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A register-based study of variations in services received among dental care attenders

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Abstract

Objectives. To investigate whether receipt of dental services, among attenders, reflects variations in dental health or whether and to what degree it is associated with socioeconomic status, with irregular or regular dental attendance and with the availability of dentists in residential areas. ***Materials and methods.*** This retrospective register-based study followed two Danish cohorts, aged 25 and 40, with a dental examination in 2009 (n = 32,351). The dental service data were registered during 2005–2009. The number of dental examinations, individual preventive services (IPS), tooth extractions, root fillings and composite fillings were analyzed in relation to socioeconomic status, irregular/regular dental attendance, inhabitant/dentist ratio and to DMFT at age 15 (DMFT15) and change in DMFT (ΔDMFT) from age 15 to age 25 and age 40, respectively. Poisson regression and negative binomial regression analyses were used. ***Results.*** The variations in number of services received in the study population were small (SD = 0.2–2.7). However, with a few exceptions, high levels of DMFT15 and ΔDMFT were associated with receipt of more dental services. Socioeconomically-privileged individuals received more dental examinations but fewer tooth extractions, root fillings and composite fillings compared to disadvantaged persons, when controlled for dental health levels. Irregular attenders received fewer IPS and composite fillings but had more extractions compared to regular attenders. ***Conclusions.*** Variations in dental care services were found to reflect variations in dental health, but the variations were also related to individual socioeconomic status, residential area and dental attendance patterns.

Key Words: *Dental care supply and distribution, dental care utilization, socioeconomic status*

Introduction

Equal access to dental healthcare is a cornerstone of Danish health legislation [1] and of the 'Nordic model' dental care systems [2]; however, studies have shown that inequalities exist in the receipt of dental services. Disadvantaged socioeconomic groups attend the dental care system less regularly and are more frequently problem-oriented dental attenders. In addition, disadvantaged groups more often receive radical types of treatments—for instance, tooth extractions in contrast to preventive and maintenance types of services. This has been demonstrated in dental healthcare systems in Europe [3–5] as well as in other parts of the world with different dental healthcare systems [6,7]. Observed inequalities in use of dental service systems and in receipt of various types of dental services will for a large part be due to different objective and subjective needs, but may also be due to unequal access to dental care per se and unequal access to certain services within the dental care system.

Variations in receipt of dental services depend on a range of factors. At the individual level, persons have different health attitudes, perceived needs, different economic resources available [7–10] and, furthermore, different social backgrounds [11–13], all contributing to different demands for dental services. The dental personnel differ, as well, in a range of ways that affect their decisions on the provision of dental services and on their interaction with patients [14–18]. Finally, structural factors in society can affect access to dental care and provision of and demand for dental services, for instance the type of reimbursement

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system or the level of out-of-pocket expenses, the dental personnel workforce distribution and the characteristics of the clinical practice [19–25]. One way to measure 'availability' of dental health services, as one dimension of access to care, has traditionally been to calculate the ratio between the population and the dentists available [26].

Variations in health service provision are considered acceptable when the variations reflect underlying differences in the population's health status [27]. Accordingly, variations in receipt of dental care services may be considered acceptable or even favorable when caused by underlying differences in people's dental health status. Hence, if variations in receipt of dental services are related to factors other than health differences, it may express inequality in access to certain services between population groups [27,28].

Due to the lack of a precise definition of 'appropriate dental care' [29,30], it may be difficult to assess when variations in dental care services are acceptable or an expression of unequal access to care. It is generally accepted that dental check-up recall intervals for patients should be based on individual risk assessments rather than schedule-based recall regimes [31], that X-rays should be used as indicated, not in routine screenings and that fillings and the removal of third molars should be performed as specifically indicated [29]; such principles will naturally cause some degree of variation in the provision of services, especially where major variations in dentists' clinical decisions have been found [18]. Moreover, intervention decisions based on diagnostics at the individual level are another reason it is very difficult to assess whether dental service variations on a sub-population and group basis are inappropriate. By including the individual dental health level in statistical models, it can be tested whether groups of people with similar levels of dental health show variations in receipt of dental services associated with other factors than their dental health level [28]. Caries experience is still the most powerful predictor of the occurrence of caries later in life [32–34]. Hence, caries experience and caries incidence can be used as indicators for later need of dental services.

Dental care attendance has a complex relation to both socioeconomic status and dental services received [35]. Individuals with regular preventive attendance are expected to receive different dental treatments than individuals with a problem-oriented and irregular attendance pattern. Dental attendance may be considered a result of unequal access to dental care, but it may also be considered an explanatory factor for variations in the receipt of specific services. Dental attendance may explain some of the expected variations in dental services and may interact with socioeconomic indicators. A previous study has suggested that the type of service received is more related to an individual's attendance patterns than to his or her socioeconomic status [36].

Inequalities in dental health have been found in Denmark as well as in other industrialized countries [4,37,38]. According to the WHO, socioeconomic inequalities in dental health have increased, despite marked reductions in caries prevalence since the 1980s [39,40]. However, variations in dental services received should ideally reflect variations in dental health if variations in dental services are associated with indicators other than dental health; such variations may be an expression of inequality and potentially contribute to the explanation of the persistent and even increasing inequality in dental health. Hence, scrutinizing the variations in the receipt of dental services may increase our knowledge of the mechanisms that may explain the inequality in dental health.

Consequently, the purpose of the present study was to investigate whether receipt of dental care services, among attenders, reflect variations in dental health or whether and to what degree it is associated with socioeconomic status, residential area, irregular and regular attendance and with the availability of dental personnel in the residential area (inhabitant/dentist ratio).

Materials and methods

The present study is a retrospective register-based study that followed two cohorts, aged 25–40, who received a dental examination in 2009 (n = 53,046). The data on the dental health of the study population are longitudinal and were measured in 1984, 1999 and 2009. Data on dental services are also longitudinal and were registered during the years 2005–2009. Socioeconomic data are cross-sectional, measured in 2009.

In general, Danish adults receive dental care in private dental clinics. The National Health Insurance (NHI) partially reimburses expenses for preventive and diagnostic services and for some restorative treatments. An 'Agreement on Dental Health Service' between The Health Insurance Negotiations Committee and the Danish Dental Association describes the terms and conditions for the deliverance of dental health services in private clinics [41]. The Agreement also includes a mandatory registration scheme under which 25- and 40-year-olds who undergo an oral examination have their dental health status registered and reported to the National Board of Health (NBH). The criteria for the registration of dental health are detailed in guidelines based on WHO registration methods [42,43]. This monitoring system is supposed to provide data to evaluate the effects of the preventive and treatment services delivered [41,42]. A register under the NBH based on this monitoring system provided the dental health data from 2009 and formed the basis for the present study and determined the composition of the initial selected study participants (Figure 1).

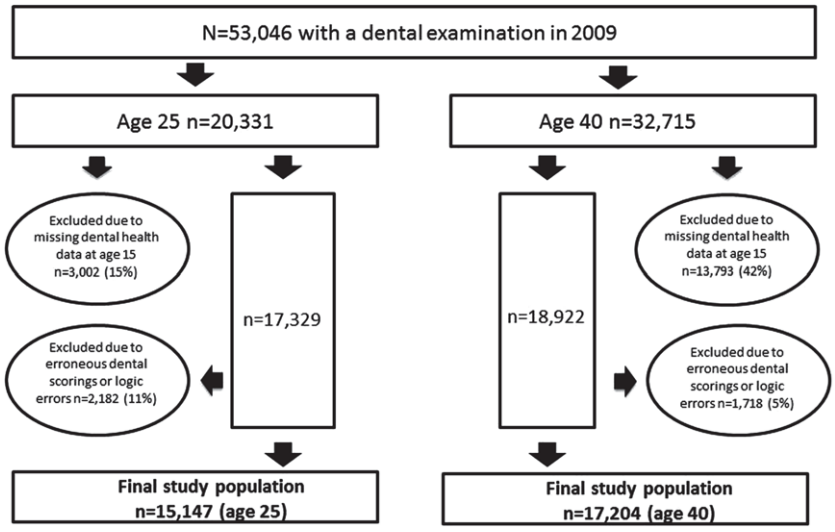

Figure 1. Flow chart of the data cleaning procedure leading to the two final study populations.

