

Traditionally, in many cross-sectional studies [8–10], the diagnostic threshold for disease is dental caries at the cavitation level, according to the diagnostic criteria formulated by the World Health Organization (WHO) [11]. This means that early stages of the disease, such as enamel caries, are not recorded. This results in an underestimation of the prevalence [12] and may increase the risk of devaluing preventive activities and non-operative interventions in favour of restorative treatment when planning resource allocation in dental care services [13]. Innes and Schwendicke [14] reviewed the evidence for dentists' thresholds for intervening restoratively in carious lesions and they found that a significant proportion of dentists would intervene where evidence and clinical recommendations would propose less invasive therapies.

There are few Norwegian epidemiological studies describing caries prevalence, including enamel caries and analysis of associations between different risk factors and dental caries within all age groups in a general adult population. The aim of this study was to describe the prevalence and distribution of dental caries and to identify factors associated with being caries free in an adult population.

Material and methods

This cross-sectional, population-based study included a structured questionnaire and a clinical examination of 1932

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individuals with one or more teeth (66.4% of the invited population). A randomly selected sample of 2909 individuals (20–79 years old) drawn from the population register at Statistics Norway was invited to participate in the study. In this age group, 112,253 people were registered in Troms County in January 2013. A power calculation, with a 2-sided, 95% confidence interval and a width of 3%, indicated 1537 individuals were required to be able to describe the prevalence of a disease (periodontitis or dental caries) occurring in approximately 10% of the population. For those who declined to participate, the reason for not attending was registered. The most common reasons for not attending were health problems and no subjective need for dental health care. All data were collected between October 2013 and November 2014, in Troms County in Northern Norway. All the participants provided informed consent to participate. The regional committee for medical and health research ethics of the University of Tromsø, Norway, approved the study (2013/348/REK Nord). More details are described in Holde et al. [15].

Questionnaire

The 15-page questionnaire included 82 questions about background characteristics, education, socioeconomic status, attitudes towards oral health and several psychosocial instruments [15]. In addition to sex and age groups (20–34 years; 35–49 years; 50–64 years; and 65–79 years old), age-grouping based on the NHANES study [16], this study includes data on questions related to municipality size, education, household income, tooth cleaning (brushing frequency + interdental cleaning), sugar containing soft drink consumption, smoking habits, and attending dental health care services (DHCS). The question about household income had six response options ranging from <150,000NOK to above 900,000NOK. These categories were then divided into four categories: "20% lowest with gross income <300,000NOK"; "medium low 300,000–599,999NOK"; "medium high 600,000-899,000NOK" and "25% highest ≥900,000NOK" (1NOK =0.11€). The municipality size was used to calculate the availability of dentists based on statistics from the Norwegian Dentist Association in Tromsø and the Dental Health Services in Troms County Council. The municipalities in the county were classified and divided into three categories based on the number of inhabitants and dentists per inhabitants. (1) *Urban*, the municipality with the largest city (Tromsø) which had the highest availability; (2) *Suburban,* two municipalities (Harstad and Lenvik) with smaller towns came next; (3) *Rural,* was the remaining municipalities without towns and with the lowest availability.

Clinical and radiographic examination

All teeth except the third molar and corresponding teeth surfaces were examined clinically and radiographically, by 11 dental teams (dentist with assisting nurse) [15]. A five-grade diagnostic scale [17] was used to register caries severity radiographically on proximal tooth and occlusal surfaces not accessible for clinical examination. Caries grades 1–2 were denoted as enamel caries and grades 3–5 as dentine caries. Caries on root surfaces was included in the registration of caries. Secondary caries was not included in the calculations of primary enamel and dentine caries, hereafter named DS_{1-5}, due to the low reliability of caries grading in connection with dental restorations [18]. Prior to study start, all examiners were trained and calibrated towards the gold standard [19], regarding the diagnostic criteria and examination procedures including radiographic examination technique. Bitewing-holders were used to standardise the technique. Two calibration tests were conducted during the study period. A set of bitewing radiographs was examined by all examiners, and congruency towards the gold standard using proportion of agreement and Cohen's kappa (κ) was evaluated with an acceptable agreement, (median κ values 0.73 and 0.77 with quartile deviations between 0.5–0.85 and 0.74–0.79, respectively) [15].

