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Social inequality in tooth loss: separate and joint effects of household income and dental visits

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Objective: The aim of the study was to investigate the separate and joint effects of household income and dental visits on tooth loss. ***Basic research design***: Participants from the Social Inequality in Cancer Cohort (SIC) were followed in registers for household income (2000), dental visits (2002-2009) and tooth loss (2010-2016). Logistic regression was used to assess the effect of household income and dental visits on tooth loss, and linear models were applied to assess the separate and joint effects of household income and dental visits. ***Results***: In total, 10.8% of the participants had tooth loss (<15 teeth present). Low household income and irregular dental visits showed significantly higher odds ratios for tooth loss. Compared to regular dental visits, irregular dental visits accounted for 923 (95% CI 840 – 1,005) extra cases of tooth loss per 10,000 persons, and compared to high household income, low household income accounted for 1,294 (95% CI 1,124 – 1,464) additional cases of tooth loss per 10,000 persons. Further, due to household income-dental visit interaction, we observed 581 (95% CI 233 – 928) extra cases of tooth loss per 10,000 persons. ***Conclusion***: Low household income and irregular dental visits are important in relation to social inequality in tooth loss. Irregular dental visits are associated with higher risk of tooth loss among persons with low household income compared to persons with high household income. Such interaction may be explained by differences in susceptibility to tooth loss across household income groups.

Keywords: *Social inequality, Tooth loss, Household Income, Dental visits, Interaction*

Introduction

In Denmark, adults older than 18 years of age receive oral health care in private dental clinics. These private dental services are subsidized publicly within a scheme of well described services (Widstrom *et al*., 2015). The level of subsidy is on average 20% for all adults, dependent on the type of service and patient's age. Over the past 30 years the proportion of adults (18 years of age or older), who attend dental care on a regular basis has increased (Scheutz *et al*., 2001; Christensen *et al*., 2007; Rosing *et al.*, 2016). Recently, a national publication found that 8 - 25% of the adult Danish population reported being irregular users of dental examinations (Petersen *et al*., 2019).

Tooth loss has a major impact on everyday life, leading to impairments such as decreased chewing ability or decline in aesthetics, resulting in pain when eating, having to swallow big lumps of food or not being able to chew all foods (Ozhayat *et al*., 2016). These consequences may lead to social discomfort, such as avoidance of smiling, laughing or eating in front of other people (Ozhayat *et al*., 2016). Even though the prevalence of tooth loss has declined over recent decades, social inequality in tooth loss is still of major concern in high income countries (Kassebaum *et al*., 2014; Elani *et al*., 2017).

Previous studies have pointed at factors such as oral health behaviors (Bernabe *et al*., 2012), smoking and alcohol consumption (Hach *et al*., 2019) to explain persistent social inequality in tooth loss. Low household income was significantly associated with tooth loss (Sanders *et al*., 2008; Seerig *et al*., 2015), partly dependent on neighborhood socioeconomic position (Sanders *et al*., 2008). Furthermore, irregular dental attendance was associated with lack of functional dentition (< 20 teeth present) (Thomson *et al*., 2010; Talakey *et al*., 2019). However, whether irregular use of dental visits contributes to the social inequality in tooth loss has not been investigated.

Thus, the aim of the study was to investigate the separate and joint effects of household income and dental visits on tooth loss.

Methods

This cohort study was based on participants from the Social Inequality in Cancer Cohort (SIC). The cohort was established in 2011 based on seven Danish cohorts (the Diet Cancer and Health study, MONICA I-III, the 1936-study and the Inter99 study) from Aarhus, greater Copenhagen and Zealand (Nordahl *et al*., 2014). Participants were excluded from the SIC cohort if they were registered with a cancer diagnosis before baseline. The

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total SIC cohort consisted of 83,006 men and women aged 20 to 93 years of age with baseline data collected between 1981 and 2001. Participants from SIC were included in the present study if they were 35 years or older in 2000 and were followed until 2016. However, 27,034 participants were excluded as they died before tooth loss was measured.

Information on household income, number of dental visits, tooth loss, and confounders were obtained from Danish registers and linked to each participant by a 10-digit personal identification number. Data on household income measured in year 2000 was obtained from income registers at Statistics Denmark (Baadsgaard *et al*., 2011). Household income is a measure based on the total income of the household and the composition of household members. Hence, household income reflects the purchasing power in the family than individual income. Household income was categorized into 4 groups: "Low" ≤ 13,521 Euros per year, which was half of the median household income level, "Low-Middle" > 13,521 ≤ 26,907 Euros, "High-Middle" > 26,907 ≤ 40,161 Euros and "High" > 40,161 Euros.