The initial study population, of 25- and 40-year-olds, was merged with data from two other registers. The 25-year-olds represented 'young adults' and the 40-year-olds represented 'middle-aged' adults. A third age-group of 65-year-olds was studied in a separate study [44]. A register under the NBH provided information on dental services delivered from 2005–2009 under the reimbursement scheme. The decision to obtain information on dental services through a limited period was made for practical reasons. Five years was considered long enough a period to be able to evaluate if attendance of the dental care system was irregular or regular. Dental health data was obtained from a third register under the NBH, from 1984 when the 40-year-old cohort was 15 years of age and from 1999 when the 25-year-old cohort was 15 years old. The data were collected by dentists employed by the Child Dental Health Service System (CDHSS) and the registration was based on detailed guidelines from the NBH [45] in accordance with WHO recommendations [43].

Citizens in Denmark have a 10-digit civil registration number (CPR), which was used as the key variable to merge data from the dental health registers with data from the dental service register. After data cleaning, it was seen that, among 40-year-olds, 42% (n = 13,793) had no dental health registration at age 15 (1984) and 15% of the 25-year-olds (n = 3002) had no dental health registration at age 15 (1999). An additional 11% of the 25-year-olds were excluded due to erroneous scorings and logical errors; and, correspondingly, an additional 5% of the 40-year-olds were excluded. The final study population represented 15,147 persons aged 25 and 17,204 persons aged 40, accounting for 75% and 53% of the eligible study population of 25- and 40-year-olds, respectively. Erroneous scorings and logical errors were found by comparing the adult dental health data with the data from the CDHSS. For example, theoretically impossible reductions in DMFT from age 15 to adulthood, persons with registered teeth extracted due to orthodontic treatments but with full dentition in the adult data set and persons with numbers of fillings or caries lesions exceeding their total number of teeth.

Five types of dental services received in the 5-year period from 2005–2009 were selected as the outcomes of interest in the present study and the types of services were: (1) Dental examination, (2) individual preventive service, (3) tooth extraction, (4) composite filling on one surface in anterior teeth and (5) root canal filling (Figure 2). One diagnostic and one preventive type of service were analyzed together with the three intervention types of treatment services. The dental services are defined in the 'Agreement on Dental Health Service' [41]. 'Individual preventive service' (IPS) covers individual instruction in preventive measures, instruction in dental hygiene (techniques and remedies), general health education (diet, tobacco), fluoride varnish applications on active caries lesions and professional plaque removal. 'Tooth extraction' includes local analgesics and uncomplicated removal of a single tooth or root. 'Composite filling, one surface, anterior teeth' includes the filling of a cavity relating to one surface on incisors or canines. 'Root filling' covers the permanent filling of one or more roots performed either conventionally or retrograde. The measure expresses the number of teeth endodontically treated, independent of the number of root canals in the specific teeth.

From the collected dental health data, the following oral health registrations were available: (1) number of natural teeth and roots present, including wisdom teeth, (2) number of teeth with a need for treatment due to primary or secondary caries and (3) number of filled teeth. A tooth with a crown was registered as filled.

On the basis of the oral health registrations from 1984, 1999 and 2009, the following indices were

constructed and used in the analyses: Number of decayed, missing and filled teeth at age 15 (DMFT15) and increase in DMFT from age 15 to 25 and from age 15 to 40, designated ΔDMFT. Due to different distributions of DMFT15 and ΔDMFT in the two cohorts, the categorization of the indicators is different in each cohort (shown in Table I). The measurement of ΔDMFT preceded the measurement of the number of dental services received, except for the time overlap of 5 years from 2005–2009. The change in DMFT was used as the explanatory indicator in relation to number of dental examinations and IPS received. However, the possibility that the number of dental examinations and IPS received, to some degree, may have influenced the size of the ΔDMFT measure cannot be ruled out. Regarding the three remaining services, tooth extractions, root canal fillings and composite fillings, the receipt of such services would directly affect the ΔDMFT measure and was considered inappropriate as an indicator. Hence, DMFT at age 15 was used as the indicator for later need for tooth extractions, root fillings and composite fillings.

Information on the distribution of dental clinics and dentists in Denmark and additional information about individuals, such as gender, educational level, income, ethnicity, labor market participation and residential area was obtained from Statistics Denmark, the national statistics agency. Educational level was classified as low (< 11 years), medium (11–14 years) and high (> 14 years) pursuant to the categories of the International Standard Classification of Education (ISCED) [46]. Residential area is a specific variable constructed on the basis of 14 criteria [47], whereby 98 municipalities were divided into so-called: (1) 'fringe', (2) 'rural', (3) 'medium' and (4) 'urban' areas. The 14 criteria were structured according to, among other things, population density, population trends, average distance to highways, number of workplaces in relation to number of inhabitants employed (commuting dependency), proportion of the labor force with primary school education, proportion of the labor force with a medium or higher level of education, average distance to areas with surplus job opportunities and taxation base per inhabitant [47]. Fringe areas are the least affluent areas and rural, medium and urban areas are more affluent. Analyses with respect to residential area were conducted at the individual level only, without aggregating data or comparing service provision at the group level. Household income was grouped into three categories according to annual household income. Labor market participation was categorized as: (1) high-profile employment, (2) medium/low-profile employment and (3) unemployment. The high-profile employment group consisted of self-employed persons and co-working spouses, senior managers and highly-skilled wage-earners. The medium/low-profile employment group consisted of wage-earners with medium and basic skills and other types of wage-earners. The unemployment group comprised persons who had been unemployed for > 6 months, people on sick leave or receiving social security or unemployment benefits, persons in education programs and retired persons. Data on the distribution of dentists in relation to inhabitants were available at the municipality level (98 municipalities in Denmark). The inhabitant/dentist ratio was calculated and then categorized by ratio size into four groups. The number of dental examinations received from 2005–2009 was used as the dependent variable in Table II. In Tables III-VI, the number of dental examinations received from 2005–2009 was used as an independent variable, named 'dental attendance'. Three levels of receipt of dental examinations were constructed arbitrarily and data driven, 0–2 examinations was considered as irregular attendance, 3–4 (25-year-olds) and 3–5 (40-year-olds) considered medium attendance and, finally, > 5 or 6 were considered regular attendance.

The outcome variables were counts of events within a limited time interval. Therefore, Poisson regression analyses were applied. Negative binomial regression analyses were chosen when the outcome variance exceeded the mean and were more appropriate after testing for goodness of fit (Akaike's Information Criterion). On the basis of the crude incidence rate ratios, explanatory variables were selected for the multiple regression analyses. The variables included were tested in a full model and step-wisely excluded if not statistically significant. Thereafter, possible interactions were tested between the dental health indicators DMFT at age 15 or ΔDMFT and the other explanatory variables, except gender, in order to investigate whether individuals with comparable levels of dental health but with different explanatory characteristics differed in types of dental services received. All possible interactions were initially included and step-wisely excluded if not statistically significant. Crude incidence rate ratios and the final multiple regression models are presented in the Tables II-VI. The Statistical Program for the Social Sciences (SPSS version 19) was used for analysis.

The study was approved by the Danish Data Protection Agency.

Results

The distribution and the mean values of the five outcome variables are illustrated in Figure 2, and resemble Poisson and negative binomial probability distributions. For both age groups, 80–90% of the population received no tooth extractions and no root fillings in the 5-year period.

Table I shows the distribution of the study subjects and the excluded individuals in relation to the explanatory variables.

Table I. Characteristics of the study population and the excluded individuals.

