Community Dent Oral Epidemiol 2008; 36: 258–268

COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY

Number of teeth – a predictor of mortality in 70-year-old subjects

Tor Österberg[1,2], Gunnar E Carlsson[2], Valter Sundh[1] and Dan Mellström[1]

Departments of [1]Geriatric Medicine and [2]Prosthetic Dentistry, Sahlgrenska Academy at Göteborg University, Göteborg, Sweden

Österberg T, Carlsson GE, Sundh V, Mellström D. Number of teeth – a predictor of mortality in 70-year-old subjects. Community Dent Oral Epidemiol 2008; 36: 258–268.

Abstract – *Objectives:* To investigate whether the number of teeth at age 70 is an independent predictor of mortality. *Methods:* Within the gerontological population studies in Göteborg, Sweden, four birth cohorts born in 1901/1902, 1906/1907, 1911/1912 and 1922 were examined cross-sectionally at 70 years of age. The total number of participants in the odontological cohorts was 1803. Mortality data were collected from the national Swedish health registers. Cox regression models were used to measure the association between mortality and the number of teeth with adjustment for covariates such as health factors, socio-economic and lifestyle factors. *Results:* The prevalence of edentulism showed a marked change from 51% in the first cohort to 16% in the last cohort. The 7-year mortality rate was 14% in women and 28% in men, and the highest in edentulous men in the last two cohorts (42% and 47% respectively). The 7-year mortality including all four cohorts showed a hazard ratio of 0.96 (95% CI 0.94–0.98; $P < 0.001$) for the number of teeth with adjustment for cohort. The corresponding 18-year mortality including the three first cohorts showed a hazard ratio of 0.98 for women and 0.97 for men. The number of teeth was an independent statistically significant predictor of 7-year mortality in both genders and of 18-year mortality in men. *Conclusions:* The result showed that each remaining tooth at age 70 decreased the 7-year mortality risk by 4%. The difference between edentulous subjects and dentate subjects with ≥20 teeth regarding 7-year mortality was significantly higher in the last compared to the first cohort. The number of teeth was a significant predictor of mortality independent of health factors, socio-economic status and lifestyle.

Key words: dental health; elderly; epidemiology; general health; survival

Tor Österberg, Department of Prosthetic Dentistry, Sahlgrenska Academy at Göteborg University, Box 450, SE 405 30 Göteborg, Sweden.
Tel: +46 31 3433127
Fax: +46 31 208103
e-mail: g.carlsson@odontologi.gu.se

Submitted 4 July 2006;
accepted 6 March 2007

Associations between edentulism and mortality have been documented in several studies (1–7). The results have not always been consistent with respect to gender, age and localities of samples, and influence of common risk factors for death. As missing teeth are a surrogate marker for previous dental disease, the relationship has been suggested to depend, among other factors, on dental infection. Therefore, the associations between periodontal diseases and coronary heart disease (CHD) and cerebrovascular disease (CVD), both common risk factors for increased mortality, have attracted growing interest during the last few decades (8–12). There have been several reports that periodontal infection increases the risk of CHD and CVD, but the quality of many of these studies and their results have been questioned (13, 14). Two recent meta-analyses found, in the few studies fulfilling their inclusion criteria, indications that periodontal disease may increase the risk of CHD and CVD (15, 16). However, one of the meta-analyses emphasized that there was no evidence of strong associations, and the other one concluded that the statistical effect size was small. Because there are several common risk factors for oral and systemic diseases, careful interpretations of their associations with mortality are needed (17, 18).

Based on this background and as the results on associations between dental health and mortality have not been conclusive, it is evident that further studies would be of interest. It was therefore the aim of this study to investigate if the number of

doi: 10.1111/j.1600-0528.2007.00413.x

teeth at age 70 was a predictor of all-cause mortality independent of previously established risk factors for mortality in elderly. The hypothesis was that a smaller number of teeth at age 70 would be associated with greater mortality in the following years.

Materials and methods

Within the gerontological population studies in Göteborg, Sweden (H70), four birth cohorts born in 1901/1902 (I), 1906/1907 (II), 1911/1912 (III) and 1922 (V) were examined at 70 years of age in 1971/1972, 1976/1977, 1981/1982, 1992/1993. The studies included medical, dental, psychological, nutritional and socio-economic data. Details of the study design have been presented elsewhere (1, 19–23). This study was approved by the ethical committee, Göteborg University, Göteborg, Sweden (Dnr. S 227-00).

