UiT The Arctic University of Norway

Faculty of Health Sciences- Department of Community Medicine

Educational gradient in dental caries

A cross-sectional study from the Tromsø 7 Study, 2015- 2016

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Abstract

Background: Dental health is an important aspect and a key indicator of general health. However, detailed data on dental health in the adult population in Norway is lacking. Literature indicates that people with lower socioeconomic position (SEP) have significantly poorer dental health than people with higher SEP. For example, adults in Norway with higher education report better self-reported dental health status compared with adults who have lower education. Therefore, although the inequality in dental health has been significantly reduced in Norway the last 50 years, findings may indicate that there still exists inequality in dental health among adults in Norway. These inequalities often manifest in a gradient.

Aim: This study sought to investigate if educational gradient in dental caries exists in the adult population in Tromsø municipality. The objective was to assess an association between educational level and dental caries experience among the participants of the Tromsø 7 study.

Materials and methods: The study population consisted of 3823 adults living in Tromsø municipality in northern- Norway who participated in the Tromsø 7 study. Social determinants: education, age, sex, household income, spouse, childhood financial situation, mother and fathers' education, siblings, and intermediary determinants: smoking, alcohol consumption, exercise, soft drinks, tooth brushing, fluoride toothpaste, interdental cleaning aids, fluoride tablets, fluoride rinse, dental care and dental satisfaction was self-reported in a questionnaire. Registration of decayed, missing, filled, teeth (DMFT) score was performed after the clinical examinations by calibrated dentists using bitewing radiographs and intra-oral clinical photographs. Descriptive statistics, chi- square test and independent t-test was performed to describe the sample. Univariable and multivariable binary logistic regression models were conducted and the association between educational level and DMFT score was adjusted for selected social and intermediary covariates.

Results: After excluding participants with missing values in education and DMFT score, the data of 3752 participants aged 40- 92 years was analyzed. The median DMFT score among all participants was 19 (9), mean 18.03 (6.41). The univariable binary logistic regression analysis showed a statistically significant association between educational level and DMFT score.

The odds for higher DMFT score followed a gradient based on educational level, meaning that the odds for higher DMFT score were observed in lower education level (primary/partly secondary education level versus tertiary education level, long) and lower odds for higher DMFT score were in higher education level (upper secondary level and tertiary education, short versus tertiary education, long). When adjusted for covariates a statistically significant association remained between education level and DMFT score. However, the educational gradient was not clearly observed between the two intermediate educational levels.

Conclusion: The present cross-sectional study demonstrated an educational gradient in dental caries among the adult population in Tromsø municipality. The results call for health promotion and disease prevention initiatives to address this social determinant and thereby reduce educational inequalities in dental health.

List of abbreviations

CI	Confidence interval
CSDH	The Commission on Social Determinants of Health framework
DMFS	Decayed, filled, missing, surfaces (permanent teeth)
DMFT	Decayed, filling, missed, teeth (permanent teeth)
dmft	Decayed, filled, missed, teeth (primary teeth)
DPC	Data- and Publication Committee
IQR	Inter quartile range
OR	Odds ratio
REC	Regional Committee of Medical and Health Research Ethics
SD	Standard deviation
SEP	Socioeconomic position
WHO	World Health Organization

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1 Introduction

1.1 Dental health and dental caries

1.1.1 Dental health status in Norway

Norway is a high-income country and was ranked as one of the best countries to live in by the United Nations Human Development Index in 2017 (1). The government in Norway provides free dental services for children, adolescent, and adults with special needs and the general adult population pay out of pocket for dental services themselves (2). The tendency during the last 30 years indicate improvement in dental health among the population in Norway (3). Today the majority of elderly have their natural teeth, only one in five over 60 years is edentulous (4). In 1975 this applied to more than 60%. Consequently, the prevalence of dental caries increased among individuals who have their natural teeth. However, the overall prevalence of caries and caries experience (number of decayed, missing and filled teeth (DMFT score)) have decreased (5).

1.1.2 Dental health in northern-Norway

Several studies indicate that people's general health is worse in circumpolar areas compared to southern areas (6, 7). A north- south gradient exists, there is a dependency between dental health and place of resident, studies have communicated poorer dental health status in the three northernmost counties (4, 5, 8). Being a resident of northern- Norway increases the likelihood of having lower number remaining teeth, having worse self-perceived dental health and lower dental service utilization (9, 10). Nevertheless, there is not sufficient data on dental health among adults in northern- Norway (4).

1.1.3 Dental caries

Dental caries is still a common dental health condition; indeed, it is one of the most widespread non-communicable diseases and is considered a major public health problem (11, 12). Dental caries affects the majority of adults and is a cumulative condition where prevalence increases with age (13, 14). Poor dental health affects quality of life and untreated caries may cause pain or discomfort, tooth loss and medical complication. Moreover, the disease creates a burden for the dental service system (11). According to the World Health

Organization (WHO), dental caries is the fourth-most expensive chronic disease to treat (13). Dental caries is a multifactorial disease affecting all surfaces of the tooth and people at all ages have a susceptibility to the disease (15). The development of dental caries is a complex interaction between acid-producing bacteria, fermentable carbohydrate, and several host factors- a shift of ecological balance between microbial biofilms and mineral structures of the tooth. There are several determinants of dental caries, both intermediary determinants which directly contribute to carious lesion development, and social determinants, which may influence dental caries (15, 16).

1.2 Social inequalities in health

WHO established the Commission on social determinants of Health (CSDH) to investigate evidence on how the structure of society, through determinants, affects health and how governments may influence population health (17). The CSDH framework identifies social and intermediary determinants and shows how these are related to each other. Social determinants are what defines an individual socioeconomic position (SEP), *i.e.* income, education, occupation, social class, gender, and race/ethnicity. Intermediary determinants refer to more downstream factors like biological and behavioral factors, psychological and material circumstances, and the health system itself. The CSDH framework communicates how political, economic, and social mechanisms (structural mechanisms) generate a set of SEP. These social determinants shape intermediary determinants and forms health outcomes. The CSDH framework shows that SEP determines different exposure and vulnerability to the intermediary determinants of health. Since resources are not equally distributed among people (18), social determinants may initiate or enhance social stratification and define individual SEP (17). SEP is associated with both prevalence of disease, self-reported health (19) and the impact of social determinants can accumulate through life and transfer across generations (20). Finally, inequality in health often manifests in a gradient (21). The social gradient in health is a term which is used to describe the slope phenomenon where people who are more advantaged in terms of SEP have better health then those who are less advantaged. This thesis will follow a conceptual framework adapted from CSDH and presented in Figure 1.