	25-year-olds							40-year-olds					
	Study population		Excluded individuals due to missing dental data at age 15		Excluded due to erroneous dental registrations or missing data			Study population		Excluded individuals due to missing dental data at age 15		Excluded due to erroneous dental registrations or missing data	
	n	%	n	%	n	%		n	%	n	%	n	%
Total study population	15,147	100	3002	100	2074	100	Total study population	17,204	100	13,793	100	1718	100
Gender							Gender						
Female	8,489	56.0	1740	58.0	938	57.5	Female	9,071	52.7	7,529	54.6	583	58.0
Male	6,658	44.0	1262	42.0	693	42.5	Male	8,133	47.3	6,264	45.4	421	42.0
Missing data					443		Missing data					714	
DMFT at age 15			a	a	a	a	DMFT at age 15			a	a	a	a
DMFT > 9	361	2.4					DMFT > 9	2,361	13.7				
DMFT = 5–9	1,973	13.0					DMFT = 2–9	13,059	75.9				
DMFT = 1–4	7,454	49.2					DMFT = 0–1	1,784	10.4				
DMFT = 0	5,359	35.4											
ΔDMFT from age 15 to 25			a	a	a	a	ΔDMFT from age 15 to 40			a	a	a	a
ΔDMFT > 7	3,465	22.9					ΔDMFT > 12	1,834	10.7				
ΔDMFT = 5–7	3,755	24.8					ΔDMFT = 3–12	13,610	79.1				
ΔDMFT = 2–4	5,097	33.7					ΔDMFT = 0–2	1,760	10.2				
ΔDMFT = 0–1	2,830	18.7											
Educational level (ISCED)							Educational level (ISCED)						
High (>14 years of education)	4,470	29.5	773	29.5	447	27.8	High (> 14 years of education)	6,662	39.1	5238	39.5	363	36.5
Medium (11 to 14 years)	8,087	53.4	1297	49.5	864	53.8	Medium (11 to 14 years)	7,898	46.4	5981	45.1	487	48.9
Low (< 11 years)	2,419	16.0	552	21.1	295	18.4	Low (< 11 years)	2,469	14.5	2051	15.5	146	14.7
Missing data			380		468		Missing data			523		722	
Household income (DKK/year)							Household income (DKK/year)						
600,000 or more	1,602	10.6	313	10.6	167	10.4	600,000 or more						
300,000–599,999	6,015	39.7	1089	36.9	616	38.3	300,000–599,999	10,886	63.3	8335	60.8	602	62.3
0–299,999	7,389	48.8	1548	52.5	826	51.3	0–299,999	4,694	27.3	3943	28.8	273	28.2
Missing data			52		465		Missing data	1,624	9.4	1427	10.4	91	9.4
										88		752	
Residential area													
Urban	9,063	59.8	1893	64.1	972	60.3	Residential area	8,658	50.3	6166	44.7	488	48.6
Medium	1,729	11.4	331	11.2	190	11.8	Urban	2,732	15.9	2169	15.7	153	15.2
Rural	3,368	22.2	539	18.2	323	20.0	Medium	4,634	26.9	4218	30.6	302	30.8
Fringe	857	5.7	192	6.5	127	7.9	Rural	1,180	6.9	1237	9.0	61	6.1
Missing data			47		462		Fringe			3		714	
							Missing data						
							Labor market participation	4,367	25.8	3440	25.5	250	25.5
							High-profile employment	11,275	66.5	8786	65.2	651	66.4
							Medium- and low-profile employment	1,312	7.7	1245	9.2	79	8.1
							Unemployment			322		980	
							Missing data						

Table I. (*Continued*).

	25-year-olds							40-year-olds					
	Study population		Excluded individuals due to missing dental data at age 15		Excluded due to erroneous dental registrationsor missing data			Study population		Excluded individuals due to missing dental data at age 15		Excluded due to erroneous dental registrationsor missing data	
	n	%	n	%	n	%		n	%	n	%	n	%
Inhabitant/dentist ratio			a	a	a	a	Inhabitant/dentist ratio			a	a	a	a
1–1223	5,777	38.5					1–1225	4,402	25.6				
1224–1557	1,740	11.6					1226–1637	4,219	24.5				
1558–1784	4,030	26.8					1638–1865	4,359	25.3				
1785+ (and 0)	3,470	23.1					1866+ (and 0)	4,224	24.6				
Dental attendance (dental examinations 2005–2009)			a	a	a	a	Dental attendance (dental examinations 2005–2009)			a	a	a	a
0–2	2,970	19.6					0–2	1,851	10.8				
3–4	3,940	26.0					3–5	5,059	29.4				
5 or more	8,233	54.4					6 or more	10,294	59.8				

a = unavailable data.
DMFT, Decayed, missing and filled teeth; ΔDMFT, Change in DMFT.

Table II. Poisson regression analysis of dental examinations.

Dental examinations									
	25-year-olds					40-year-olds			
	Crude incidence rate ratio		Full model			Crude incidence rate ratio		Full model	
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
Intercept			4.4	4.3; 4.6	Intercept			5.54	5.41; 5.68
Gender					Gender				
Female	1.09	1.07; 1.11	1.07	1.06; 1.09	Female	1.04	1.03; 1.05	1.04	1.02; 1.05
Male (ref.)	1	—	1	—	Male (ref.)	1	—	1	—
Increase in DMFT from age 15 to 25					Increase in DMFT from age 15 to 40				
ΔDMFT > 7	1.04	1.02; 1.07			ΔDMFT > 12	1.06	1.05; 1.07	1.07	1.05; 1.10
ΔDMFT = 5–7	1.08	1.06; 1.11			ΔDMFT = 3–12	1.05	1.03; 1.07	1.05	1.03; 1.08
ΔDMFT = 2–4	1.05	1.03; 1.07			ΔDMFT = 0–2 (ref.)	1	—	1	—
ΔDMFT = 0–1 (ref.)	1	—							
Household income (DKK/year)					Household income (DKK/year)			NS	
0–299,999	0.92	0.90; 0.94	0.98	0.95; 1.00	0–299,999	0.96	0.94; 0.98		
300,000–599,999	0.94	0.92; 0.96	0.97	0.95; 0.99	300,000–599,999	0.98	0.97; 0.99		
600,000+ (ref.)	1	—	1	—	600,000+ (ref.)	1	—		
Educational level					Educational level			NS	
Low	0.82	0.80; 0.84			Low	0.97	0.95; 0.99		
Medium	0.95	0.94; 0.97			Medium	1.01	1.00; 1.02		
High (ref.)	1	—			High (ref.)	1	—		
Residential area					Residential area			NS	
Fringe	1.10	1.06; 1.13	1.10	1.06; 1.14	Fringe				
Rural	1.09	1.07; 1.11	1.09	1.06; 1.11	Rural				
Medium	1.09	1.06; 1.11	1.08	1.05; 1.11	Medium				
Urban (ref.)	1	—	1	—	Urban (ref.)				
					Labor market participation				
					Unemployment	0.95	0.93; 0.98	0.94	0.92; 0.97
					Medium or low profile employment	1.03	1.02; 1.05	1.02	1.01; 1.04
					High profile employment (ref.)	1	—	1	—

Table II. (*Continued*).

Dental examinations									
	25-year-olds					40-year-olds			
	Crude incidence rate ratio		Full model			Crude incidence rate ratio		Full model	
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
Inhabitant/dentist ratio					Inhabitant/dentist ratio				
1784+ (and 0 dentists)	1.08	1.06; 1.10	1.05	1.02; 1.07	1784+ (and 0 dentists)	1.01	1.00; 1.03	1.01	0.99; 1.03
1558–1784	1.09	1.07; 1.11	1.08	1.06; 1.10	1558–1784	1.02	1.00; 1.04	1.01	1.00; 1.03
1224–1557	1.11	1.09; 1.14	1.09	1.06; 1.12	1224–1557	1.04	1.02; 1.06	1.04	1.02; 1.06
1–1223 (ref.)	1	—	1	—	1–1223 (ref.)	1	—	1	—
Interactions									
ΔDMFT × Edu. Lv									
ΔDMFT > 7 × Low			0.90	0.83; 0.97					
ΔDMFT > 7 × High			1.08	1.04; 1.13					
ΔDMFT = 5–7 × High			1.08	1.04; 1.12					
ΔDMFT = 2–4 × High			1.04	1.00; 1.08					
ΔDMFT = 0–1 × Low			0.80	0.75; 0.86					
ΔDMFT = 0–1 × Medium			0.93	0.89; 0.96					
ΔDMFT = 0–1 × High (ref.)			1	-					

Non-significant interaction terms are omitted due to clarity of the layout.
NS, Non-significant; DMFT, Decayed, missing and filled teeth; ΔDMFT, Change in DMFT.