Statistical analyses

All statistical analyses were performed with IBM® SPSS® Statistics 24 (New York, NY). Missing data occurred at very low frequency (0.7–4.7%) except for drinking sugar containing soft drinks (8.2%). An analysis of missing data pattern, computed by SPSS, showed that the missing values appeared to be random. All analyses were made on participants with complete data. Bivariate analyses were conducted to identify differences between caries, demographic, socioeconomic and behavioural indicators using independent *t*-tests and one-way analysis of variance (ANOVA). The chi-square test was used for categorical variables. As there were multiple comparisons in the ANOVA test, a Bonferroni correction of significant levels was made to protect against type 1 errors.

A simple linear regression was calculated to predict the number of surfaces with dentine caries (DS_{3-5}) based on the number of enamel caries (DS_{1-2}) lesions. In a binary logistic regression analysis, people with zero (0) initial or dentinal caries (DS_{1-5}) lesions were used as dependent variable (i.e. caries free). Education, toothbrushing frequencies, interdental cleaning frequencies, frequencies of consumption of sugar containing soft drinks, and dental service attendance were used as independent variables. The logistic regression model strategy used was as follows: First, crude associations for each variable with the odds of being caries free were studied in a univariate model. Secondly, multivariate models were used to study the adjusted associations. Variables were added to the model and those that showed a significant univariate association were retained. The associations are presented as odds ratios (ORs) with 95% confidence intervals (CI). The Hosmer–Lemeshow goodness-of-fit test was used to examine whether the final model adequately fitted the data. The significance level was set at p-value ≤ .05.

A Microsoft Excel spreadsheet was used to create Lorenz curves and calculate Gini coefficients. The Lorenz curves were made according to the modifications suggested by Poulsen et al. [20]. Gini coefficients were calculated using the Riemann sum estimate (middle sum). This provided an exact value of the area under the curve when the curve is based on straight segments, which is true for Lorenz curves.

Results

Background characteristics of the participants are presented in Table 1. The participants had a mean age of 47.0 (SD 15.3) years; 988 out of 1932 (51%) were women. Approximately 28% of all the individuals reported that they brushed their teeth once a day or less often and almost 15% of the participants were smokers. Just above 50% of the participants attended dental health care services (DHCS) annually and about one fourth with an interval of every second year or longer.

Table 1. Age, municipality size, education level, household income, tooth brushing, interdental cleaning, sugar soft-drinks, smoking, attendance to Dental Health Care Service (DHCS), and internal loss for each variable.

	Total		Internal loss	
	n	%	*n*	%
All cases	1932	100		
Age				
20–34	478	24.7		
35–49	607	31.5		
50–64	559	28.9		
65–79	288	14.9		
Total	1932	100	0	0
Municipality size				
Rural (larger town)	466	24.1		
Suburban (smaller town)	598	31.0		
Urban	867	44.9		
Total	1932	100	1	0.1
Education				
Secondary school	281	14.7		
High School	835	43.6		
University	798	41.7		
Total	1914	100	18	0.9
Household income				
20% lowest	269	14.5		
Medium low	632	34.0		
Medium high	584	31.5		
25% highest	372	20.0		
Total	1857	100	75	3.9
Toothbrushing				
≤1 per day	537	28.1		
≥2 per day	1372	71.9		
Total	1909	100	23	1.2
Interdent cleaning				
Seldom/Never	127	6.9		
Sometimes	989	53.7		
Daily	726	39.4		
Total	1842	100	90	4.7
Sugar soft Drinks				
Seldom	999	56.3		
Few times/week	672	37.9		
Several times/week	103	5.8		
Total	1774	100	158	8.2
Smoking				
Yes	284	14.8		
No	1635	85.2		
Total	1919	100	13	0.7
Attendance DHCS				
Every year	1015	52.9		
Every second year/longer	473	24.6		
When problem	431	22.5		
Total	1919	100	13	0.7

Proportions were calculated on total responses of each variable.

Dental caries prevalence

Table 2 summarises the mean values for different caries experience measures at the surface and tooth level. The elderly age groups had the highest DMFT, DMFS, DFT, and DFS values. In contrast, the mean numbers of intact teeth, DT, $DS_{1–2}$, $DS_{3–5}$, $DS_{1–5}$, $DS_{1–5}$+sec, were highest in the youngest age group. There were significant differences between all the age groups except for DT and all DS values, in which there were no significant differences between the two oldest age groups, nor were there any significant differences between secondary caries and age groups.