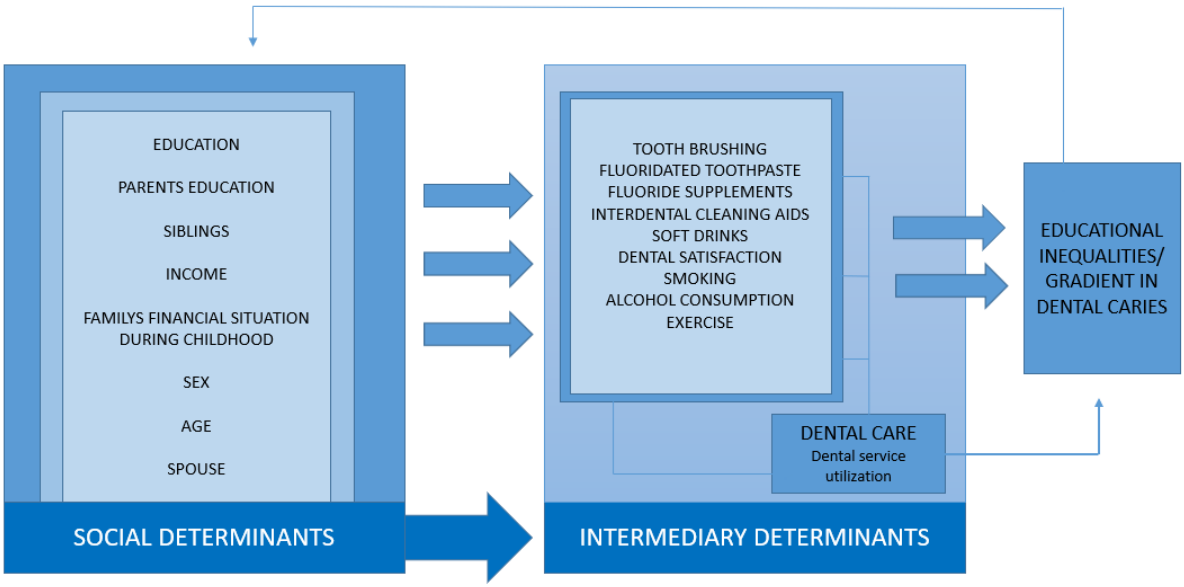

Figure 1- Conceptual framework of the study, based on the CSDH framework of social and intermediary determinants.

1.3 Intermediary determinants of dental caries

Studies have shown that intermediary determinants like biological factors are highly related to dental caries risk (22). Dental caries is at some extent presumed as a heritable disease and genetics may lead to variation in susceptibility to dental caries (22, 23). Behavioral determinants of dental caries include nutrition, oral hygiene, fluoride supplements and tobacco. Sugar intake, poor oral hygiene and insufficient fluoride exposure has for a long time been considered as a determinant for dental caries (15, 24). The relationship between diet and dental caries has been well documented (25) and there is evidence that dental caries is a diet-mediated disease and that free sugars are the primary necessary dietary factor which cause dental caries (24, 26, 27). A systematic review which aimed to assess the effect of tooth brushing found an increase in incidence of dental caries in individuals who performed oral hygiene measures like tooth brushing less than at least ones a day (28). Although, it was not stated whether it is the fluoride that affects dental caries or just the tooth brushing itself. Smoking is a habit which has an influence on oral health, and studies have found that smokers had higher dental caries prevalence than non- smokers (29-32). Another study showed that smoking promote growth of cariogenic microorganisms (33). Finally, intermediary determinants of caries are shaped by social determinants (17).

1.4 Social determinants of dental caries

Even though dental caries is primarily related to biological factors which operate directly in the oral cavity (15), social determinants are other factors related to caries risk (34). The most commonly used social determinants regarding health inequalities is educational attainment, occupation, social class and income (18). These indicators have different causal pathways to health. The Norwegian Directorate of Health published a report in 2008 which suggested that education is a basis and a contributor to processes, which influences health (35). Educational level is often acquired in early adulthood and captures long-term influences of childhood circumstances and adult resources on health (17). In Norway education is free and in 2020, 35.3 % of the adult population had tertiary education (36).

1.5 Social inequalities in dental caries

The relationship between social determinants and dental health, *i.e.* social inequalities in dental health, has been investigated in several studies (37-42). Although the measure of dental caries differs, the studies showed how dental health varies with social determinants. A systematic review, conducted by Schwendicke and colleges, demonstrated lower SEP to be significantly associated with higher risk of having caries lesions or caries experience (41). Costa and colleges included 41 studies on social determinants and dental caries in their systematic review (39). They found an association between social determinants and caries experience in adults. Lower SEP were associated with higher caries prevalence. In 2018 a study, aimed to update the latter systematic review, found evidence that high caries experience had an association with lower SEP and that SEP could be a marker for increased dental caries risk (40). Evidence between SEP and dental caries has to some extent been contradictory in adults (38, 43, 44). A review found that several studies did not find a significant relationship between SEP and dental caries/DMFT score, hence the relationship was inconsistent among adults (44). These findings are in line with a cross-sectional study from 2015, conducted by Steele and colleges, which reported an unclear relationship between DMFT score, and SEP in adults (43). Several Norwegian studies reported inequalities in dental health (45, 46). However, they were not conducted in northern- Norway and only one of these studies aimed to investigate educational inequalities. A cross-sectional study performed in rural areas of northern- Norway with adult participants showed that the strongest predictor of being caries free was attending dental services annually (47). The current

knowledge of educational inequalities/gradient in dental caries among adults in northern-Norway, namely Tromsø municipality, is lacking.

1.6 Research question and null-hypothesis

The research question of this thesis was to investigate if educational gradient in dental caries exists in the adult population in Tromsø municipality. The objective was to assess an association between educational level and dental caries experience among the participants of the Tromsø 7 study. The null-hypothesis stated that there was no association between educational level and dental caries experience in the Tromsø population.

2 Materials and Methods

2.1 The Tromsø study

The Tromsø study is an ongoing population based survey in the municipality of Tromsø, in northern- Norway (48). It was initiated in 1974 to contribute to the combat of high mortality of cardiovascular disease and since then seven surveys have been conducted. The data used in this thesis were collected in the Tromsø 7 study from March 2015 to November 2016 (49). The study included two main steps: questionnaire-based data collection and basic examinations (first visit). A pre-defined sample of 13 000 people were invited for a second visit including more comprehensive examinations (second visit). This thesis use data from both the questionnaire-based study and the first visit (dental station) examination.