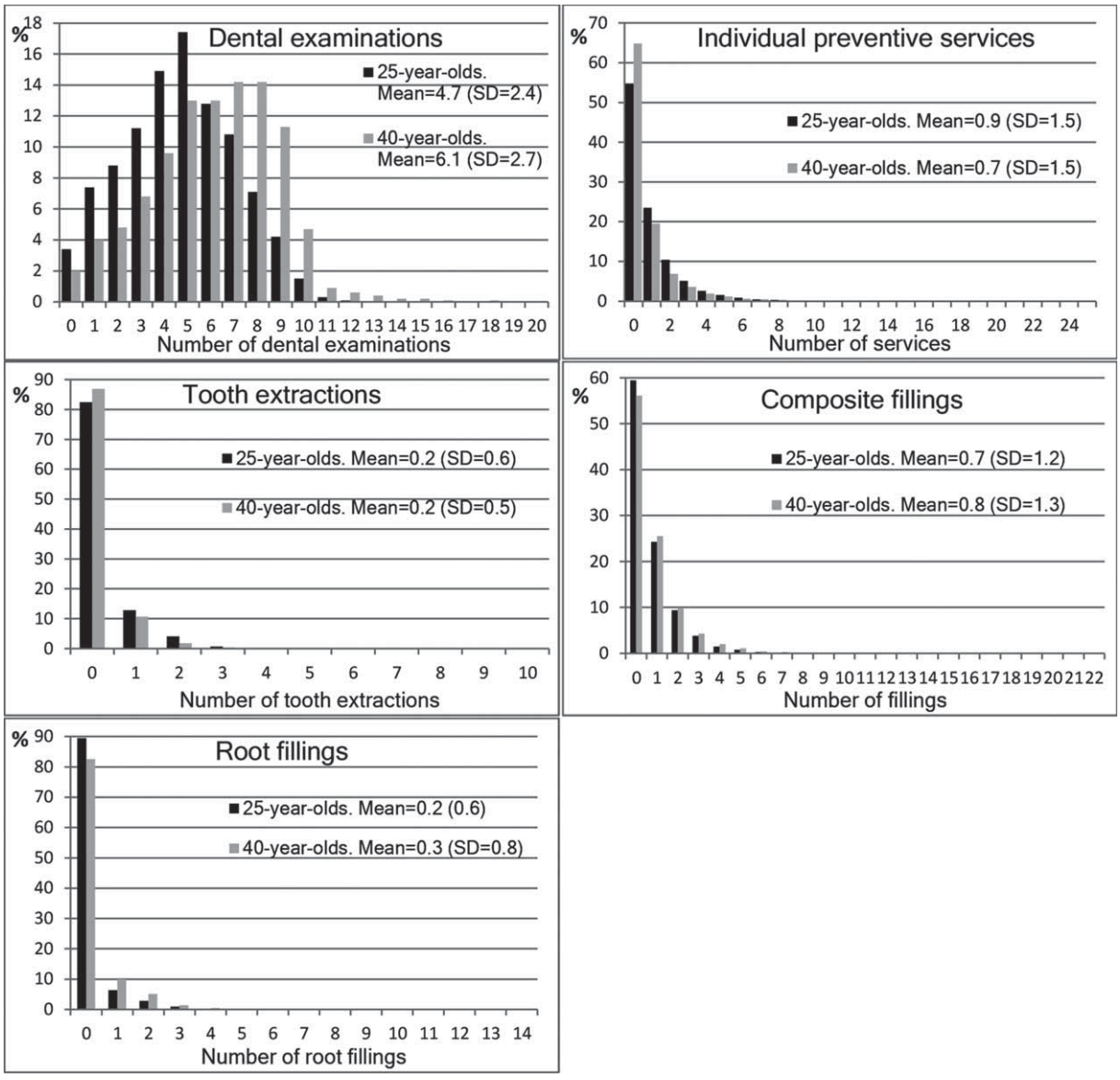

Figure 2. Distributions of dental services from 2005–2009 for 25- and 40-year-olds.

Dental examinations

Table II shows the Poisson regression analyses of dental examinations in relation to socioeconomic factors, inhabitant/dentist ratio and ΔDMFT, illustrating the crude incidence rate ratios (IRR) and IRR in the full model. Persons aged 25 with the highest increase in DMFT (ΔDMFT > 7) and with low educational level had 0.8 fewer dental examinations over 5 years than persons with ΔDMFT > 7 and high educational level (calculated from the IRR of the respective groups) (Table II). Twenty-five year-olds with low education and low increase in DMFT (ΔDMFT = 0–1) received 3.5 dental examinations/5 years compared to 4.4 dental examinations/5 years in the reference group (Table II).

Among 40-year-olds, educational level, household income and residential area were not statistically significantly related to the number of dental examinations received.

Individual preventive services

Table III illustrates that a high increase in DMFT was associated with more IPS among persons with regular dental attendance compared to the reference group. However, high increase in DMFT and less frequent dental attendance was associated with fewer IPS compared to the reference group (ΔDMFT = 0–1 × 5 or more dental examinations). Moreover, among 25-year-olds, low educational level, urban residence, female gender and low inhabitant/dentist ratio were associated with the receipt of more IPS (Table III).

Among 40-year-olds, the individuals who received the highest numbers of IPS received, on average, 4.5 IPS/5 years compared to those who received the fewest, corresponding to 0.1 IPS/5 years. Persons in fringe areas received numbers of IPS no different from the reference group, when adjusted for the remaining variables and dental health.

Table III. Negative binomial regression analysis of individual preventive services.

Individual preventive services									
25-year-olds					40-year-olds				
	Crude incidence rate ratio		Full model			Crude incidence rate ratio		Full model	
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
Intercept			0.96	0.85; 1.07	Intercept			0.90	0.75; 1.08
Gender					Gender				
Female	1.17	1.12; 1.23	1.12	1.06; 1.17	Female	1.09	1.04; 1.15	1.07	1.02; 1.13
Male (ref.)	1	—	1	—	Male (ref.)	1	—	1	—
Increase in DMFT from age 15 to 25					Increase in DMFT from age 15 to 40				
ΔDMFT > 7	1.68	1.56; 1.80			ΔDMFT > 12	1.82	1.65; 2.01		
ΔDMFT = 5–7	1.31	1.21; 1.41			ΔDMFT = 3–12	1.14	1.05; 1.23		
ΔDMFT = 2–4	1.15	1.07; 1.23			ΔDMFT = 0–2 (ref.)	1	—		
ΔDMFT = 0–1 (ref.)	1	—							
Household income (DKK/year)					Household income (DKK/year)				
0–299,999	0.96	0.89; 1.04	0.96	0.84; 1.04	0–299,999	1.45	1.34; 1.56	1.24	1.13; 1.35
300,000–599,999	0.89	0.82; 0.96	0.91	0.84; 0.98	300,000–599,999	1.10	1.05; 1.16	1.08	1.02; 1.14
600,000+ (ref.)	1	—	1	—	600,000+ (ref.)	1	—	1	—
Educational level					Educational level				
Low	1.17	1.09; 1.26	1.37	1.27; 1.48	Low	1.12	1.04; 1.20	1.09	1.00; 1.18
Medium	1.02	0.96; 1.07	1.10	1.04; 1.17	Medium	1.05	1.00; 1.10	1.10	1.04; 1.16
High (ref.)	1	—	1	—	High (ref.)	1	—	1	—
Residential area					Residential area				
Fringe	0.89	0.84; 0.99	0.80	0.71; 0.90	Fringe	0.81	0.74; 0.84		
Rural	0.89	0.84; 0.94	0.81	0.75; 0.87	Rural	0.63	0.59; 0.67		
Medium	1.04	0.96; 1.11	0.91	0.86; 1.03	Medium	0.79	0.74; 0.85		
Urban (ref.)	1	—	1	—	Urban (ref.)	1	—		
					Labor market participation				
					Unemployment	1.50	1.38; 1.64		
					Medium or low profile employment	0.98	0.93; 1.03		
					High profile employment (ref.)	1	—		
Inhabitant/dentist ratio					Inhabitant/dentist ratio				
1784+ (and 0 dentists)	0.90	0.84; 0.94	0.92	0.85; 1.00	1784+ (and 0 dentists)	0.73	0.69; 0.78	0.86	0.80; 0.93

Table III. (*Continued*).