Association between enamel ($DS_{1–2}$) and dentine ($DS_{3–5}$) caries

A significant regression equation was found (F (1,1930) = 195.34, $p < .001$) with an R^2 of 0.092. Participants' predicted number of surfaces with dentine caries was equal to 0.479 + 0.103 enamel caries per dentine caries surface. Participants' mean number of surfaces with dentine caries increased 0.103 for each surface with enamel caries.

Primary dental caries distribution ($DS_{1–5}$) versus ($DS_{3–5}$)

Approximately 18% of the participants in the youngest age group (20–34 years) had no caries experience ($DS_{1–5} = 0$) (Table 3). In the same age group, 46% had no dentine caries ($DS_{3–5} = 0$). The same tendency of difference between the outcomes remained through all age groups. With increasing age, the proportion of individuals without caries experience decreased. Over 50% of the individuals in the youngest age group had a mean DS_{1-5} value of ≥5 surfaces (Table 3).

Figure 1 shows the Lorenz curves comparing all carious lesions ($DS_{1–5}$) between different age cohorts. Where the curve intersects with the Y-axis (X = 100%) indicates the fractions of the population with and without caries, although in the latter group most people had restorations and also some teeth had been extracted due to caries. In the age cohorts 20–34, 35–49, 50–64 and 65–79 years, the fraction without active caries are approximately 18%, 28%, 55% and 61%, respectively. From the curves, it can be estimated that the most caries-prone 20% in the same cohorts have 52, 67, 81 and 80% of the total number of carious lesions, respectively.

Primary dental caries ($DS_{1–5}$) in relation to demographic, socioeconomic, and behavioural factors

Urbanised municipalities, non-smoking, toothbrushing and interdental cleaning habits, seldom drinking sugar containing soft drinks, and attending DHCS regularly were all factors significantly related to a lower mean $DS_{1–5}$ ($p < .001$ to .004) (Table 4).

Predictors of being caries free (having zero primary dental caries, $DS_{1–5}$)

In the univariate analysis, the odds of belonging to the 'caries free' group, i.e. having zero visual caries signs,

Table 2. Caries prevalence caries exposed surfaces and teeth.

		DMFS	DFS	$DS_{1–2}$	$DS_{3–5}$	$DS_{1–5}$	Sec	$DSprox_{1–2}$	$DSprox_{3–5}$
	n	Mean (CI)	Mean (CI)	Mean (CI)	Mean (CI)	Mean (CI)	Mean (CI)	Mean (CI)	Mean (CI)
Surface level									
All	1932	46.0 (44.6, 47.5)	31.2 (30.2, 32.1)	3.0 (2.8, 3.3)	0.8 (0.7, 0.9)	3.8 (3.6, 4.1)	0.5 (0.4, 0.5)	2.0 (1.8, 2.1)	0.6 (0.5, 0.6)
Sex									
Men	945	48.3 (46.3, 50.4)	32.0 (30.7, 33.3)	3.0 (2.7, 3.3)	1.0 (0.8, 1.1)	3.9 (3.6, 4.3)	0.6 (0.5, 0.6)	1.9 (1.7, 2.1)	0.7 (0.6, 0.8)
Women	987	43.9 (41.8, 45.9)	30.4 (29.0, 31.8)	3.1 (2.8, 3.4)	0.6 (0.6, 0.7)	3.7 (3.4, 4.1)	0.4 (0.3, 0.5)	2.0 (1.8, 2.2)	0.5 (0.4, 0.6)
Age (years)									
20–34	464	17.9 (16.5, 19.3)	14.1 (12.9, 15.2)	5.4 (4.9, 6.0)	1.5 (1.3, 1.7)	6.9 (6.3, 7.6)	0.4 (0.3, 0.5)	3.9 (3.5, 4.2)	1.2 (1.0, 1.3)
35–49	606	31.4 (29.9, 33.0)	24.5 (23.3, 25.7)	3.7 (3.3, 4.2)	0.8 (0.6, 0.9)	4.5 (4.0, 5.0)	0.5 (0.4, 0.5)	2.3 (2.0, 2.6)	0.6 (0.5, 0.7)
50–64	554	62.7 (60.6, 64.4)	46.0 (44.5, 47.6)	1.4 (1.1, 1.7)	0.4 (0.3, 0.6)	1.8 (1.5, 2.2)	0.5 (0.4, 0.6)	0.8 (0.6, 0.9)	0.3 (0.2, 0.4)
65–79	308	87.1 (84.6, 89.6)	43.4 (40.7, 45.8)	1.0 (0.7, 1.2)	0.4 (0.3, 0.5)	1.4 (1.1, 1.7)	0.6 (0.4, 0.7)	0.5 (0.3, 0.6)	0.3 (0.2, 0.3)
	n	Number-T	Intact-T	DMFT	DFT	DT			
		Mean (CI)	Mean (CI)	Mean (CI)	Mean (CI)	Mean (CI)			
Teeth level									
All	1932	24.9 (24.7, 25.2)	12.9 (12.6, 13.2)	15.1 (14.8, 15.4)	12.0 (11.7, 12.2)	1.1 (1.0, 1.2)			
Sex									
Men	945	24.6 (24.3, 24.9)	12.3 (11.9, 12.8)	15.7 (15.2, 16.1)	12.2 (1.8, 12.6)	1.3 (1.2, 1.4)			
Women	987	25.2 (25.0, 25.5)	13.5 (13.0, 13.9)	14.5 (14.1, 15.0)	11.7 (11.4, 12.1)	0.9 (0.8, 1.0)			
Age (years)									
20–34	464	27.2 (27.0, 27.3)	19.5 (19.0, 20.0)	8.5 (8.0, 9.0)	7.7 (7.2, 8.2)	1.7 (1.5, 1.9)			
35–49	606	26.6 (26.4, 26.7)	15.6 (15.1, 16.0)	12.4 (12.0, 12.9)	11.0 (10.6, 11.4)	1.1 (1.0, 1.2)			
50–64	554	24.6 (24.2, 25.0)	8.6 (8.2, 9.0)	19.4 (19.0, 19.8)	15.9 (15.5, 16.3)	0.8 (0.7, 0.9)			
65–79	308	18.8 (18.2, 19.8)	5.5 (5.1, 5.9)	22.5 (22.1, 22.9)	13.2 (12.5, 13.9)	0.8 (0.7, 1.0)			