2.2 Study population

Tromsø has approximately 80 000 inhabitants and all inhabitants of the municipality aged 40 years or older were invited to participate (n= 32 591) (49). A total of 21 083 women and men aged 40-99 years from both rural and urban areas attended the study (attendance rate 65%). The dental station had 3943 (19%) participants (50).

In this thesis, 3752 participants were included, and 191 participants were excluded from the statistical analysis due to missing values in educational level and DMFT score (Fig. 2).

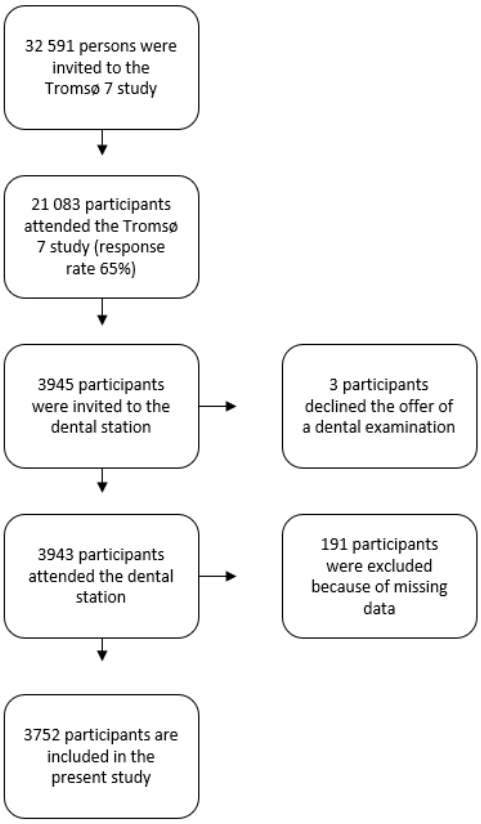

Figure 2- Flowchart of the participants included in this study.

2.3 Data collection

All invited person's received a brochure containing information about the Tromsø study together with a questionnaire (Q1) (49). They also received a username and a password if they preferred to complete the questionnaire (Q1) digitally. When they logged in, the participants were presented with questionnaires. Q2 was a more comprehensive questionnaire which also contained several questions regarding oral health. If anyone needed assistance in completing the questionnaires, they received help from trained technicians at the location when they attended the first visit. All participants had the opportunity to attend the first visit, where they went through a basic examination. In the Tromsø 7 study, oral health was included for the first time. Data regarding oral health was collected at the dental station and it was the last station in the first visit basic examination (50).

2.4 Dental station

Every hour the first two participants who came to the location of the first visit of the basic examination, were asked to participate in the dental examination (50). Only three participants declined the offer of a dental examination and did not attend the clinical dental examination at the dental station. Each participant received a dental examination free of charge. At the dental station dental hygienists took orthopantomgram (OPG), 4 bite wings, 8 clinical intra oral photos (Canon EOS 60D, Canon 105 mm; Sigma EM-140 DG) and measured clinically periodontal pocket depth. Third molars were excluded from analysis. The dental hygienists who collected the data were prior to the study trained and calibrated. The participants received personal information regarding treatment needs if there were any findings during the examination. For those who did not visit dental health clinics on a regular basis, the clinicians presented a list with clinics for them to contact.

2.5 Variables

2.5.1 Dental caries experience (DMFT score)

Dental caries was expressed as dental caries experience and decayed, misses and filled teeth (DMFT) index, suggested by WHO (51) and it was used as an outcome in this study. The registration of DMFT score was performed after the clinical examinations based on bite wing radiographs and intra-oral clinical photographs by seven calibrated dentists (50). Tooth status

was recorded as healthy, decayed, missing, or filled. To record decayed teeth, the classification proposed by Amarante and colleges was used (52). The seven dentists had a good level of agreement, mean inter- examiner agreement was Kw= 0, 70 and intra-examiner agreement was Kw= 0, 81. For statistical analyses the DMFT score was dichotomized into lower DMFT score (0-19) and higher DMFT score (20-28) and the cut-off point was the median DMFT score value in the study sample.

2.5.2 Educational level

The social determinant, participant's educational level, was a predictor in this study. It was self-reported in a questionnaire (Q1) and defined by the following question: "What is the highest level of education completed?" The possible answers given in the questionnaire were: Primary/partly secondary education (up to 10 years of schooling), upper secondary education (a minimum of three years), tertiary education, short (collage/university less than 4 years) and tertiary education, long (collage/university 4 years or more). The same groups were used in statistical analyses, and the last group was chosen to be the reference group in the binary logistic regression analysis.

2.5.3 Other social determinants

Other social determinants were preselected based on conceptual framework of this study (Fig.1) and used as covariates. They were self-reported in questionnaires (Q1 and Q2).

Sex (male or female) and age per 31.12.2015 were reported in the questionnaires.

Participants reported household's gross taxable income last year by choosing one of the following income categories: less than 150 000 NOK; 150 000 - 250 000 NOK; 251 000 - 350 000 NOK; 351 000 - 450 000 NOK; 451 000 - 550 000 NOK; 551 000 - 750 000 NOK; 751 000 - 1 000 000 NOK; more than 1 000 000 NOK. Income was recoded for the statistical analysis in to four categories: low (≤ 450 000 NOK), lower middle (451- 750 000 NOK), upper middle (751- 1 000 000 NOK) and high (> 1 000 000 NOK).

Participants reported civil status answering yes or no to the following question: "Do you live with a spouse/partner?"

Participants were asked about their childhood circumstances. “How was your family’s financial situation during childhood?” The possible answer were: very good, good, difficult, very difficult. The variable which explained the family’s financial situation during childhood was dichotomized into, difficult (very difficult, difficult) and good (very good, good). “What is your mother’s highest completed education?” “What is your father’s highest completed education?”. The alternative answer were: primary/partly secondary education (up to 10 years of schooling), upper secondary education (a minimum of three years), tertiary education short; collage/university less than 4 years, tertiary education long; collage/university 4 years or more. Variable explaining “how many siblings do you have/ have you had?” was recoded into 3 categories: ≤ 2, 3-4 and >4.

2.5.4 Intermediary determinants

Intermediary determinants were preselected based on conceptual framework of this study (Fig. 1) and were used as covariates. Health related characteristics were taken from the self-reported questionnaires (Q1 and Q2).

Smoking status was defined by the following question: “Do you/did you smoke daily?” The alternative answers were: never, yes; now, yes; previously. These categories were used in the statistical analyses.

Participants were asked about their alcohol consumption: “How often do you usually drink alcohol?” The answers were: never, monthly, or more seldom, 2- 4 times per month, 2- 3 times per week, 4 or more times per week. The variable “alcohol consumption” was recoded in to three categories: never/seldom (never, monthly, or more seldom), monthly (2- 4 times per month), and weekly (2- 3 times per week, 4 or more times per week).