Individual preventive services									
25-year-olds					40-year-olds				
	Crude incidence rate ratio		Full model			Crude incidence rate ratio		Full model	
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
1558–1784	0.89	0.84; 0.94	0.86	0.81; 0.92	1558–1784	0.74	0.69; 0.79	0.87	0.82; 0.94
1224–1557	1.04	0.96; 1.12	0.98	0.90; 1.08	1224–1557	0.77	0.73; 0.82	0.86	0.80; 0.93
1–1223 (ref.)	1	—	1	—	1–1223 (ref.)	1	—	1	—
Dental attendance (dental examinations 2005–2009)					Dental attendance (dental examinations 2005–2009)				
0–2	0.39	0.36; 0.41			0–2	0.40	0.37; 0.44	0.37	0.34; 0.41
3–4	0.59	0.55; 0.62			3–5	0.57	0.54; 0.60	0.58	0.55; 0.61
5+ (ref.)	1	—			6+ (ref.)	1	—	1	—
Interactions					Interactions				
Increase in DMFT from age 15–40 × dental attendance					αDMFT × Residential area × Labor market participation				
ΔDMFT > 7 × 0–2 dental examinations/ 5 years			0.69	0.55; 0.85	ΔDMFT > 12 × Medium × Unemployment			2.68	1.12; 6.43
ΔDMFT > 7 × 5 or more dental examinations			1.79	1.62; 1.97	ΔDMFT > 12 × Medium × Medium/low profile			2.54	1.25; 5.20
ΔDMFT = 5–7 × 0–2 dental examinations/5 years			0.72	0.57; 0.90	ΔDMFT > 12 × Medium × High profile			3.47	1.67; 7.18
ΔDMFT = 5–7 × 5 or more dental examinations			1.31	1.19; 1.44	ΔDMFT = 3–12 × Medium × Unemployment			2.53	1.14; 5.61
ΔDMFT = 2–4 × 5 or more dental examinations			1.11	1.02; 1.22	ΔDMFT = 3–12 × Medium × High profile			1.90	1.05; 3.43
ΔDMFT = 0–1 × 0–2 dental examinations			0.45	0.38; 0.53	ΔDMFT = 0–2 × Medium × Medium/low profile			1.97	1.05; 3.70
ΔDMFT = 0–1 × 3–4 dental examinations			0.60	0.52; 0.69	ΔDMFT>12 × Urban × High profile			1.62	1.25; 2.10
ΔDMFT = 0–1 × 5+ dental examinations/ 5 years (ref.)			1	—	ΔDMFT = 0–2 × Medium × High profile			0.40	0.23; 0.71
					ΔDMFT = 0–2 × Urban × High profile (ref.)			1	—

Non-significant interaction terms are omitted due to clarity of the layout.
DMFT, Decayed, missing and filled teeth; ΔDMFT, Change in DMFT.

Table IV. Negative binomial regression analysis of tooth extractions.

Tooth extractions									
	25-year-olds					40-year-olds			
	Crude incidence rate ratio		Full model 3			Crude incidence rate ratio		Full model 3	
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
Intercept			0.10	0.09; 0.11	Intercept			0.07	0.06; 0.09
Gender					Gender				
Female	1.23	1.14; 1.33	1.29	1.19; 1.39	Female	1.04	0.96; 1.13	1.11	1.02; 1.21
Male (ref.)	1	—	1	—	Male (ref.)	1	—	1	—
DMFT at age 15					DMFT at age 15				
10+	3.14	2.60; 3.80	2.60	2.14; 3.15	10–32	1.81	1.53; 2.14	1.44	1.21; 1.72
5–9	2.01	1.79; 2.25	1.77	1.57; 1.99	2–9	1.27	1.10; 1.47	1.17	1.00; 1.36
1–4	1.44	1.32; 1.58	1.37	1.25; 1.50	0–1 (ref.)	1	—	1	—
0 (ref.)	1	—	1	—					
Household income (DKK/year)	NS				Household income (DKK/year)				
0–299,999					0–299,999	2.10	1.87; 2.36	1.39	1.20; 1.61
300,000–599,999					300,000–599,999	1.54	1.41; 1.68	1.31	1.20; 1.44
600,000+ (ref.)					600,000+ (ref.)	1	—	1	—
Educational level					Educational level				
Low	2.29	2.05; 2.55	2.07	1.84; 2.31	Low	2.34	2.10; 2.62	1.66	1.46; 1.89
Medium	1.40	1.28; 1.54	1.33	1.21; 1.46	Medium	1.39	1.26; 1.52	1.24	1.12; 1.38
High (ref.)	1	—	1	—	High (ref.)	1	—	1	—
Residential area					Residential area				
Fringe	1.48	1.28; 1.72	1.17	1.01; 1.37	Fringe	1.45	1.45; 1.93	1.42	1.22; 1.65
Rural	1.45	1.33; 1.58	1.24	1.14; 1.36	Rural	1.27	1.16; 1.40	1.15	1.04; 1.27
Medium	1.33	1.19; 1.44	1.19	1.06; 1.34	Medium	1.36	1.21; 1.52	1.27	1.14; 1.43
Urban (ref.)	1	—	1	—	Urban (ref.)	1	—	1	—
					Labor market participation				
					Unemployment	2.70	2.35; 3.11	1.49	1.25; 1.76
					Medium or low profile employment	1.28	1.15; 1.41	1.02	0.91; 1.14
					High profile employment (ref.)	1	-	1	
Inhabitant/dentist ratio			NS		Inhabitant/dentist ratio			NS	
1784+ (and 0 dentists)	1.38	1.26; 1.52			1784+ (and 0 dentists)	1.22	1.09; 1.37		

Table IV. (*Continued*).

	Tooth extractions									
	25-year-olds					40-year-olds				
	Crude incidence rate ratio		Full model 3			Crude incidence rate ratio		Full model 3		
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
1558–1784	1.27	1.15; 1.39			1558–1784	1.15	1.03; 1.29		
1224–1557	1.40	1.24; 1.58			1224–1557	1.25	1.12; 1.40		
1–1223 (ref.)	1	—			1–1223 (ref.)	1	—		
Dental attendance (dental examinations 2005–2009)			NS		Dental attendance (dental examinations 2005–2009)				
0–2	1.18	1.07; 1.29			0–2	2.07	1.85; 2.30	1.72	1.53; 1.93
3–4	0.96	0.88; 1.05			3–5	1.06	0.96; 1.16	1.09	0.99; 1.19
5+ (ref.)	1	—			6+ (ref.)	1	—	1	—

NS, Non-significant; DMFT, Decayed, missing and filled teeth.

Tooth extractions

Table IV shows that the characteristics of those 25-year-olds who had the highest number of teeth removed were female gender, DMFT at age 15 ≥ 10 and had a low educational level and a residence in a fringe area (0.8 tooth extractions/5 years). By comparison, males with DMFT at age 15 = 0 and high educational level who were urban residents had 0.1 teeth removed in the same period. Household income, inhabitant/dentist ratio and dental attendance showed no association with tooth extractions.

At age 40, individuals who were female with DMFT at age 15 ≥ 10, low income, low educational level and fringe area residence who were unemployed received 0–2 examinations/5 years had a mean of 0.9 tooth extractions/5 years. The reference group (male, DMFT = 0–1, high income, high educational level, urban residence, high profile employment, ≥ 6 examinations/5 years) had 0.07 extractions/5 years.

Composite fillings

Table V shows that, among 25-year-olds, those who received the most fillings were persons with DMFT at age 15 > 9 (IRR = 3.46, full model). When adjusted for DMFT at age 15, persons with low educational level and with ≥ 5 examinations/5 years received 0.7 fillings/5 years compared to persons with a high educational level and 0–2 examinations/5 years, who received 0.3 fillings/5 years. Gender, household income and the inhabitant/dentist ratio had no association with the number of composite fillings received.