All cases and related to sex and age. 95% Confidence Interval for Mean (CI). DS_{1+2}: Enamel caries grade 1–2; $DS_{3–5}$: Dentine caries grade 3–5; $DS_{1–5}$: Enamel and dentine caries grade 1–5; Sec: secondary caries; DSprox: Proximal surfaces. Intact teeth: no fillings or dentine caries.

Table 3. Proportion of primary caries: enamel and dentinal caries grade 1–5, (DS_{1-5}), and dentinal caries grade 3–5, ($DS_{3–5}$) in relation to age group.

	$DS_{1–5}$						$DS_{3–5}$					
	Age groups (years)						Age groups (years)					
	20–34		35–49		50–79		20–34		35–49		50–79	
Number surfaces with caries	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
0	17.9	17.9	28.4	28.4	57.2	57.2	46.3	46.3	61.9	61.9	79.6	79.6
1	7.5	25.4	14.9	43.2	13.5	70.7	21.8	68.1	21.8	83.7	11.6	91.2
2	5.2	30.6	10.2	53.3	10.3	81.0	9.7	77.8	8.1	91.8	4.5	95.7
3	6.9	37.5	9.1	62.4	4.9	85.9	10.4	88.2	3.5	95.3	1.7	97.4
4	8.8	46.3	6.6	68.9	3.5	89.4	3.2	91.4	2.1	97.4	0.8	98.2
5	6.0	52.3	5.0	73.9	2.4	91.8	3.2	94.6	1.0	98.4	0.8	99.0
6	6.5	58.9	4.6	78.4	1.9	93.7	1.1	95.7	0.3	98.7	0.1	99.1
7	4.5	63.4	2.6	81.0	1.0	94.7	0.9	96.6	0.2	98.9	0.5	99.6
8	5.2	68.7	2.5	83.4	0.9	95.6	1.4	98.0	0.0	98.9	0.0	99.6
9	4.1	72.8	1.2	84.6	0.5	96.1	0.6	98.6	0.2	99.1	0.2	99.8
10	4.1	76.9	1.5	86.1	0.6	96.7	0.6	99.2	0.2	99.3	0.0	99.8
11–13	8.4	85.3	5.0	91.1	1.8	98.5	0.2	99.4	0.5	99.8	0.0	99.8
14–16	5.9	91.2	2.0	93.1	0.3	98.8	0.4	99.8	0.0	99.8	0.1	99.9
17–20	3.7	94.9	2.0	95.1	0.6	99.4	0.2	100.0	0.0	99.8	0.1	100.0
21–30	3.9	98.8	3.8	98.9	0.5	99.9			0.2	100.0		
31–37	1.2	100.0	1.1	100.0	0.0	99.9						
38–46					0.1	100.0						