Participants reported how often they exercise, and the alternative answer were: never, less than ones a week, ones a week, 2-3 times a week, approximately every day. The variable physical activity was recoded into three categories: never/seldom (never, less than ones a week), often (ones a week, 2-3 times a week), daily (approximately every day).

Participants were asked about their soft drink consumption: “How much soft drinks with sugar do you normally drink?” The possible answers were: rarely/never, 1-6 per week, 1 per day, 2-3 per day, 4 or more per day. The variable soft drinks was collapsed into the following

categories: never/rarely (rarely/never and 1-6 per week) and daily (1 per day, 2-3 per day, 4 or more per day).

Participants rated their teeth and dentures by answering the question: “How satisfied or dissatisfied are you with your teeth or denture?” The possible answers were a scale from 1 (very dissatisfied) to 5 (very satisfied). The variable was dichotomized in to not satisfied (1, 2, 3) and satisfied (4, 5).

Dental hygiene habits of the participants were defined by the questions: “How often do you usually brush your teeth?” The following alternatives were given: once a week or more seldom, a couple times a week, once a day, twice or more daily. The variable “tooth brushing” was dichotomized in to weekly (ones a week or more seldom, a couple of times a week) and daily (one time a day, two or more daily). “Do you use some of these oral hygiene products- and if so, how often- fluoride toothpaste?” “Do you use some of these oral hygiene products- and if so, how often- floss, interdental brushes and/or tooth-sticks?” “Do you use some of these oral hygiene products- and if so, how often- fluoride tablets?” “Do you use some of these oral hygiene products- and if so, how often- fluoride mouth rinse?” The alternative answers were: never/seldom, a couple times a month, a couple times a week, daily. The variables regarding fluoride toothpaste, fluoride tablets, fluoride flush, dental floss/interdental brushes/tooth sticks (interdental cleaning aids) were dichotomized into no (never/seldom) and yes (a couple times a month, a couple times a week, daily).

In addition, the participants also reported if they regularly attended dental care services by the following question: “Do you go regularly to the dentist/dental care?” Answers were: yes; more than ones a year, yes; every year, yes; every other year, yes; but it is more than 2 years between the appointments, no; only for acute problems, no; never. The variable “dental care” was dichotomized into no (no; only for acute problems, no; never) and yes (yes; more than ones a year, yes; every year, yes; every other year).

2.6 Ethical perspectives and permissions

The Regional Committee of Medical and Health Research Ethics for Northern- Norway (REC North) and the Norwegian Data Protection Authority (NSD) approved the Tromsø Study (48). All the participants of the Tromsø 7 study had given informed consent. Therefore, all

procedures were in accordance with the Declaration of Helsinki. This master thesis project was approved by REC (204416) and NSD (989599).

2.7 Statistical analysis

Statistical Package for the Social Sciences was used for data management and statistical analysis (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp). Level of significance was set at 5 %. Descriptive statistics was performed to describe the study sample. Chi- square test and independent sample t-test were used to check for statistical difference in determinants between participants having lower and higher DMFT scores. Univariable and multivariable binary logistic regression analyses were performed to investigate association between educational level and DMFT score, by calculating odds ratios (ORs) and 95% confidence intervals (95% CI). Multivariable binary logistic regression model was constructed and the association between educational level and DMFT score was adjusted for pre-selected social and intermediary variables which were significant in Table 1. Omnibus test was used to check the overall model significance (53). Multicollinearity was tested. A sensitivity analysis, which included all the variables in Table 1, was conducted. The results from the sensitivity analysis were similar to the final multivariable binary logistic regression model (see Appendix). Nagelkerke R-square was reported, and it was 47.1% for the multivariable model.

3 Results

3.1 Sample characteristics, social and intermediary determinants

The number of participants included in this present study was 3752. Out of them 1939 (51.7%) were women and 1813 (48.3%) men. The median DMFT score among all participants was 19, inter quartile range (IQR) 9 and mean 18.03, standard deviation (SD) 6.41. In total, 1968 (52.5 %) of the participants had lower DMFT score (0-19) and 1784 (47.5 %) had higher DMFT score (20-28).

The distribution of dental caries determinants between lower and higher DMFT groups is presented in Table 1. The proportion of participants having lower and higher DMFT scores was statistically significantly different regarding the following social determinants: education level, household income, parent's education level, siblings, and the following intermediary determinants: smoking, alcohol consumption and exercise. A higher proportion of participants having higher DMFT score were older, had no spouse, reported difficult childhood financial situation, brushed teeth weekly (versus daily), did not use fluoride toothpaste and fluoride tablets, and had no dental satisfaction. There was no difference in sex, consumption of soft drinks, use of interdental cleaning aids, fluoride mouth rinse distribution and dental care service utilization among participants having lower and higher DMFT scores.

Table 1- Determinants of dental caries included in this study stratified by lower and higher DMFT score.

Determinants	Lower DMFT 0-19	Higher DMFT 20-28	Missing values n (%)	p-value
Social determinants				
Education level[c]				**<0.001[d]**
Primary/partly secondary education	290 (30.79)	652 (69.21)		
Upper secondary education	568 (51.68)	531 (48.32)		
Tertiary education, short	405 (55.25)	328 (44.75)		
Tertiary education, long	705 (72.09)	273 (27.91)		
Age[a]	51.75 (8.79)	65.14 (9.62)		**<0.001[b]**
Sex[c]				0.741[d]
Female	1012 (52.19)	927 (47.81)		
Male	956 (52.73)	857 (47.27)		
Household income[c]			132 (3.5)	**<0.001[d]**
Low income	265 (32.76)	544 (67.24)		
Lower middle income	519 (48.37)	554 (51.63)		
Upper middle income	526 (60.67)	341 (39.33)		
High income	626 (71.87)	245 (28.13)		
Spouse[c]			193 (5.1)	**<0.001[d]**
Yes	1501 (53.95)	1281 (46.05)		
No	365 (46.98)	412 (53.02)		
Childhood financial[c] situation			88 (2.3)	**<0.001[d]**