The odontological investigations were performed in 40% of the sample of the cohorts I and II and in the total sample of cohorts III and V. The total number of participants in the odontological investigations was 1803 subjects (Table 1). Cohort IV was not included in this study because it was only examined at age 75 and 80. In the odontological samples of cohorts I, II and III, the nonresponders did not differ in basic demographics from the responders (19–23). In cohort V, a new questionnaire was sent to the nonparticipants. This 'nonresponse questionnaire' was completed by 183 subjects, 68% of the nonresponders. These data showed that the prevalence of edentulism was higher in nonresponders than in responders ($P < 0.01$) but in other aspects such as myocardial infarction, anginal pain, diabetes, cancer, hypertension and smoking, there were no differences except for two factors in men, hypertension and smoking, which were more common in the nonresponders ($P < 0.05$).

Table 1. Number of participants and participation rate (% in parenthesis) in the odontological studies of four 70-year-old cohorts I, II, III, V (year of examination and maximal follow-up time of each cohort in parentheses)

	I (1971/1972) (28 years)	II (1976/1977) (23 years)	III (1981/1982) (18 years)	V (1991/1992) (7 years)
Female	199 (83)	216 (77)	302 (69)	232 (60)
Male	186 (85)	199 (85)	279 (76)	190 (63)
Total	385 (84)	415 (81)	581 (72)	422 (62)

Investigations

The odontological investigations were based on interviews, clinical and radiographic examinations when the subjects were 70 years of age. In this study only the number of teeth has been used. The recording of teeth was based mainly on clinical findings and included intact, restored and crowned teeth, as well as roots but excluding nonrepairable roots. The study population was coordinated with the national registers of causes of death and cancer including all registered cases up to 31 December 2000. The follow-up time for survival for the oldest cohort (I) was 28 years and for the youngest (V) 7 years (Table 1).

Based on previous studies (20, 24–27), the following factors were considered as potential confounders in the analysis of the relationship between the number of teeth and mortality: income (from official register), education, marital status, smoking, physical activity, social activity, drug consumption, diseases, and anthropometrical factors. The coding of the potential confounders is described in the following: (1) Education: elementary school, higher education than elementary school; (2) marital status: married, not married. A social activity index was created by combining six variables: reading daily newspaper, reading magazines weakly, accessibility to summer cottage, doing travels, attending association meetings, driving a car. In the present study, the coding used was 0 = doing none of the six activities, 1–6 = the number of activities performed. Smoking was coded in three levels: 0 = never smoked; 1 = previous smoking; 2 = current smoking.

Low physical activity was a dichotomization of self-assessed physical level during the period after 60 years of age: 1 = have mainly been physically inactive during that period, 0 = all others. Anthropometrical factors such as body height and weight, body mass index (BMI) and waist circumference were also taken as confounders. Low BMI was defined as a three-level linear variable: 1 = upper 75% BMI values of the sample; 2 = percentiles 15–25 of the sample; 3 = lowest 15% of the sample. High BMI was defined as a mirror image of low BMI; 1 = lower 75% BMI values of the sample; 2 = percentiles 75–85 of the sample; 3 = highest 15% of the sample. The advantage of this coding is that the effect of low BMI is estimated independent of the effect of high BMI, and vice versa. The result is comparable with a discrete spline model with regard to the effect of BMI on mortality.

The following prevalent diseases and drug consumption were defined in accordance with structured interviews and medical examinations: diabetes mellitus, ischemic heart disease, claudicatio intermittens, chronic bronchitis, cancer, number of drugs used, use of antihypertensive drug, and self-assessed health (feeling healthy, not feeling healthy). Serum cholesterol and triglycerides, blood hemoglobin and plasma glucose were also included as potential confounders. These methods have been described previously (19–27). Income and social activity index were not recorded in cohort V.