Among 40-year-olds, infrequent dental attendance was associated with fewer composite fillings when adjusted for other variables. Persons with DMFT at age 15 > 9 were associated with more composite fillings among high-income groups in both urban (IRR = 1.89) and fringe areas (IRR = 1.97) compared to low-income groups in urban (IRR = 0.55) and fringe areas (IRR = 1.00).

Root fillings

Table VI shows that the 25-year-old females with low educational level and high income received more root fillings compared to males who were highly educated with low income when adjusted for the remaining indicators. Persons with DMFT at age 15 > 9 from a fringe area and with 0–2 examinations in 5 years received almost no root fillings (IRR = 0.18) (Table VI).

As for the 40-year-olds, low educational level, unemployment and frequent dental attendance were associated with more root fillings. Persons with DMFT at age 15 > 9, low income and fringe area residence did not differ in the number of root fillings received compared to the reference group

Table V. Negative binomial regression analysis of composite filling treatments.

Composite fillings anterior teeth, 1 surface									
	25-year-olds					40-year-olds			
	Crude incidence rate ratio		Full model			Crude incidence rate ratio		Full model	
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
Intercept			0.46	0.43; 0.49	Intercept			0.56	0.49; 0.64
Gender					Gender				
Female	1.01	0.96; 1.06	0.97	0.93; 1.03	Female	1.11	1.06; 1.16	1.08	1.03; 1.13
Male (ref.)	1	—	1	—	Male (ref.)	1	—	1	—
DMFT at age 15					DMFT at age 15				
DMFT > 9	3.53	3.07; 4.06	3.46	3.00; 3.99	DMFT = 10–32	2.18	1.98; 2.39		
DMFT = 5–9	2.32	2.14; 2.51	2.24	2.06; 2.42	DMFT = 2–9	1.36	1.26; 1.48		
DMFT = 1–4	1.61	1.52; 1.71	1.59	1.50; 1.69	DMFT = 0–1 (ref.)	1	—		
DMFT = 0 (ref.)	1	—	1	—					
Household income (DKK/year)			NS		Household income (DKK/year)				
0–299,999	0.98	0.90; 1.07			0–299,999	1.43	1.33; 1.54		
300,000–599,999	0.99	0.91; 1.08			300,000–599,999	1.16	1.10; 1.22		
600,000+ (ref.)	1	—			600,000+ (ref.)	1	—		
Educational level					Educational level				
Low	1.55	1.44; 1.68	1.54	1.42; 1.66	Low	1.44	1.35; 1.54	1.26	1.17; 1.36
Medium	1.21	1.14; 1.29	1.18	1.11; 1.25	Medium	1.15	1.10; 1.21	1.09	1.04; 1.15
High (ref.)	1	—	1	—	High (ref.)	1	—	1	—
Residential area					Residential area				
Fringe	1.29	1.16; 1.43	1.02	0.91; 1.13	Fringe	1.08	0.99; 1.18		
Rural	1.15	1.08; 1.32	0.95	0.89; 1.02	Rural	1.04	0.99; 1.10		
Medium	1.24	1.15; 1.34	1.12	1.04; 1.22	Medium	1.14	1.07; 1.22		
Urban (ref.)	1	—	1	—	Urban (ref.)	1	—		
					Labor market participation				
					Unemployment	1.59	1.45; 1.73	1.27	1.14; 1.41
					Medium or low profile employment	1.10	1.04; 1.16	0.98	0.92; 1.04
					High profile employment (ref.)	1	—	1	—

Table V. (*Continued*).

Composite fillings anterior teeth, 1 surface									
	25-year-olds					40-year-olds			
	Crude incidence rate ratio		Full model			Crude incidence rate ratio		Full model	
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
Inhabitant/dentist ratio			NS		Inhabitant/dentist ratio			NS	
1784+ (and 0 dentists)	1.16	1.09; 1.24			178+ (and 0 dentists)	0.96	0.90; 1.02		
1558–1784	1.16	1.09; 1.23			1558–1784	0.98	0.92; 1.05		
1224–1557	1.31	1.21; 1.43			1224–1557	1.01	0.95; 1.08		
1–1223 (ref.)	1	-—			1–1223 (ref.)	1	—		
Dental attendance (dental examinations 2005–2009)					Dental attendance (dental examinations 2005–2009)				
0–2	0.66	0.62; 0.71	0.60	0.55; 0.64	0–2	0.57	0.52; 0.62	0.52	0.48; 0.57
3–4	0.78	0.73; 0.83	0.79	0.75; 0.84	3–5	0.72	0.68; 0.76	0.74	0.70; 0.78
5+ (ref.)	1	—	1	—	6+ (ref.)	1	—	1	—
					Interactions				
					DMFT at age 15 × Household income × residential area				
					DMFT > 9 × 0–299,999 × Urban			0.55	0.35; 0.88
					DMFT > 9 × 600,000+ × Fringe			1.97	1.04; 3.75
					DMFT > 9 × 600,000+ × Urban			1.89	1.58; 2.26
					DMFT = 2–9 × 600,000+ × Urban			1.32	1.15; 1.51
					DMFT = 0–1 × 0–299,999 × Urban			1.41	1.03; 1.94
					DMFT = 0–1 × 600,000+ × Urban (ref.)			1	—

Non-significant interaction terms are omitted due to clarity of the layout.
NS, Non-significant; DMFT, Decayed, missing and filled teeth.

Table VI. Negative binomial regression analysis of root filling treatments.

Root fillings									
25-year-olds					40-year-olds				
	Crude incidence rate ratio		Full model			Crude incidence rate ratio		Full model	
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
Intercept			0.04	0.03; 0.06	Intercept			0.56	0.49; 0.64
Gender					Gender				
Female	1.18	1.08; 1.28	1.23	1.12; 1.34	Female	1.13	1.06; 1.20	1.08	1.03; 1.13
Male (ref.)	1	—	1	—	Male (ref.)	1	—	1	—
DMFT at age 15					DMFT at age 15				
DMFT > 9	7.00	5.72; 8.55			DMFT > 9	2.18	1.98; 2.39		
DMFT = 5–9	4.53	3.97; 5.16			DMFT = 2–9	1.36	1.26; 1.48		
DMFT = 1–4	2.20	1.96; 2.47			DMFT = 0–1 (ref.)	1	—		
DMFT = 0 (ref.)	1	—							
Household income (DKK/year)					Household income (DKK/year)				
0–299,999	0.83	0.73; 0.95	0.79	0.68; 0.91	0–299,999	1.34	1.20; 1.48		
300,000–599,999	0.93	0.81; 1.07	0.86	0.75; 1.00	300,000–599,999	1.25	1.16; 1.34		
600,000+ (ref.)	1	—	1	—	600,000+ (ref.)	1	—		
Educational level					Educational level				
Low	2.94	2.60; 3.33	2.42	1.96; 2.57	Low	1.61	1.47; 1.77	1.26	1.17; 1.36
Medium	1.46	1.31; 1.63	1.32	1.17; 1.48	Medium	1.27	1.18; 1.36	1.09	1.04; 1.15
High (ref.)	1	—	1	—	High (ref.)	1	—	1	—
Residential area					Residential area				
Fringe	1.31	1.11; 1.155			Fringe	1.19	1.05; 1.34		
Rural	1.13	1.02; 1.25			Rural	1.02	0.95; 1.10		
Medium	1.09	0.95; 1.25			Medium	1.11	1.01; 1.21		
Urban (ref.)	1	—			Urban (ref.)	1	—		
					Labor market participation				
					Unemployment	1.71	1.51; 1.93	1.27	1.14; 1.43
					Medium or low profile employment	1.25	1.16; 1.35	0.98	0.92; 1.04
					High profile employment (ref.)	1	—	1	—
Inhabitant/dentist ratio			NS		Inhabitant/dentist ratio	NS			

Table VI. (*Continued*).