Good	1487 (54.93)	1220 (45.07)		
Diffucult	449 (46.92)	508 (53.08)		
Mothers education[c]			100 (2.7)	**<0.001[d]**
Primary/partly secondary education	1233 (45.21)	1494 (54.79)		
Upper secondary education	440 (71.54)	175 (28.46)		
Tertiary education, short	173 (81.99)	38 (18.01)		
Tertiary education, long	87 (87.88)	12 (12.12)		
Fathers education[c]			135 (3.6)	**<0.001[d]**
Primary/partly secondary education	1019 (44.69)	1261 (55.31)		
Upper secondary education	506 (62.09)	309 (37.91)		
Tertiary education, short	234 (75.24)	77 (24.76)		
Tertiary education, long	163 (77.25)	48 (22.75)		
Siblings[c]			285 (7.6)	**<0.001[d]**
≤ 2	1071 (60.61)	696 (39.39)		
≤ 4	549 (50.18)	545 (49.81)		
>4	233 (38.45)	373 (61.55)		
Intermediary determinants				
Smoking[c]			16 (0.4)	**<0.001[d]**
Yes, now	239 (46.59)	274 (53.41)		
Yes, previously	774 (45.37)	932 (54.63)		
Never	950 (62.62)	567 (37.38)		
Alcohol consumption[c]				**<0.001[d]**
Weekly	601 (54.64)	499 (45.36)		
Monthly	818 (55.50)	656 (45.50)		
Never/seldom	549 (46.60)	629 (53.40)		
Exercise[c]				**<0.001[d]**
Daily	574 (51.71)	536 (48.29)		
Weekly	1137 (54.64)	944 (45.36)		
Never/seldom	257 (45.81)	304 (54.19)		
Soft drink[c]			133 (3.5)	0.942[d]
Weekly	64 (52.89)	57 (47.11)		
Daily	1862 (53.23)	1636 (46.77)		
Tooth brushing[c]			72 (1.9)	**<0.001[d]**
Weekly	14 (27.45)	37 (72.55)		
Daily	1922 (52.96)	1707 (47.04)		
Fluoridated toothpaste[c]			127 (3.4)	**<0.001[d]**
No	149 (31.63)	322 (68.37)		
Yes	1776 (56.31)	1378 (43.69)		
Interdental cleaning aids[c]			130 (3.5)	0.066[d]
No	455 (56.03)	357 (43.67)		
Yes	1472 (52.38)	1338 (47.62)		
Fluoride tablets[c]			374 (10.0)	**0.002[d]**
No	1730 (53.36)	1512 (46.64)		
Yes	91 (66.91)	45 (33.09)		
Fluoride rinse[c]			243 (6.5)	0.520[d]
No	1565 (53.45)	1363 (46.55)		
Yes	319 (54.91)	262 (45.09)		
Dental care[c]			69 (1.8)	0.066[d]
No	165 (47.97)	179 (52.03)		
Yes	1775 (53.16)	1564 (46.84)		
Dental satisfaction[c]			52 (1.4)	**<0.001[d]**
Satisfied	1224 (58.20)	879 (41.80)		
Not satisfied	729 (45.65)	868 (54.35)		

Values in the table: [a] means (SD) for continuous variables and [c] number (%) for categorical variables
[b] Independent sample t-test
[d] Pearson`s chi-square test
Subgroups may not be total due to missing values

3.2 Educational gradient in dental caries

The univariable binary logistic regression analysis showed a statistically significant association between educational level and DMFT score. The odds for higher DMFT score followed a gradient based on educational level, meaning that the highest odds for higher DMFT score were observed in the lowest education level (primary/partly secondary education level versus tertiary education, long) and lower odds for higher DMFT score were in higher education levels (upper secondary level and tertiary education, short versus tertiary education, long, respectively) (Table 2). Those participants who had primary/partly secondary education (versus tertiary education, long) had 5.81 times higher odds to have higher DMFT score (OR=5.81, 95% CI= 4.77-7.07), those with upper secondary education (versus tertiary education, long) had 2.41 times higher odds for higher DMFT score (OR= 2.41, 95% CI= 2.01-2.90) and those with tertiary education, short had 2.09 times higher odds to have higher DMFT score (OR= 2.09, 95% CI= 1.71-2.56).

When adjusted for the covariates (age, household income, spouse, childhood financial situation, parents' educational level, siblings, smoking, exercise, alcohol, tooth brushing, fluoride toothpaste, fluoride tablets, dental satisfaction), a statistically significant association between educational level and DMFT score remained. However, the educational gradient was not clearly observed between the two intermediate educational levels; the odds for higher DMFT score were slightly lower in upper secondary education level compared with tertiary education, short (versus tertiary education, long). Participants who had primary/partly secondary education (versus tertiary education, long) had 2.06 times higher odds to have higher DMFT score (OR=2.06, 95% CI= 1.50-2.83), those with upper secondary education (versus tertiary education, long) had 60% higher odds for higher DMFT score (OR= 1.60, 95% CI= 1.21-2.11) and those with tertiary education, short had 66 % higher odds to have higher DMFT score (OR= 1.66, 95% CI= 1.24-2.22).

Table 2- Odds ratio (OR) with 95% Confidence intervals (CI) for the association between education level and dental caries experience (DMFT score) in the adult population of the Tromsø 7 study.

	Univariable regression		**Multivariable regression**	
Education level	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Tertiary education, long	Reference group		Reference group	
Primary/partly secondary education	5.81 (4.77-7.07)	**<0.001**	2.06 (1.50-2.83)	**<0.001**
Upper secondary education	2.41 (2.01-2.90)	**<0.001**	1.60 (1.21-2.11)	**0.001**
Tertiary education, short	2.09 (1.70- 2.56)	**<0.001**	1.66 (1.24-2.22)	**0.001**

The multivariable regression model was adjusted for the following variables: Age, household income, spouse, dental satisfaction, childhood financial situation, parents' education level, siblings, smoking, alcohol consumption, exercise, tooth brushing, fluoride toothpaste and fluoride tablets.

4 Discussion

4.1 Summary of the main findings

This present cross-sectional study demonstrated an educational gradient in dental caries among the adult participants of the Tromsø 7 study. The results from the univariable binary regression analysis showed an educational gradient between all the levels of education. The adjusted multivariable binary logistic regression analysis confirmed a statistically significant association between all levels of education and DMFT score; the education gradient existed but was less clear between intermediate education levels (upper secondary education and tertiary, short). Based on these results, the null hypothesis stating that there was no association between educational level and DMFT score in the study sample, can be rejected.

4.2 Discussion of the results

4.2.1 Social inequalities in dental caries

In this study, all educational levels were statistically significantly associated with DMFT score. Participants with primary/partly secondary education (versus tertiary education, long) had the highest odds to have higher DMFT score compared to the participants having upper secondary and tertiary education, short. This is in line with findings in other studies (39-41).