Information on dental visits was obtained from the National Health Service Register (NHSR) (Andersen *et al*., 2011) between 2002 and 2009, both years included. Dental visits were defined as visiting the dentist or dental hygienist for routine check-up. The number of dental visits was calculated for each year during this period. Subsequent yearly dental visits were categorized as regular dental visits (≥ once every second year), often (4 times in 8 years, but not necessarily in every second year) and irregular (< 4 times in 8 years).

The number of teeth present was obtained from NHSR between 2010 and 2016. In NHSR, clinical information on the number of teeth is limited to persons turning 40 or 65 years of age. Data on all purchased dental health services are stored by service-numbers. There are two service-numbers for dental cleaning (1-14 teeth present and ≥ 15 teeth present). Thus, we used the service-numbers of the dental cleanings to define tooth loss as < 15 teeth present. We identified participants with zero teeth present by cross-referencing number of teeth with the purchase of dental services. Participants were included in the study as persons with zero teeth present, if they were registered with zero teeth present and no dental services were received in the following years, which would require present teeth.

Educational level, employment status and marital status were obtained from registers at Statistics Denmark in 2000. Age was included as a stepwise continuous variable with cuts at < 50 years of age, 50 – 60 years of age and > 60 years of age. Employment was dichotomized as yes/no, 'No' participants were either unemployed, received disability pension or were retired. Habitation was dichotomized into 'living alone' (divorced, widowed or living alone) and 'Living with someone' (married or living with a partner). Data on the highest attained educational level were obtained from the Population Educational Register at Statistics Denmark (Sortso *et al*., 2011). Education was registered according to International Standard Classification of Education (ISCED) (United Nations 2011) and further categorized into 'low' (primary and lower secondary), 'medium' (upper secondary, vocational or technical education and short-cycle non-university education), and 'high' (medium-cycle university or non-university programs and long-cycle university programs).

Statistical analysis

Univariate analyses were used to describe the study and excluded populations. Bivariate analyses with Chi Square tests were used to explore the characteristics of the study population between household income groups. Logistic regression analyses estimated the separate effects of household income and dental visits on tooth loss. Absolute effects were estimated using general linear models with identity link functions (Andersen *et al*., 2010). First, tooth loss was modeled as an additive function of the independent variables dental visits and household income. In addition, the interactions between dental visits and household income in relation to tooth loss were assessed using both logistic and linear regression. The logistic and linear regression models were adjusted to age, gender, education, cohabitation and employment status. Alpha was set at 0.05. Analyses were performed in SAS, version 9.4 (SAS Institute, Cary, North Carolina, USA).

Ethics

All seven cohorts included in the SIC cohort (the Copenhagen city heart study, the Diet Cancer and Health Study, MONICA I-III, the 1936-study and the Inter99 study) were approved by the Scientific Committee and the Data Protection Agency, ID number 2010-54-0932. Informed consent was obtained from all participants.

Results

Of 55,972 participants, 12,524 were excluded due to lack of information on tooth loss, 333 were excluded because of age (< 35 years) and 794 due to missing information on household income or educational level. Hence the study population comprised 42,321 participants.

Among the study population, 4,604 participants (10.9%) had tooth loss (< 15 teeth present). Persons with low household income were characterized by being older, low educated, irregular dental visits, more often suffering from tooth loss, living alone and unemployment (Table 1).

The logistic regression analyses showed a trend in tooth loss among household income groups, meaning the lower the household income level, the higher odds ratio for tooth loss. Persons with low household income had OR = 5.01 (95% CI, 4.08 – 6.14) of tooth loss compared to persons with high household income. This trend was also found among dental examination groups, where irregular users of dental visits had OR = 2.42 (95% CI, 2.23 – 2.62) times higher odds of tooth loss than regular users of dental visits (Table 2).

The separate absolute effects of dental visits and household income on tooth loss are presented in Table 3. In absolute terms, 1,294 (95% CI, 1,124 – 1,464) extra cases of tooth loss per 10,000 persons were observed among persons with low household income compared to persons with high household income. Significant differences in tooth loss were also observed in relation to dental visits, where 923 (95% CI, 840 – 1,005) extra cases per 10,000 persons were observed among persons attending dental visits irregularly compared to regular

Table 1. Descriptive characteristics by household income level among 42.321 men and women in the Diet, Cancer and Health Study