Statistics

Cox proportional hazards regression models (Cox models for short) were used to measure and test the association between the number of teeth and survival with or without covariates such as health, socio-economic and lifestyle factors, and cohort (year of birth). Tests of interaction were performed to find out if the association between cohort and survival was the same in different levels of the number of teeth, or equivalently, if the association between the number of teeth and mortality was the same in all cohorts.

Using the number of teeth as a predictor of mortality rests on the assumption of an approximately linear effect, and this assumption has been verified by also modelling the mortality risk as a nonlinear function of the number of teeth by using polynomials to power two and three and logarithmic and power transformations 0.5–2.0. None of the nonlinear models improved the association in a substantial or systematic way over simpler linear models. However, this result may partially be due to low power to detect deviation from linearity, and the association is also reported in four nominal categories: edentulous, one to nine remaining teeth, 10–19 remaining teeth and 20 or more remaining teeth. In comparisons, the edentulous group is used as a reference class, with which the three other groups are compared (Tables 2 and 3).

Two comparable parameters are used in the analysis, one model estimated and one descriptive. The relative hazard or hazard ratio (HR) is estimated from Cox models and the (cumulative) mortality risk of death per 1000 risk years is a descriptive measure of the sample that defines the sample observed relative risk (RR). As HR is a type of relative risk, it is for models with only one explanatory contrast factor directly comparable with the sample observed RR both in effect size and confidence interval.

More formally, HR is an estimate of the instantaneous risk of death in a subgroup of the population relative to the risk of death in a reference group at any arbitrarily chosen point of time during the follow-up period. HR is calculated as $\exp(\beta)$, where β is the regression coefficient of the Cox model. This means that the effect of the factor is assumed to be linear in the log HR scale, which must be considered when interpreting the reported parameter values. If HR is 0.96 for the number of teeth (corresponding to a 4% reduction in hazard per teeth), the model estimated difference in hazard between subjects with 0 teeth and 20 teeth is not 80% (4×20), but 56% ($=1 - 0.96^{20}$).

Table 2. Seven-year mortality and association between mortality and the number of teeth, observed number of risk years, deaths per 1000 risk years, and relative mortality risk with 95% confidence interval, estimated hazard ratios from Cox proportional hazards regression models adjusted for covariates

Number of teeth	Subjects	Deaths	Sum of risk years	Deaths per 1000 years	Relative risk	RR 95% CI	Hazard ratio[a]	HR 95% CI[a]
Women								
0	362	71	2297	31	1.00	Ref. group	1.00	Ref. group
1–9	148	19	965	20	0.64	0.36–1.07	0.71	0.42–1.20
10–19	233	30	1534	20	0.63	0.40–0.98	0.65	0.42–1.02
20–32	206	15	1392	11	0.35	0.19–0.61	0.36	0.19–0.66
Total	949	135	6189	22				
Men								
0	258	102	1447	70	1.00	Ref. group	1.00	Ref. group
1–9	202	60	1223	49	0.70	0.50–0.97	0.65	0.46–0.91
10–19	212	49	1349	36	0.52	0.36–0.73	0.51	0.36–0.74
20–32	182	28	1194	23	0.33	0.21–0.51	0.38	0.24–0.60
Total	854	239	5213	46				

[a]Estimated from Cox regression model with significant variables in Table 6 as covariates.

Table 3. 18-year mortality and association between mortality and the number of teeth, observed number of risk years, deaths per 1000 risk years and relative mortality risk with 95% confidence interval, estimated hazard ratios from Cox proportional hazards regression models adjusted for covariates

Number of teeth	Subjects	Deaths	Sum of risk years	Deaths per 1000 years	Relative risk	RR 95% CI	Hazard ratio[a]	HR 95% CI[a]
Women								
0	322	223	4123	54	1.00	Ref. group	1.00	Ref. group
1–9	121	71	1684	42	0.78	0.59–1.02	0.81	0.61–1.07
10–19	159	104	2196	47	0.88	0.69–1.11	0.94	0.74–1.20
20–32	115	55	1702	32	0.60	0.44–0.81	0.70	0.51–0.96
Total	717	453	9706	47				
Men								
0	229	200	2190	91	1.00	Ref. group	1.00	Ref. group
1–9	180	163	1786	91	1.00	0.81–1.24	1.02	0.82–1.27
10–19	145	113	1715	66	0.72	0.57–0.91	0.74	0.58–0.94
20–32	110	74	1391	53	0.58	0.44–0.76	0.64	0.48–0.84
Total	664	550	7082	78				

[a]Estimated from Cox regression model with significant variables in Table 7 as covariates.