Proportion of individuals (%) and cumulative proportion (cumulative %).

increased for individuals who brushed their teeth twice daily, cleaned interdentally daily, drank sugar-containing soft drinks seldom, or attended dental services annually (Table 5). When the model was adjusted for all significant variables in a multivariable model, daily interdental cleaning was no longer significantly associated with zero caries. In the final model, attending dental services annually was the strongest predictor of being caries free. The goodness-of-fit of measurement used in the final model was an acceptable fit on the Omnibus test of model coefficient (χ^2 120.6, $p > .001$) and Hosmer and Lemeshow test (χ^2 3.63, $p = .821$). The factors used as predictor in the model explained 9% of the variance of caries (Nagelkerke's R^2 of 0.094).

Discussion

The choice of a threshold level for reporting caries is crucial when describing prevalence and distribution in a population [12,13]. Using a more cavity-oriented perspective with presenting only dentine caries $DS_{3–5}$, gives an indication of mean number of decayed surfaces that are not treated (i.e. filled) while by including enamel caries ($DS_{1–2}$), the total caries status in the examined population is revealed. The latter could contribute to information about the need for non-operative caries treatment. Depending on which perspectives were used to report how many in the youngest age group who were caries free, the proportion differed significantly.

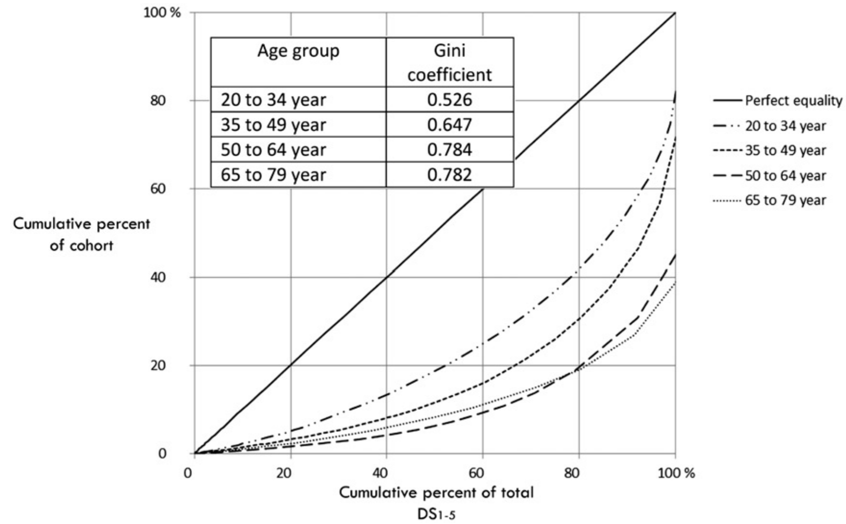

Figure 1. Caries distribution ($DS_{1–5}$) in relation to age. The intersection with the Y-axis (X = 100 %) indicates the fractions of the population with caries and no caries.

Table 4. Bivariate analysis between the mean number of surfaces with primary caries (enamel and dentinal) and different explanatory variables.