Root fillings									
25-year-olds					40-year-olds				
	Crude incidence rate ratio		Full model			Crude incidence rate ratio		Full model	
	Exp (B)	95% CI	Exp (B)	95% CI		Exp (B)	95% CI	Exp (B)	95% CI
1784+ (and 0 dentists)	1.38	1.23; 1.53			1784+ (and 0 dentists)				
1558–1784	1.19	1.07; 1.32			1558–1784				
1224–1557	1.19	1.03; 1.37			1224–1557				
1–1223 (ref.)	1	—			1–1223 (ref.)				
Dental attendance (dental examinations 2005–2009)					Dental attendance (dental examinations 2005–2009)				
0–2	2.26	2.05; 2.49			0–2 examinations/5 years	1.62	1.47; 1.77	0.52	0.48; 0.57
3–4	1.20	1.08; 1.33			3–5	1.06	0.99; 1.14	0.74	0.70; 0.78
5+ (ref.)	1	—			6+ (ref.)	1	—	1	—
Interactions					Interactions				
Increase in DMFT × Residential area × Dental attendance					DMFT at age × Household income × Residential area				
DMFT > 9 × fringe area × 0–2 examinations			0.18	0.05; 0.73	DMFT > 9 × 0–299,999 × urban area			0.55	0,35; 0.88
DMFT = 5–9 × fringe area × 0–2 examinations			0.23	0.08; 0.63	DMFT > 9 × 600,000+ × fringe area			1.97	1.03; 3.75
DMFT = 5–9 × fringe area × 3–4 examinations			0.32	0.11; 0.90	DMFT > 9 × 600,00+ × urban area			1.87	1.58; 2.26
DMFT = 5–9 × Urban area × 0–2 examinations			0.55	0.37; 0.82	DMFT = 2–9 × 600,000+ or more × urban area			1.32	1.15; 1.51
DMFT = 1–4 × fringe area × 0–2 examinations			0.28	0.10; 0.75	DMFT = 0–1 × 0–299,999 × urban area			1.41	1.03; 1.94
DMFT = 1–4 × urban area × 0–2 examinations			0.60	0.43; 0.85	DMFT = 0–1 × 600,000+ × urban area (ref.)			1	—
DMFT > 9 × urban area × 5+ examinations			6.88	4.59; 10.32					
DMFT = 5–9 × urban × 5+ examinations			5.04	3.95; 6.44					
DMFT = 1–4 × urban × 5+ examinations			2.43	1.96; 3.01					
DMFT = 0 × rural area × 5+ examinations			0.59	0.43; 0.82					
DMFT = 0 × urban area × 0–2 examinations			2.98	2.34; 3.79					
DMFT = 0 × urban area × 3–4 examinations			1.34	1.03; 1.73					
DMFT = 0 × urban area × 5+ examinations (ref.)			1	—					

Non-significant interaction terms are omitted due to clarity of the layout.
NS, Non-significant; DMFT, Decayed, missing and filled teeth.

(DMFT at age 15 = 0–1, high income, urban resident) (Table VI).

Discussion

Key results

Poor dental health (high number of DMFT at age 15 and large ΔDMFT) was associated with higher numbers of dental care services and is considered the type of variation that is expected and acceptable [27]. However, some undesirable variations may have been seen. Socioeconomically-privileged individuals received more dental examinations and fewer tooth extractions, root fillings and composite fillings compared to disadvantaged persons, when controlling for dental health. Irregular attenders received fewer preventive services and fewer composite fillings, but received more extractions. Compared to the remaining explanatory variables, the inhabitant/dentist ratio was not a very strong indicator of the dental services received. Some area variations in the receipt of dental services were seen. More dental examinations and more tooth extractions were received in fringe and deprived areas when controlling for other explanatory indicators.

Discussion of the method

The included five dental services were considered the most relevant because elements from primary, secondary and tertiary prevention principles were covered, by choosing two diagnostic and preventive oriented services and three operative treatment types of services. Furthermore, root fillings and tooth extractions are often two alternative treatments, which patients need to choose between, when dealing with progressed complications from dental caries. Therefore, variations in root fillings and tooth extractions were considered interesting when comparing different socioeconomic groups. Composite fillings in anterior teeth were chosen before fillings in posterior teeth, because of practical barriers (changes in the reimbursement scheme in the middle of the study period).

The cross-sectional nature of the socioeconomic indicator variables obtained in 2009 prevents causal interpretations but rest on the assumption that, in 2009, socioeconomic status is a proxy for earlier individual or area-based characteristics that can influence the type of services individuals receive. If indicators are stable or even irreversible—for instance, educational level, it will increase the validity of the indicator. Individual membership of the different groups of labor market participation, income and residential area could change more readily and, therefore, induce risk of misclassification bias. Household income is probably more prone to change in the young adult cohort since this age group is probably less settled in life and may still be pursuing an education, compared with the 40-year-olds. The associations between household income and outcomes, therefore, should be interpreted with this in mind.

In 2009, 25% (25-year-olds) and 8.5% (40-year-olds) moved to a different municipality in Denmark (Statistics Denmark). This means that the residential area of the population was not static, which has to be taken into consideration in determining whether residential area is significantly associated with the number of dental services received. Furthermore, since residential area was included at the individual level in the analyses, it is not possible to distinguish whether the influence of the area in which people live on the number of services received at the individual level is due to compositional or contextual mechanisms [48].

The structural indicator of inhabitant/dentist ratio is considered to be stable because existing dental clinics are typically taken over by young dentists and the establishment of new dental clinics is rare.

Since dental attendance is measured over the same 5-year period as the outcome measure, the risk of changing attendance patterns over time can be ignored. The type and number of dental services delivered in the 5-year period are likely to be correct since there are economic incentives for the dentists to report the type of service delivered in order to receive the correct reimbursement and, furthermore, because the National Board of Health continuously monitors the level and type of dental services delivered. The applied definition of 'dental attendance' is mere a proxy for dental attendance patterns, since data were not available on dental care attenders who did not receive a dental examination in 2009, but may have received other types of services. Such individuals are, therefore, not included in the study.

Correct dental health information reported by dental personnel to the National Board of Health is a requirement for reimbursement and, therefore, an incentive to provide the mandatory and correct registrations. Moreover, the data set has been thoroughly cleaned for logical errors when the two dental health registers were merged. A potential variability in the assessment of dental health may decrease the reliability of the data since no calibration of dental examiners was possible. Nor was it possible to calculate inter- and intra-examiner reliability. However, if examiner variability is completely due to chance, the validity of the data should still be good, especially with a large number of examiners. Furthermore, the large study population will compensate for the lower reliability of data [49].

The number of teeth present with dental caries at the cavity level, the number of teeth present and the number of teeth with fillings are robust and simple measures that can be collected fairly easy and by simple procedures and are indicators recommended by the WHO [43]. Dentists and dental hygienists daily

perform these procedures, which are fundamental skills for dental personnel. Furthermore, guidelines are provided by the health authorities for dental health registration under the Child Dental Health Service System as well as the Private Dental Service System [42,45]. A study comparing the reliability of the data collected from public health records with data collected by trained examiners concluded that data from public health records are not decisively inferior to data obtained by trained examiners and, if used in large enough settings, could replace conventional examinations by trained and calibrated examiners [50]. The nationwide Danish caries recording system on which the 1984 and 1999 registrations are based has been evaluated in a study that showed acceptable levels of consistency, although with lower reproducibility than normally reported for epidemiological surveys [51].

Other oral diseases than dental caries can lead to the need for dental care services; therefore, caries experience (DMFT) and change in DMFT are not the only indicators of later dental care need. Presence of periodontal disease or other oral diseases simultaneously with low DMFT may confound the results in a way that persons judged in low need of dental care actually have a high need due to conditions not captured by the DMFT measure. Regarding periodontal disease, epidemiological studies are difficult to interpret due to the diversity of measures used to describe and quantify disease and the absence of uniform definitions and classifications [52]. Hence, the use of periodontal status as an indicator for later dental care need would be influenced by the same serious limitations. Furthermore, data on periodontal status or other oral diseases were not available for the present study.

The DMFT measure has been criticized for its conflicting components [53] in the sense that missing teeth is considered a much more serious dental health problem than number of filled teeth. In the present study, this is not considered a major problem, since the FT component is dominant in comparison with the DT and MT components. However, analyses with the separate components may give rise to larger differences between groups, since the composite character of the DMFT measure to some degree reduces the sensitivity of identifying the level of dental health of individuals.