Costa and colleges (2012) conducted a systematic review investigating association between dental caries experience and indicators of SEP among 19- 60- year old adults (39). The present study included 40- 92- years old adults. The quality of the included observational studies varied and there was a high degree of heterogeneity present. There was a diversity of SEP indicators and parameters used for dental caries, therefore meta-analysis was not conducted. In the present study SEP was measured by education level as main predictor and income as a covariate. Both variables are commonly used as social determinants regarding health inequalities. The authors reported an association between dental caries and SEP variables, lower SEP was associated with higher dental caries experience. In line with the this systematic review, a systematic review and meta-analysis conducted by Schwendicke and colleges (2014) included observational studies which investigated the association between SEP (parental or own education or occupation or income) and dental caries experience and concluded that there was an association (41). The included studies had different measures for SEP and dental caries. Since no age limit was set, both DMFT and dmft indexes, presenting

caries experience in permanent and primary dentition, respectively, were analyzed. In the present study, only DMFT index was included as only adult population was investigated. The authors chose to preform meta-analysis only for the association between SEP and caries experience (DMFT/dmft> 0). The combined effect for the included studies comparing caries experience in individuals from lower to higher education level was statistically significant (OR: 1.29, CI: 1.14- 1.45). It should be noted that it is inappropriate to compare directly ORs from this study and the present one since in general ORs are highly sensitive to cut-off points. The same systematic review reported lower SEP to be significantly associated with higher risk of having caries lesions or caries experience, which was significantly higher in countries with high compared to low human development index. However, there was a high degree of heterogeneity, and the level of evidence was regarded as low due risk of bias of included studies. Nevertheless, the present study was performed in Norway, a country that has high human developing index. The result of the present study, demonstrating educational gradient in dental caries experience among adults in Norway, supports findings of this systematic review. In 2018, Costa and colleges updated their systematic review from 2012 with 20 studies that met the inclusion criteria and investigated association between SEP and dental caries (40). The quality of the included studies ranged from moderate to high quality, however, there was a high degree of heterogeneity present. The most frequent SEP indicators were level of schooling and university education. In the meta-analysis dental caries were defined as DMFT score. The meta-analysis showed that the combined effect for the included studies was statistically significant regarding association between education level and dental caries experience. Higher caries experience was associated with lower SEP.

In contrast, a review conducted by Reisine and Psoter (2001) sought to summarize the evidence regarding the association between incidence and prevalence of dental caries (44). The included studies had several categories for SEP, although the authors did not mention education as a measure of SEP, and dental caries experience measures did vary considerably, making comparisons difficult. The authors did not find any statistically significant relationship between SEP and dental caries experience among adults aged 18 to 64 years. In the age group from 64 years old and older they reported the same findings. However, in the latter age group there seemed to be a trend in the direction of an inverse relationship between SEP and dental caries experience. A plausible explanation of these contradicting findings may be that the authors of this review included studies that did not report education level and used other measures of SEP such as total family income the past year, occupation, poverty status,

Medicaid recipient, eligible for free learning and developing services or supplemental nutrition programs. Another study supports the findings of the latter review. A cross-sectional study from 2015, conducted by Steele and colleges, aimed to investigate inequalities in several indicators of oral health using four different social determinants (income, education level, index of deprivation and occupational social class) in adults aged ≥ 21 (43). They reported an unclear relationship between DMFT (the presence of decay teeth and the number of DMFT), and SEP among adults in the United Kingdom. Steele and colleges study did not include aspects of intermediate determinants; therefore, the authors might exclude aspects that are important in the complex understanding of social inequalities in dental caries. The present study has several intermediary determinants as covariates that could be adjusted for in the analysis. Therefore, the present study does not exclude aspects that might be significant in the complex understanding of educational inequalities in dental health.

In Norway, the Norwegian Institute of Public Health concluded that it exists substantial inequalities in health, especially between educational groups (54). Health varies with education level, higher education is associated with better general health and increasing life expectancy (35). In Norway adults with higher education have better self-reported dental health status compared with adults who have lower education (10). This is in line with the findings of the present study. Inequalities in dental health has also been reported in Norwegian studies (45-47). Oscarson and colleges (2017) recently conducted a cross-sectional study including both questionnaire and clinical examination of a randomly selected sample of 20- 79 years old in northern- Norway (47). In line with the present study, they found among others that lower SEP, defined as education and income, was associated with a higher prevalence of dental caries. The present study targeted only adults in Tromsø municipality, while the latter study targeted people who were registered in Troms County, including rural areas. It is expected that individuals residing in university cities, like Tromsø, hold higher education compared to individuals residing in rural areas (55). Nevertheless, the educational gradient in dental caries was observed even in this well-educated population. The results of the study conducted by Oscarson and colleges cannot be generalized for an urbanized area in norther-Norway. Moreover, it is not known if dental caries followed the educational gradient. Another Norwegian study (2007) had a longitudinal design and was conducted by Holst and colleges (46). It sought to examine changes in social inequality in dental health in Mid- Norway using data from The Trøndelag Health Study. They concluded that it still existed social inequality, based on education level, in DMFT and decayed, missing,

filled surfaces (DMFS) among the adult participants. This is in line with the present study conducted in Tromsø city, northern-Norway, where education level was statistically significantly associated with dental caries experience.

It is however difficult to know the direction of the causal relationship between education level and health (35). Health could be an outcome affected by education level. However, it could be conversely- health conditions may affect what kind of placement people get in the social hierarchy. In Norway children follow similar education paths until the age of 16, then follows educational differentiation. Health related differences may already exist before or are developing during the educational course. Rahkonen and colleges (1997) analyzed Finnish survey material of adults with information on self-reported general health, own education and conditions of childhood measured by parents' education level and income (56). The findings from this study indicate that health status of adults first and foremost was related to own education level, supporting that the variation in education level is of causal importance for later health development.