	Primary caries (enamel and dentinal ($DS_{1–5}$)	p value (CI: 95%)
Municipality		<.001
Urban (larger town)	2.5 (3.9)	(2.2, 2.7)
Suburban (smaller town)	4.9 (7.2)	(4.3, 5.4)
Rural	5.0 (6.7)	(4.4, 5.6)
Household income		<.056
20% lowest	4.6 (6.0)	(3.9, 5.3)
Medium low	3.8 (5.9)	(3.3, 4.3)
Medium high	3.8 (6.2)	(3.4, 4.3)
25% highest	3.3 (5.3)	(2.8, 3.8)
Education		<.001
Sec. School	2.9 (4.6)	(2.4, 3.5)
High School	4.4 (6.3)	(4.0, 4.8)
University	3.6 (5.9)	(3.2, 4.0)
Smoking		<.004
Yes	4.8 (7.3)	(3.9, 5.6)
No	3.9 (5.7)	(3.4, 3.9)
Toothbrushing		<.001
TB ≤1 per day	4.8 (6.5)	(4.2, 5.3)
TB ≥2 per day	3.5 (5.6)	(3.2, 3.8)
interdental cleaning		<.001
Seldom/Never	5.2 (7.2)	(3.9, 6.5)
Sometimes	4.4 (6.0)	(4.0, 4.8)
Daily	2.7 (5.2)	(2.3, 3.0)
Sugar soft drinks		<.001
Seldom	3.1 (5.2)	(2.8, 3.4)
Few times/week	4.8 (6.6)	(4.3, 5.3)
Daily	6.7 (7.5)	(5.2, 8.2)
Attendance DHCS		<.001
Every year	3.0 (5.7)	(2.7, 3.4)
Every second year and longer	3.9 (5.6)	(3.4, 4.7)
When problem	5.6 (6.5)	(5.0, 6.2)

When dentin caries ($DS_{3–5}$) was used as outcome the proportion of participants who were caries free was around 50%, but when enamel caries ($DS_{1–2}$) was included, only 18% of the population had no caries. Interestingly, the caries distribution was more equally distributed in the youngest age group, indicating that a larger proportion of participants in that age group had several more surfaces with caries than the two oldest age groups, in which 20% of the population carried 80% of the caries burden.

The results regarding the various DFT components are consistent with other cross-sectional studies [8,9,10,21,22]. The present study reports primary caries with enamel lesions as the diagnostic threshold, in an effort not to underestimate caries [12,13,23]. However, there are few studies in adults where the prevalence of both enamel and dentine caries has been reported (DS_{1-5}). Norderyd et al. [21], using the sum of enamel and dentine caries in a Swedish population, reported a sum score of 3.7 for the age cohorts 20- and 30-year-olds, which was almost half of the mean number in the present study.

According to Fyffe et al. [13], using enamel caries as threshold will also stimulate a non-operative approach in favour of restorative care, i.e. preventive treatment measures of early signs of caries (enamel caries). One argument against this, especially in adults, is that some of the enamel lesions probably will remain static over the years [24], and do not necessarily indicate deteriorating health. However, to gain knowledge of whether caries lesions are progressing over time needs a different study design.

Lorenz curves provide an opportunity to study the cumulative frequency distribution of caries, which is useful, in addition to the conventional measures of centrality, such as the mean and median values. Lorenz curves are a statistical tool that shows inequalities in disease and risk distribution [25]. The skewed distribution of caries in the present study, especially in the elderly age groups, is consistent with other studies on caries that have been performed in younger age groups using Lorenz curves [20,26,27], but direct comparisons are difficult due to different study designs and, e.g. different diagnostic criteria.

The fact that social inequalities, such as lower education and income levels, play an important role in the variation of caries distribution, with a higher prevalence of caries in different populations, has been discussed in several reports [6,28].

Surprisingly, in the present study, socioeconomic status (education and income) had minor associations with being ‘caries free’, i.e. having zero visual caries signs, which is

Table 5. Logistic regression of variables associated with having no visual signs of caries ($DS_{1–5}$).

		Crucial measures		Univariate			Multivariate: Adjusted for variables in the model		
Variable	Level	*N*	% with no caries	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Education	Sec. school	124	44.1	1.2	0.9, 1.6	.184			
	High school	303	36.3	0.8	0.7, 1.1	.168			
	University	316	39.6	Reference	Reference				
Smoking	Yes	284	39.1	Reference	Reference				
	No	1635	38.8	0.9	0.8, 1.3	.922			
Toothbrushing	≤1 per day	169	31.5	Reference	Reference		Reference	Reference	
	≥2 per day	571	41.6	1.5	1.3, 1.9	<.001	1.4	1.1, 1.8	.005
Interdental cleaning	Seldom/Never	38	29.9	Reference	Reference		Reference	Reference	
	Sometimes	321	32.5	1.1	0.7, 1.7	.565	0.9	0.6, 1.4	.753
	Daily	360	49.6	2.3	1.5, 3.4	<.001	1.5	0.9, 2.3	.079
Sugar soft drinks	Seldom	429	42.9	2.3	1.5, 3.7	<.001	1.7	1.1, 2.8	.029
	Few times/week	211	31.4	1.4	0.9, 2.3	.145	1.1	0.7, 1.9	.604
	Daily	25	24.3	Reference	Reference		Reference	Reference	
Attendance DHCS	Every year	485	47.8	3.0	2.3, 3.9	<.001	2.4	1.8, 3.2	<.001
	Every sec. year or longer	157	33.2	1.6	1.2, 2.2	.001	1.5	1.1, 2.1	.012
	When problem	100	23.2	Reference	Reference		Reference	Reference	