The sample observed mortality risk is the number of deaths in a group divided by the total number of years/1000 at risk in the group, and RR is the ratio between the observed risk in one subgroup and the reference group.

The number of risk years for a person in the study is the number of days from the date of medical and odontological examination at age 70 to the date of death, or to the end of 7-year (or 18-year) follow-up if still alive, divided by 365.25. Confidence intervals for relative risks are calculated as conditional binominal intervals.

The software used for the statistical analysis was SAS version 8.02 for Windows (SAS Institute Inc., Cary, NC, USA).

Results

The prevalence of edentulism showed a marked change during the 20 years covered by the four cohorts of 70-year-old subjects: from 51% in cohort I (examined in 1971/1972) to 16% in cohort V (examined in 1991/1992). During the same time period, the proportion of subjects with ≥20 teeth increased from 14% to 38%.

Associations between mortality and birth year

The 7-year mortality rate was higher in men (28%) than in women (14%) when all cohorts were pooled. The mortality in men decreased from 31% in cohort I to 23% in cohort V, and for women from 16% to 11%. A Cox regression model on 7-year mortality showed 2% lower risk per later birth year both in females and males (hazard ratio, HR = 0.98, 95% CI 0.97–0.99 in the total model). The association between 18-year mortality and birth year (1901–1912) was somewhat weaker and not significant at the 5% level, HR = 0.99, 95% CI 0.97–1.00. This indicates that the change in mortality rate is smaller between cohorts 1901–1902 and 1911–1912 than between cohorts 1911–1912 and 1922, assuming that the birth year effect is the same for the 7- and 18-year follow-ups. This assumption is confirmed from the results of the model with 7-year follow-up for birth years 1901–1912, giving HR = 0.99, CI 0.96–1.02.

Associations between the number of teeth and mortality

The survival rate according to the number of teeth differed between genders and cohorts (Figs 1 and 2). The total cumulative survival over 7 and 18 years was 80% and 31%, respectively, for edentulous women, 60% and 13% for edentulous men. The corresponding figures for those with ≥20 teeth were 93% and 52% for women and 85% and 33% for men (these figures can be calculated from Tables 2 and 3; e.g. for edentulous women on line 0 [number of teeth], the numbers under subjects and deaths from Table 2: 1 − 71/362 = 0.804 = 80%). The difference in 7-year mortality between edentulous subjects and those with ≥20 teeth was evident among men in cohorts II and III and in both genders in cohort V. The 7-year survival for men in cohort V was 94% for those with ≥20 teeth, and 53% for the edentulous subjects. The same difference in 18-year mortality was most marked in women in cohort I and among men in cohort II (Figs 1 and 2).