4.2.2 Educational gradient in dental health

In line with the results of the present study, educational gradient in dental health was demonstrated in other studies. Sabbah and colleges (2007) found educational gradients in perceived oral and general health in American adults aged 17 years and older in their cross-sectional study (37). Similar studies reported social gradients in perceived oral health among adults (34, 57-59). The result of the present study demonstrated educational gradient in clinical measured dental caries experience, not perceived oral health. Evidence indicates that self-reported health is, to an extent, a reliable predictor (60). However, some studies documented gaps in the prevalence of diseases, as measured by self-reported versus clinically diagnosed (61). This implies that clinical measured health may be a more reliable predictor than self-reported. Differences in self-reported versus clinically measured dental health may be explained in terms of optimism (62). For instance, older people may have the ability to adapt to slow declining health, and maybe higher expectations when people with higher SEP report poorer health states. Lambert and colleges (2010) aimed to explore the caries experience of the adult Belgian population in relation to social indicators, educational attainment, occupational status and economic status (63). In their cross-sectional study, 2742 participants completed a questionnaire and 2563 were examined clinically. The statistical

analysis was restricted to economically active adults, while students and retired adults were excluded. In contrast, the present study included 40- 92- years old adults, therefore it is likely to presume that retired adults are included in the statistical analysis. The study showed that participants with higher educational level had lower DMFT score than those with lower education. The authors demonstrated a social gradient *i.e.* educational gradient, however not in DMFT, but in decreasing trend in the proportion of edentulousness. The present study reports an educational gradient in dental caries experience. However, there was a slight difference between upper secondary and tertiary short education when adjusted for covariates. This may partly be explained by Norwegian social policies. Norway is a social democratic welfare state, with a wide-ranging social safety net where the state has a responsibility for ensuring that every member of society have access to fundamental goods which leads to low levels of inequality. It is however challenging to compare populations from different countries using education level as predictor. The level and length of education depends on when people were born, and which country people live in.

In Norway, the Norwegian Directorate of Health concludes in a report that general health inequalities manifest in a gradient (64). Social gradient in dental health has also been reported in Norwegian studies. A longitudinal study conducted by Gülcan and colleges (2014) aimed to assess the development of social inequalities in dentition status, use of dental services and uncovered demand for dental care and oral impacts in 65-70-years elderly in Norway (45). In the present study, participants were 40- 92-year-old, therefore the findings cannot be directly compared. The participants were from three different parts of Norway, southern, western, and northern- Norway and the included counties represented both rural and urban areas and geographic variation. The study showed social inequality, education level was statistically significantly associated with dentition status. Missing teeth (MT) was more prevalent among those with lower education in 2007, the same tendency was observed in 2012. In line with the present study the authors reported social gradient in dental health. However, Gülcan and colleges concluded that social inequalities in dental health among elderly vary across the life-course and seem to decline in later stages of life.

4.2.3 Possible explanations for the educational gradient in dental caries

Why health inequalities exist within populations has been widely discussed. The explanation for the social gradient in health is complex, and not fully understood. However, a theory in

the explanation of the educational gradient in health is that people with higher education have higher life course stability, which may lead to better lifestyle choices and contribute to better health (35). Literature indicates that people with higher education have better living conditions, more stable employments, safer working environments, less unemployment, and divorces and that these factors are interlinked to health in adulthood. It is possible the same factors also promote healthy choices, including adequate oral hygiene measures and a healthy diet. In addition to the educational gradient, health related behaviors are also involved in the development of dental caries, suggesting the existence of a behavioral gradient. Adler and colleagues (1994) argued that social gradients in health are influenced by a complex interaction between social and intermediary determinants (65). There are also educational gradients in physical activity, diet and smoking in Norway (54). A possible mechanism may be that people with higher education have more knowledge about healthy lifestyle. It is also likely that people with higher education have more flexible jobs that enable them to adopt health-promoting behaviors. Abegg and colleges (1999) suggested that more flexible jobs were associated with higher probability of adopting better dental hygiene (66). This may support the argument that more flexible jobs, which is associated with higher educational attainment, could be one of the pathways linking education to dental health.

Another theory in the explanation of the educational gradient in health is economic resources. In Norway, there is an educational gradient in income (67). It is therefore possible that income, which is one of the covariates in the present study, has an important mechanism in the educational gradient in dental caries. A study conducted in Sweden concluded that it was more expensive to comply with nutrition recommendations than to not comply (68). The theory that healthy food is more expensive, and that people with higher education *i.e.* higher income therefore have healthier diet, may also be the case in Norway. This may be supported by the findings in the present study demonstrating educational gradient in dental caries experience among adults in Tromsø, since dental caries to a certain extent is a diet- mediated disease. Another explanation emphasizes the inability to afford preventive and regular dental care due to lack of income (69). There is some evidence from epidemiological studies that behavior explains a proportion of the inequalities in dental caries. Sabbah and colleges (2009) conducted a study aiming to examine the socioeconomic inequalities in intermediary determinants and to assess if behaviors eliminate socioeconomic disparities in oral health in a sample of adult Americans (70). They concluded that poor health-related behavior was more common among less educated, even after adjusting for covariates. Education (and income)

inequalities in clinical and self-reported oral health decreased after adjusting for intermediary determinants but did not disappear. However, studies have failed to demonstrate that behaviors significantly reduce inequality in dental health. Sanders and colleges (2006) cross-sectional study did not find significant effect of intermediary determinants on inequalities in oral health in a sample of adults in Australia (71). The result of these studies implicitly is in line with the present study, as educational gradient in dental caries experience remained even after adjustment by intermediary determinants. This evidence contradicts the traditional view that dental caries has a strong behavioral component and may support the CSHD framework showing that the structural mechanisms are the root cause of health inequalities (17).

4.2.4 Strategies to reduce inequalities in dental caries

Considering the results from the present study it's crucial to increase awareness of the social determinants of dental health inequalities. Social inequality seems to exist, even in countries like Norway with a long tradition of oral health promotion and disease prevention. The responsibility for protecting dental health equity rests with governments. Policies and strategies to reduce health inequalities should not limit themselves to only intermediary determinants, they must include policies specifically designed to address underlying social determinants of health inequalities (17, 72, 73). This is in accordance with the CSDH which states that inter-sectoral policymaking is significant because many of the social determinants that influences health are in sectors other than the health sector; therefore, social determinants can only be addressed through strategies that reach beyond the health sector (17). However, evidence for strategies to reduce health inequalities is still limited (74-76). Preferably, a strategy should have maximum effect on the ones that have lower education (77). A population approach may lead to increased inequality because measures aimed at the population are generally more effective within groups with higher education, since they are often better placed and potentially more motivated to utilize health promoting initiatives. Based on the result for this thesis, and in line with the CSDH framework, a targeted population approach improving health of lower educated groups would expect to improve dental health where dental caries experience is at its highest and due to this action additionally address health inequalities *i. e*. flattening the slope of the gradient. Therefore, expanding dental public health programs are important for improving and reducing inequalities in dental health, like health promoting interventions, no sugar, only healthy meals at lower education institutions and additional classes about intermediary determinants. Oral health promotion can

be integrated in curricula, with higher intensity in lower educational institutions and dental care for those with lower education may be subsidized. One of the most important aspects of addressing dental- and general health, is that non-communicable dental- and general health conditions share the same determinants (78). Therefore, should dental health interventions be integrated with general health promotion and disease prevention strategies.