contradictory to findings in other studies [6,28]. One reason for the difference could be that Costa et al. [6] and Steele et al. [28] used decayed teeth or the composite indices DMFT and DMFS as outcome measures. In the present study, by using both enamel and dentinal caries as outcomes, the caries burden seems to be more equally distributed independently of educational level or income. This applies at least in populations where a majority has high school education or higher, which was the case in this study. Nevertheless, it seems that behavioural factors such as sugar-containing soft drinks consumption, toothbrushing frequency and annual dental attendance affected the probability of being healthy. People who attend DHCS irregularly were less likely to be healthy, and this is confirmed in other studies [29,30]. However, this must be confirmed, preferably in longitudinal studies. In present study, people living in rural areas had a higher caries prevalence compared with people living in Tromsø, lower availability to dentists and longer distance to the dental health care clinics might be explanations for the differences but also people's attitudes towards oral health care. To handle the complexity of how all of these factors and underlying mediators are associated with oral health, there is a need for more theoretical modelling, such as the Andersen's behavioural model [31] and more comprehensive analysis [6].

Although there is a group with better oral health, there is still a significant group of individuals with signs of dental caries. The distribution of caries among participants in the youngest age groups shows a relatively high frequency of dental caries even though these people have grown up in an era of free access to dental health care and in a society in which dental health care organised with a preventive approach. Are there reasons to reconsider our caries preventive strategies? It might be time to reassess and upgrade the population-based preventive approach, especially to the younger population. In a recent study in Norway, Widström et al. [32] found that chair-side preventive treatment measures delivered by dentists and dental hygienists were numerous but not fully in accordance with today's evidence-based practice. Jensen et al. [33] reported that although the information given at the dental visit includes recommendations on toothbrushing, there are weaknesses concerning the fluoride concentration in toothpaste, rinsing procedures after brushing or toothpaste brushing techniques. As for the two oldest age groups who showed a particularly skewed caries distribution, this might indicate the need for a more selective preventive and treatment strategy for the subgroup with the highest need.

To ensure validity and reliability, all teams were trained and evaluated to a gold standard prior to the survey and calibration tests were performed during the course of the study with acceptable agreement [15]. Since the study was conducted during a period of approximately one year, one weakness might be that only two calibration tests were carried out in addition to the initial training. Another weakness could be that only inter-examiner agreement was tested, which does not reveal the observers' tendency to systematic under- or overestimation of caries. The strengths of this study are its large sample size, high-attendance rate and the inclusion of almost all adult age groups. The overall internal loss was low, somewhat higher for the variable sugar-containing soft drinks which may have influenced the result. The oldest age group had a slightly lower response rate [15], which can cause an under- or overestimation of oral health problems among the oldest age group, and must be considered in interpreting the data. Due to the overall high participation rate [15] and that, the caries data seem to correlate with other comparable studies, generalisation of the results nationally and to the northern part of Norway is justified. Total primary caries $DS_{1–5}$ was the main outcome variable in the present study and it is important to highlight at least two arguments that could have an impact on the results. First is a paradigm shift that has occurred in recent years towards a more restrictive diagnostic threshold for cavity preparation and restoration. Secondly, the elderly age groups have more dental fillings and hence a smaller chance of developing primary caries. However, secondary caries made just a minor contribution to total caries, and the presence of secondary caries did not differ between the age groups.

Conclusions

Dental caries remains common, particularly in the youngest age group; a substantial proportion of participants had several carious surfaces. In contrast, in the two oldest age groups, those with the highest proportion of caries were fewer. Living in rural areas, low socioeconomic status, less frequent tooth cleaning, and sugar-containing soft drink intake were associated with a higher prevalence of dental caries. Seen from a health perspective to be 'caries free', i.e. have zero visual signs of caries, behavioural variables seem to have greater influence compared with socio-economic variables. The results call for an evidence-based review of both population- and individual-based preventive programmes.

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Disclosure statement

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