Characteristic	*Low income*[1] *N=1,830* *%*	*Low-Middle income*[1] *N=19,292* *%*	*High-Middle income*[1] *N=15,527* *%*	*High income*[1] *N=5,672* *%*	*p value*
Mean age (SD)	62.5 (6.6)	59.4 (7.1)	56.8 (6.9)	57.7 (6.0)	
Education[2]					
Low education	49.4	34.2	19.9	14.3	
Medium education	48.2	62.9	71.4	58.2	
High education	2.4	2.9	8.7	27.5	<0.0001
Tooth Loss					
< 15 teeth present	24.1	15.6	6.5	2.8	<0.0001
Gender					
Female	73.2	62.8	50.5	50.6	<0.0001
Cohabitation					
Living alone	57.4	36.0	17.6	14.9	<0.0001
Employment					
Unemployed	82.8	50.5	18.9	13.1	<0.0001
Dental visits[3]					
Regular	68.7	74.7	78.5	78.5	
Often	10.4	9.6	9.0	8.8	
Irregular	20.9	15.7	12.5	12.7	<0.0001

[1]Low household income (≤ 13,521 Euro), Low-Medium household income (> 13,521 ≤ 26,907 Euro), High-Medium household income (> 26,907 ≤ 40,161 Euro), High household income (> 40,161 Euro). [2]Low education (primary and lower secondary education); High education (upper secondary, vocational or technical education, medium-cycle university or non-university programs, as well as long-cycle university programs). [3]Regular (every other year or more), Often (4 times in 8 years, but no every other year), Irregular (< 4 times in 8 years)

Table 2. Household income and dental visits, and tooth loss (< 15 teeth present) among 42,321 men and women in the Social Inequality in Cancer Cohort.

	N	*OR*[1]	*95 % CI*
Household Income[2]			
High income	5,672	1.00	
High-Middle income	15,527	2.18	1.83 - 2.59
Low-Middle income	19,292	4.07	3.43 - 4.83
Low income	1,830	5.01	4.08 - 6.14
*Adjusted for age, gender, education, cohabitation and employment status			
Dental visits[3]			
Regular	32,296	1.00	
Often	3,945	1.44	1.29 - 1.60
Irregular	6,080	2.42	2.23 - 2.62

[1]Adjusted for age, gender, education, cohabitation and employment status.
[2]Low household income (≤ 13,521 Euro), Low-Medium (> 13,521 ≤ 26,907 Euro), High-Medium (> 26,907 ≤ 40,161 Euro), High (> 40,161 Euro).
[3]Regular (every other year or more), Often (4 times in 8 years, but no every other year), Irregular (< 4 times in 8 years)

Table 3. Additive effect of household income and dental visits on tooth loss, among 42,321 men and women in the Social Inequality in Cancer Cohort.

	N	*No. Events*[1]	*RD (95% CI)**
Household Income[2]			
High	5,672	157	0 (Ref)
High-Medium	15,527	1,002	298 (205 - 392)
Low-Medium	19,292	3,004	847 (750 - 944)
Low	1,830	441	1,294 (1,124 - 1,464)
Dental visits[3]			
Regular	32,296	3,030	0 (Ref)
Often	3,945	468	324 (225 - 423)
Irregular	6,080	1,106	923 (840 - 1,005)

[1]Adjusted for age, gender, education, cohabitation and employment status.
Risk Difference (RD) per 10,000 persons for tooth loss (4,604 events of < 15 teeth present).
[2]Low household income (≤ 13,521 Euro), Low-Medium (> 13,521 ≤ 26,907 Euro), High-Medium (> 26,907 ≤ 40,161 Euro), High (> 40,161 Euro).
[3]Regular (every other year or more), Often (4 times in 8 years, but no every other year), Irregular (< 4 times in 8 years)

attendees. To improve the statistical power in the interaction analyses, we dichotomized household income (low household income < 101,000dkk) and dental visits (irregular oral visits < 4 times in 8 years). The joint effect of low household income and irregular dental visits per 10,000 persons was 1,843 (95% CI, 1,538 – 2,147) extra cases of tooth loss (Table 4). If there was no interaction between household income and dental visits, the joint effect would have been (841 + 421) = 1,262 cases, However, the number of extra cases of tooth loss per 10,000 persons due to interaction was (1,843 – [841 – 421]) = 581 (95% CI, 233 – 928) (Table 4).

Analyses of the general characteristics of the excluded population (N=13,651) showed higher proportions of persons with low household income, low education, irregular dental visits, unemployment or living alone, compared to the study population (data not shown).

Discussion

These findings showed that social inequality in tooth loss persists, and that paying dental visits on an irregular basis increased the risk of tooth loss. The effect of irregular dental visits on tooth loss varied across household income groups, indicating that persons with low household income may be more susceptible to tooth loss when paying dental visits irregularly, than persons with high household income.