The socioeconomic indicators have been obtained from high-quality registers via Statistics Denmark, and the group membership classification has a low risk of misclassification due to the straightforward nature of the indicators (gender, income, educational level, residential area and labor market participation).

In spite of the limitations of register-based studies, the validity and reliability of the present data are considered acceptable, because of: (1) the large study population, (2) the simple characteristics of the dental health measures, (3) the well-known registration procedures for the dental personnel and (4) the high quality registers providing socioeconomic and demographic data.

Since dental care providers have economic incentives to provide data on patients and treatments, it is assumed that almost all persons eligible for the study were initially included and 'drop outs' are considered to be few and random. Missing dental health data from 1984–1999, together with erroneous dental health scorings, were the primary reason for the exclusion of subjects in the data-cleaning process. Excluded subjects were found to differ in a few parameters (Table I), but the differences were minor and not deemed to be of relevant size to affect the representativeness of included subjects in relation to attenders of the dental care system.

Interpretations of the results

Gender differences were not the primary focus of this study and the variable was included in models primarily for control purposes. However, females received more dental services than males when adjusted for dental health and the remaining explanatory variables. This indicates that differences seen in dental health between males and females may be explained, in part, by different dental attendance patterns.

The observation that educational level was associated with dental examinations corresponds with findings in numerous previous studies [3,5,6]. Behavioral characteristics are probably one reason that low educated individuals had dental examinations conducted more sporadically, as suggested by Sisson [54], and the 'too rare' receipt of dental examinations may be a mediator for socioeconomic inequality in dental health. It is worth noticing that educational level, which is often a powerful socioeconomic indicator, was not associated with dental examinations for the 40-year-old cohort, which indicates that socioeconomic inequality with respect to this type of service is greater for young adults. However, comparison between the two different cohorts is complex due to their varying composition and cohort effects.

The minor influence of household income on number of dental examinations received could be seen as a positive finding and in balance with the described principle of equal access to health services. Unfortunately, the present data do not provide information on the number of persons who opt out of dental care because of an economic barrier. The present study only comprises persons who have overcome this barrier, which seems to exist [7,25]. This sort of barrier may be of a smaller magnitude in a relatively egalitarian society such as Denmark [55].

Low educational level and unemployment were uniquely associated with more individual preventive services (IPS) when adjusted for change in dental

health and the remaining explanatory indicators. This is an inverse relationship to that seen with dental examinations and the reverse of what was found by Manski and Moeller [6]. If socioeconomic status is considered a risk factor for future caries, which is arguably fair to do [56], the present observed variation could indicate that dental care providers succeed in performing risk assessments based on more than caries experience and succeed in addressing high risk groups and providing them with more preventive services.

Low education and unemployment were associated with more tooth extractions, more composite fillings and more root fillings when adjusted for DMFT at age 15 and for the remaining explanatory variables. A corresponding association between educational level and tooth extractions was found by Roberts-Thomson et al. [35]; however, this study did not control for dental health level [35]. Despite similar DMFT levels at age 15, the severity of the underlying conditions may be worse in lower socioeconomic groups and may explain the higher need for interventions later in life. If extractions are chosen over endodontic treatments as a realistic alternative, the variations observed could indicate some inequality. Furthermore, the findings can hardly be interpreted as inequality of access to these types of services, but the present findings may be a result of inequality of access to timely diagnostics or inequality of access to other tooth-retaining or preventive services.

The 25-year-olds from areas other than urban areas received ~ 10% more dental examinations. This finding may reflect that urban dentists have changed recall procedures more readily based on risk assessments and that the traditional 'biannual recall' regime is more widely used outside urban areas. The low level of variation among 40-year-olds with respect to dental examinations is consistent with previous findings [18] and, as Bader and Shugars [18] describe it, 'provision of examinations and prophylaxes, where criteria for need often are based on schedules rather than clinical conditions and symptoms'. The 40-year-old cohort may have been more used to a schedule-based type of recall, which may explain the cohort difference.

The 25-year-olds from rural and fringe areas received ~ 20% fewer preventive services than medium area and urban residents. This may be an indication of inequality of access to this type of dental service and may contribute to inequality in dental health between these areas. Such differences may be due to different psychosocial mechanisms and health attitudes between fringe and urban areas both among attenders and providers of dental care. Among the 40-year-olds, indications of some inequality of access to preventive services are also seen since the people deemed to be in high need of preventive services (ΔDMFT > 12) from fringe areas did not receive more services than persons deemed to have a low need for preventive services (ΔDMFT = 0–2) from urban areas. The interaction terms in Table III also indicate a possible imbalance in the receipt of preventive services between urban and medium areas, since persons deemed to have a low need of services in urban areas received 60% more preventive services than corresponding persons with a low need of services in medium areas. It seems that, while fringe area residents may have received too few services, urban residents may have received too many.

In both age cohorts, significantly fewer tooth extractions were performed in urban areas, although very few teeth in total were extracted. This may be due to a higher acceptance of missing teeth outside urban areas and a higher demand for tooth-retaining services in urban areas. Higher extraction rates in rural areas compared to urban areas were also found by Brennan and Spencer [19]. The association between tooth extractions and household income for 40-year-olds could indicate that the low-income group experiences some inequality of access to alternative treatments to extractions.

Regarding root fillings, it seems that, among 25-year-olds, it was primarily urban residents deemed to be in high need of dental services (DMFT at age 15 > 9) who received root fillings. These findings support the suggestion from Crocombe et al. [57] that some regional cultural attitudinal variations are present, which could explain variation in services when adjusted for individual socioeconomic position and dental health. In addition, the present findings support proposals for more favorable treatment patterns among urban citizens with regular dental check-up habits and a more preventive orientation aimed at retention of teeth (more endodontic treatments and fewer extractions) [28]. Some of the same trends with respect to root fillings were seen among the 40-year-olds. It seems that persons from less privileged socioeconomic groups who were considered to be in high need of dental services opted out of this type of treatment. As seen among 25-year-olds, irregular attendance was associated with fewer root fillings when adjusted for dental health, indicating that irregular attenders may choose tooth extractions over root fillings.

The interpretation of the inhabitant/dentist ratio indicator is probably intertwined with the area-based socioeconomic indicator since more dentists work in larger cities and low-population fringe areas often have more inhabitants per dentist. It seems, however, that both indicators had a unique relation to the number of services received. Persons from areas with few inhabitants per dentist received fewer dental examinations, but more preventive services. The indicator showed no statistically significant association with any of the three treatment services. This may indicate that the observed area variations in dental services were not caused by lack of dental personnel in these areas.

Generalizability

Since the final study population accounts for a large percentage of the actual attenders of the dental care system in the two age groups (75% and 53%) and since excluded individuals only differed slightly on individual parameters, it is likely that the results can be generalized to all attenders of the dental care system in the respective age groups, to dental care systems similar to the Danish system and to systems within the 'Nordic Model'. However, the dental services included in the present study only represent a part of several types of services available in the dental care service system. One group of services (fixed and removable prosthetics, local anesthesia) does not result in reimbursement from the NHI and are, therefore, more expensive to the patient and not part of the registers used for the present study. The results from the present study cannot be extrapolated to describe variations in the receipt of such services.

Conclusions

The results confirm that variations in dental care services reflect variations in dental health, but the variations are also related to individual socioeconomic status, residential area and dental attendance patterns. There are indications of socioeconomic inequalities in the receipt of dental care services. The inequalities in the receipt of dental services may explain some of the inequality seen in dental health among those who attend the dental care system. Such knowledge may help to assist health planners in their efforts to adapt the dental care system to the change in prevalence and distribution of dental diseases and to secure that the legal principle of equal access to dental care is met. Recommendations of political incentives to be initiated to motivate more disadvantaged persons to engage in regular, prevention-oriented dental attendance would seem reasonable, although an earlier English study has shown a tendency for persons already compliant to react more readily to health recommendations and incentives from health authorities than the primary target groups [58].

The dental health data for the present study were collected with the purpose of monitoring dental health levels in the population of attenders of the dental care system. Such systematic data collection would be even more valuable if supplemented with outcome measures of the treatments provided [59] and, furthermore, would help to provide more precise definitions of 'appropriate dental care' [30]. More research in this area is recommended.

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