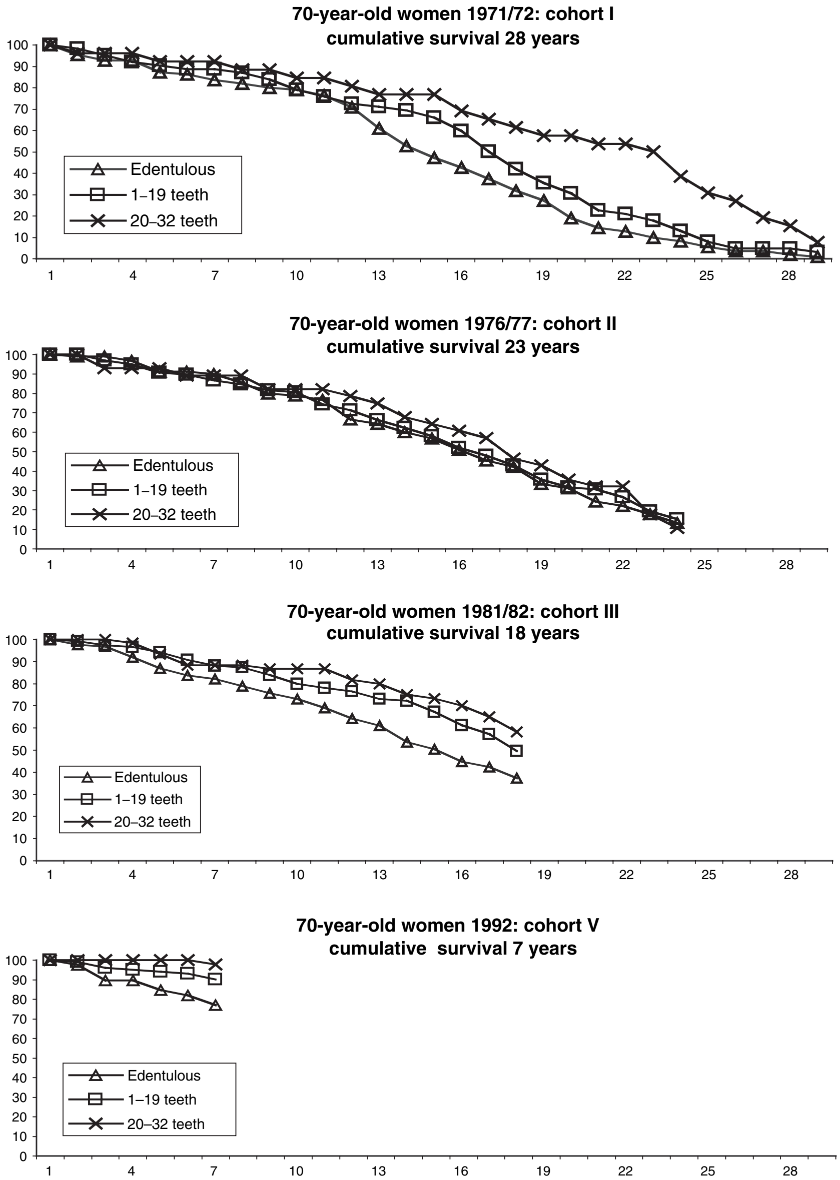

Fig. 1. Survival curves for women in four 70-year-old cohorts according to the number of teeth. The *x*-axis gives the number of years of follow-up.

The unadjusted excess mortality risk over 7 years for edentulous people compared with those with ≥20 teeth were approximately three for both women and men (70/23 and 31/11 from Table 2) with a relative risk of 2.78 (95% CI 2.0–4.0) for the total sample. Also for the 18-year mortality, the excess risk was similar for women and men (Table 3) with a relative risk of 1.61 (1.3–2.0) for the total sample.

Among the nonresponders in cohort V (n = 183), there was a lower 7-year mortality probability (relative risk 0.82 in both genders) in those reporting only natural teeth compared with edentulous and partially edentulous subjects with removable dentures. This association, although statistically not significant, was comparable with the result of the main analysis, showing comparable association for corresponding categories (RR 0.50 for women and 0.53 for men).

The interaction of the number of teeth and birth year on mortality was significant (P = 0.01), showing a trend in later cohorts against higher mortality among edentulous and a lower mortality among dentate subjects.

Associations between the number of teeth and 7- and 18-year mortalities were highly significant for both women and men according to the total cohort-adjusted data (Table 4). Hazard ratios from Cox models for the 7-year period were 0.96 in both women and men, and for the 18-year period 0.98 in women and 0.97 in men. The association became stronger in the later cohorts; in cohort V, the hazard ratios