The present study was based on a prospective cohort study with linkage to the Danish registers of household income, as well as purchase of dental services, dental cleaning, employment status, cohabitation and highest attained educational level. This reduces the risk of misclassification of exposures, outcome and confounders. Furthermore, the large sample gave sufficient power for interaction analyses, which is a major strength of the present study. From a public health perspective, estimating the separate and joint effect of dental visits and household income on tooth loss in absolute terms is important, as they may provide a more useful judgment of the importance of the regularity of dental visits, as the interpretation and magnitude of absolute terms are more straight forward than relative terms (Knol *et al*., 2012). We also estimated the joint effect on the relative scale, but did not find significant results. Thus, the emphasis in the present study was in absolute terms, to identify factors where intervention may reduce social inequality in tooth loss.

The findings should, however, be interpreted with caution. Despite the prospective cohort design, we did not have information on tooth loss before 2000. This increases the risk of reverse causation and may limit interpreting the results as a causal relation. Reverse causation is most likely among participants older than 50 years at baseline, as they may have lost teeth before the measures of household income and dental visits were obtained. In addition, tooth loss was measured as < 15 teeth. This does not correspond with the WHO (1992) definition of a functional dentition (20 teeth present). However, the actual number of teeth present was not available. The external validity of the study may also be questioned. The study population was constructed from seven existing cohorts from greater Copenhagen and Aarhus, and overrepresented persons who are healthier and have higher household income than the general Danish population (Tjonneland *et al*., 2007). Furthermore, 12,576 participants were excluded due to missing information on tooth loss. Proportionately more people with low household income were found in the excluded population. It is likely that the proportion of tooth loss among the excluded population was higher than in the study population. Thus, we may have introduced selection bias, which lowers internal validity, thus we may have underestimated the effect of low household income and irregular dental visits on tooth loss. In addition, there may be some misclassification of dental visits. Persons who visit the dentist with acute problems or pain are likely to receive a dental examination in order to diagnose the problem and treatment plan. Consequently, persons who often have acute dental problems might be categorized regular dental visitors, although were only examined for a specific problem. Persons who seek dental care with acute problems or pain are more likely to lose their teeth than those seeking preventive care. There may also be unmeasured confounding as parental education has been associated with tooth loss (Han *et al*., 2017) and may also be associated with regular dental attendance through health consciousness.

In accordance with other studies (Seerig *et al*., 2015; Talakey *et al*., 2019), these results associate tooth loss with irregular dental care and low household income. Different methods have been used to explain persistent social inequality in tooth loss. Studies using Structural Equation Models (SEM) found that socioeconomic position (SEP) directly predicted tooth loss or tooth retention

Table 4. Joint effect of household income and dental visits among 42,321 men and women in the Social Inequality in Cancer Cohort Study

	Household Income[1]						*Extra Events Due to Interaction*
	High-Medium			*Low*			
Dental visits[2]	N	No. Events	RD (95% CI)	N	No. Events	RD (95% CI)	RD (95% CI)
Regular	34,792	3,189	0 (Ref)	5,696	309	421 (254 - 583)	
Irregular	1,447	974	841 (757 - 925)	386	132	1,843 (1,538 - 2,147)	581 (233 - 928)

Risk Difference (RD) per 10,000 persons for tooth loss (4,604 events of < 15 teeth present)
[1]Low household income (≤ 13,521), High-Medium household income (> 13,521)
[2]Irregular (≤ 4 times in 8 years)., Regular (> 4 times in 8 years)

(Bernabe *et al*., 2012; Vettore *et al*., 2016; Bomfim *et al*., 2018). However, no study found that dental visits mediated between SEP and tooth loss (Vettore *et al*., 2016; Bomfim *et al*., 2018). In addition, a multilevel analysis found that persons with low household income had fewer teeth present than those with high income (Sanders *et al*., 2008). Unfortunately, they did not include dental visits in the analyses, but nevertheless, the results showed an interaction between household income and neighborhood socioeconomic position in relation to tooth loss. This is in line with the present study where irregular dental visits seem partly to explain social inequality in tooth loss.

In conclusion, we show major income inequalities in tooth loss. This may be due to dental care being considered very expensive despite partial subsidies. In addition, the risk of tooth loss due to irregular dental visits was higher among persons with low household income, indicating that persons with low household income may be more susceptible to tooth loss from irregular dental visits. Acquiring regular preventive dental visits among persons with low household income may substantially lower the number of persons with tooth loss.

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