4.3 Methodological considerations

4.3.1 Inequality, inequity, and gradient

Inequality and inequity are terms that are sometimes confused. The term inequality simply refers to the uneven distribution of health of individuals or groups (79). In contrast, the term inequity, is a type of health inequality that is unjust. Health inequities exist if there is systematic differences in health or social determinants between social groups (race and religion) and therefore are differences in health which are patterned by social determinants an examples of health inequity (80, 81). This definition is in accordance with the CSDH framework where they define health equity as the absence of unfair, avoidable or remediable differences in health among social groups (17). Therefore, is the crucial distinction between the terms that inequalities are simply a description of unequal quantities, while inequities require a moral judgment that the inequality is unjust. In this thesis the term inequalities are used to describe differences in dental caries experience. The term gradient is used to describe the slope phenomenon were people who are more advantaged in SEP *i.e.* education level have better dental health than those that are less advantaged (82).

4.3.2 Strengths and limitations

The strengths of the present study is that it is a population-based study with high response rate, as only three of the participants who were selected to participate in the dental examinations declined to attend the dental station (50). Additionally, the data used in the study was already collected, so there were no additional expenditures and no need to disturb the participants. Another strength was applying a multivariable binary logistic regression analysis, as it is a tool allowing multiple explanatory variables being examined simultaneously and reducing effect of confounding factors thereby strengthening the conclusion of the study (83). Nevertheless, the study has some limitations because of factors that are not accounted for. Sugar is a significant intermediary determinant of dental caries, but in the present study no information regarding the participant's total sugar intake was available. Another limitation of this study is the nature of cross-sectional design (84). The primary limitation with cross-sectional studies is that no casual or temporal relationship can be claimed between the variables *i.e*. it was not possible to assess causal relationship between education level and dental caries experience. CSHD framework suggest that education through intermediate determinants lead to health inequalities, therefor one may assume that

education is a cause. However, there are theories suggesting that inferior health may lead to lower education (35).

4.3.3 Method for assessing dental caries experience

In this study, dental caries was defined as dental caries experience (DMFT). DMFT index includes not only disease, but also the treatment experience (FT and MT), which may be influenced by several factors, such as, age and utilization of dental health services (85). It has been shown that both dental caries and periodontitis are the most common indications for dental extraction (86). Consequently, it is impossible to be sure that all missing teeth were removed because of dental caries. Therefore, the interpretation or comparison of DMFT scores should be cautious. I could have chosen to define dental caries as only decayed teeth (DT). DT would show only the active disease at this point of time, untreated caries. However, it may not represent the whole disease spectra. DMFT index is the most predominant dental caries measure and therefore it was chosen to be used in this thesis.

4.3.4 Internal validity

Internal validity says something about if the instrument measured correctly what was intended to measure (87). In this present study DMFT was assessed clinically and participants will likely remember well their education level. Therefore, both measures can be evaluated as valid methods.

Several potential confounders and mediators may influence the relationship between education level and dental caries experience. A confounder is a variable that is associated with both exposure and outcome while a mediator is a variable which lies on the causal pathway helping to explain association between the exposure and outcome (88). The present study has several covariates that can be adjusted for in the analysis. The selection of covariates was based on well-known CSDH conceptual framework, which also include aspects of both social and intermediary determinants of dental caries.

Selection bias occurs when the association between exposure and outcome is different for those who are selected for the study and those who are in the target population (87). The Tromsø Study is a population-based study where participation is optional. Therefor selection

bias cannot be ruled out. Studies have shown that participants in health surveys often have better health and higher education level than the non-responders (89, 90), consequently there might be an overrepresentation of participant with better dental health and higher education in this study. The underestimation of association may have been caused by a "healthy participant effect". However, the process of selection used during the Tromsø 7 study may have reduced the risk of selection bias. Nevertheless, one may argue that the participants were not randomly selected. Moreover, there is no information about the participant who were not asked to participate in the dental station.

Information bias occurs when the participants do not report information accurately (87). In the present study, the data about social and intermediary determinants were self-reported. Participants may not recall events or habits, especially events that has taken places several years ago. A risk of misclassification has likely occurred in this study due to using self-reported measurements, where participants may have chosen another answer than they should either on purpose or by mistake. Self-reported alcohol consumption, smoking and other behavior might be underreported by the participants because these habits are socially stigmatized in Western society (91). These limitations may create systematic errors that deviate from the true value systematically which might result in an incorrect estimate of the association between exposure, education level, and outcome, dental caries experience.

4.3.5 External validity

External validity assesses if the results of the study apply to other people who may differ from the study population (87). Several studies showed that it exists a north- south gradient in dental health (4, 5, 8). The present study was performed in northern- Norway. Therefore, it is possible that the participants may not represent all groups in the population in Norway. However, the study sample was similar to the general population in Tromsø in regards to the distribution of sex, age and educational attainment (92). In the present study there were 51.7 % women, while in Tromsø municipality there were 48.6 % women of the same age in year 2021. Regarding education level, 26. 1% in the present study had tertiary education, long and 25.1% had primary/partly secondary education, while in Tromsø municipality there were 17.1 % how had tertiary education, long and 22. 5% had primary/partly secondary education. Therefore, the results of this thesis may be generalizable to at least Tromsø population in

terms of sex and age, while those with tertiary education, long may be slightly over-represented in the present study.

5 Conclusion

The present cross-sectional study demonstrated an educational gradient in dental caries among the adult population in Tromsø municipality.

Social inequalities in dental caries are avoidable. The results of this study call for health promotion and disease prevention initiatives to address this social determinant and thereby reduce educational inequalities in dental health.

Based on this thesis, several new research questions have emerged. For the future research on dental caries in Norway, several important questions need to be answered to understand the association between SEP and dental caries; which SEP indicator is most appropriate to use and how has the gradient behaved over time, from childhood to late adulthood? As the results call for reducing educational inequalities in dental health, several interventions should be designed, and their cost-effectiveness should be tested.

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Appendix 1: Supplementary table 1

Sensitivity analysis which includes all the variables in Table 1.

	Multivariable model	
Education level	**OR (95% CI)**	**p- value**
Tertiary education, long	Reference group	
Primary/partly secondary education	2.13 (1.53-2.95)	**<0.001**
Upper secondary education	1.71 (1.29-2.28)	**<0.001**
Tertiary education, short	1.73 (1.29-2.33)	**<0.001**

Adjustment variables in the multivariable model with all variables: Age, sex, household income, spouse, dental satisfaction, childhood financial situation, parent's education, siblings, smoking, alcohol consumption, exercise, soft drink, tooth brushing, fluoride toothpaste, interdental cleaning aids, fluoride rinse, fluoride tablets and dental care.