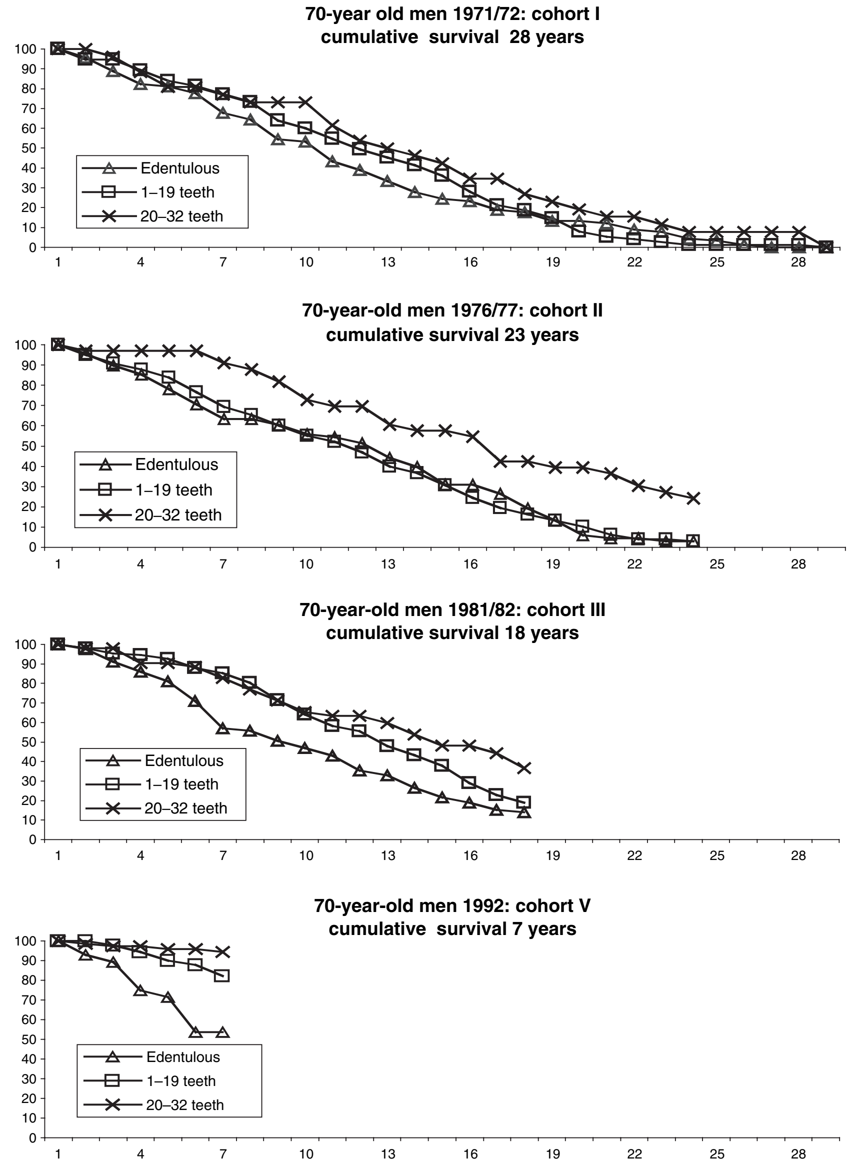

Fig. 2. Survival curves for men in four 70-year-old cohorts according to the number of teeth. The *x*-axis gives the number of years of follow-up.

Table 4. Associations between the number of teeth at baseline and mortality during 7 and 18 years in cohorts of 70-year-old subjects

	7-year mortality		18-year mortality	
Cohort	Women (n = 949)	Men (n = 854)	Women (n = 717)	Men (n = 664)
I	0.96 (0.91–1.01) NS	0.98 (0.95–1.01) NS	0.97 (0.95–0.99)**	0.98 (0.96–1.00)*
II	1.00 (0.96–1.04) NS	0.96 (0.92–0.99)**	1.00 (0.98–1.02) NS	0.98 (0.96–0.99)*
III	0.98 (0.95–1.01) NS	0.96 (0.92–0.98)***	0.98 (0.96–0.99)**	0.96 (0.95–0.98)***
V	0.92 (0.88–0.96)***	0.94 (0.91–0.97)***		
Cohort-adjusted				
Total	0.96 (0.94–0.98)***	0.96 (0.94–0.97)***	0.98 (0.97–0.99)**	0.97 (0.96–0.98)***

Hazard ratio (95% CI) according to univariate Cox regression models. ***$P < 0.001$; **$0.001 < P < 0.01$; *$0.01 < P < 0.05$; NS, not significant, $P > 0.05$.

for 7-year mortality were 0.92 in women and 0.94 in men.

The 7-year prospective mortality for cardiovascular cause showed the same relation to the number of teeth as the total mortality, a 4% lower relative risk per remaining tooth at age 70 ($P < 0.001$), and the corresponding figure for cancer mortality was 3% ($P < 0.01$).

Association between mortality and the number of teeth and covariates

Prevalence of concomitant disorders and conditions at age 70 is presented in Table 5 together with univariate associations with cohort-adjusted 7-year mortality. A lifestyle factor as physical inactivity was a significant predictor in both genders. Smokers in both genders and previous smokers among women had significantly higher 7-year mortality compared with nonsmokers. The corresponding associations between smoking and 18-year mortality were highly significant in both genders. Diabetes, ischemic heart disease, feeling not healthy, number of drugs, higher serum triglycerides and higher plasma glucose were other significant factors for 7-year mortality in both genders (Table 5).

According to the multiple Cox regression model, the number of teeth and ischemic heart disease were significant predictors of mortality over 7 years in both genders, but other factors differed between men and women (Table 6). In women, lower BMI, higher level of plasma glucose, and impaired self-assessed health were significant predictors, whereas in men lower blood hemoglobin and a higher level of serum triglycerides were significant. Besides these factors, social activity in both genders and drug-treated hypertension in women were predictors of 18-year mortality. However, the number of teeth was not a significant predictor in women (Table 7). Smoking was statistically significant ($P < 0.01$) only in women and in the pooled data, and previous smoking was only significant in the pooled data. If a lower statistical level ($P < 0.05$) was chosen, smoking was significant for 7-year mortality, and previous smoking for 18-year mortality in women.

Tests of interaction between sex and all other predictors of mortality were performed for both uni- and multi-variable models. None of the tests reached 5% significance.

After adjusting for the most important covariates under investigation in the present study, the main result is that the number of teeth still is an important predictor of mortality. These results are

Table 5. Prevalence in % (Prev) and mean (SD) of baseline characteristics at age 70 of the study group: 898 women and 820 men

	Women		Men	
Predictors	Prev/mean	HR	Prev/mean	HR
Socio-economic				
Not married	49	1.20 (0.84–1.71) NS	25	1.41 (1.07–1.87)*
Elementary school	77	1.04 (0.67–1.62) NS	75	1.13 (0.82–1.57) NS
Lifestyle				
Smoking versus nonsmoking	15	1.84 (1.19–2.85)**	32	1.44 (1.02–2.05)*
Previous smoking versus nonsmoking	14	1.89 (1.20–2.97)**	42	1.24 (0.88–1.75) NS
Physical inactivity	23	1.48 (1.00–2.18)*	15	2.03 (1.49–2.77)***
Antropometry				
Body height (cm)	161 (5.8)	0.98 (0.95–1.01) NS	174 (6.4)	0.99 (0.97–1.01) NS
Waist circumference (cm)	87 (11.5)	0.99 (0.97–1.01) NS	93 (10.5)	1.01 (0.99–1.02) NS
Low BMI	1.38 (0.67)	1.42 (1.13–1.78)**	1.37 (0.67)	1.14 (0.95–1.38) NS
High BMI	1.36 (0.67)	0.95 (0.73–1.24) NS	1.29 (0.59)	1.10 (0.89–1.36) NS
Diseases, disabilities				
Diabetes	6	3.01 (1.80–5.02)***	9	1.77 (1.21–2.58)**
Ischemic heart disease	22	2.17 (1.49–3.15)***	30	1.77 (1.36–2.31)***
Cladiucatio intermittens	6	1.78 (0.98–3.24) NS	8	1.52 (1.01–2.31)*
Chronic bronchitis	8	1.29 (0.72–2.31) NS	16	1.43 (1.03–1.98)*
History of cancer	10	1.24 (0.71–2.19) NS	7	1.66 (1.06–2.61)*
Number of drugs	2.4 (2.1)	1.17 (1.08–1.27)***	1.9 (2.0)	1.16 (1.09–1.23)***
Antihypertensive drug	29	1.49 (1.03–2.14)*	19	1.25 (0.91–1.72) NS
Feeling not healthy	30	1.79 (1.25–2.58)**	27	1.39 (1.06–1.84)*
Blood analyses				
Serum cholesterol (1 SD)[a]	6.4 (1.2)	0.91 (0.75–1.10) NS	5.7 (1.2)	0.89 (0.77–1.04) NS
Serum triglycerides (1 SD)[a]	1.5 (0.7)	1.31 (1.12–1.53)***	1.5 (0.8)	1.21 (1.09–1.34)***
Blood hemoglobin (1 SD)[a]	138 (10.6)	1.02 (0.81–1.29) NS	149 (13.2)	0.87 (0.76–0.99)*
Plasma glucose (1 SD)[a]	5.1 (1.5)	1.35 (1.20–1.52)***	5.4 (1.8)	1.17 (1.07–1.27)***

Hazard ratio, HR (95% CI) for 7-year mortality adjusted for cohort in a univariate Cox regression model. ***$P < 0.001$; **$0.001 < P < 0.01$; *$0.01 < P < 0.05$; NS, not significant, $P > 0.05$.
[a]The hazard ratios were calculated per 1 SD increase.

Table 6. Significant ($P < 0.01$) predictors of 7-year mortality in four cohorts of 70-year-old subjects

Predictors	Women (n = 905)	Men (n = 826)	Total (n = 1731)
Gender (male = 1, female = 0)			2.45 (1.92–3.12)***
Low BMI	1.48 (1.17–1,88)***		1.30 (1.12–1.52)***
Ischemic heart disease	1.91 (1.29–2.83)**	1.47 (1.11–1.96)**	1.52 (1.20–1.93)***
Number of drugs			1.08 (1.02–1.13)**
Plasma glucose (1 SD)[a]	1.26 (1.12–1.41)***		1.15 (1.06–1.26)**
Blood hemoglobin (1 SD)[a]		0.83 (0.73–0.95)**	
Serum triglycerides (1 SD)[a]		1.23 (1.08–1.40)**	1.20 (1.08–1.33)**
Feeling not healthy	1.66 (1.14–2.41)**		
Number of teeth	0.97 (0.95–0.99)**	0.96 (0.95–0.98)***	0.97 (0.95–0.98)***

Hazard ratio (95% CI) cohort adjusted according to the multiple Cox regression model. Selection of predictors with backward selection. ***$P < 0.001$; **$0.001 < P < 0.01$.
[a]The hazard ratios were calculated per 1 SD increase.

Table 7. Significant ($P < 0.01$) predictors of 18-year mortality in three cohorts of 70-year-old subjects

Predictors	Women (n = 661)	Men (n = 607)	Total (n = 1268)
Gender (male = 1, female = 0)			1.98 (1.67–2.36)***
Ischemic heart disease		1.50 (1.24–1.82)***	1.37 (1.18–1.59)***
Number of drugs		1.07 (1.03–1.12)**	
Drug treated hypertension	1.35 (1.10–1.67)**		
Plasma glucose (1 SD)[a]	1.27 (1.16–1.39)***		1.16 (1.08–1.23)***
Blood hemoglobin (1 SD)[a]		0.86 (0.78–0.95)**	
Smoking	1.54 (1.16–2.03)**		1.33 (1.11–1.60)**
Previous smoking			1.30 (1.08–1.55)**
Social activity	0.80 (0.73–0.88)***	0.88 (0.82–0.95)***	0.85 (0.80–0.90)***
Number of teeth		0.98 (0.97–0.99)**	0.99 (0.98–0.99)**

Hazard ratio (95% CI) cohort adjusted according to multiple Cox regression model. Selection of predictors with backward selection. ***$P < 0.001$; **$0.001 < P < 0.01$.
[a]The hazard ratios were calculated per 1 SD increase.

illustrated in Tables 2 and 3, where the unadjusted relative risks for the number of teeth categories are not markedly different from the covariate-adjusted hazard ratios. The estimated effect of one additional remaining tooth on mortality is somewhat lower in the covariate-adjusted model, but still shows an important independent effect in the total and gender-stratified samples and in both follow-up periods, except for the 18-year follow-up of women (Tables 4, 6 and 7).

Discussion

The results of this study showed that there was a significant association between the number of teeth and mortality independent of other common risk factors. The mortality risk over 7 years was almost three times greater for edentulous people compared with those with ≥20 teeth in both genders. A similar result, hazard ratio of 2.6, has been reported for the 10-year mortality in 80-year old edentulous subjects (5). In the present study, it was higher also over 18 years but to a smaller extent (Tables 2 and 3).

In the multiple Cox regression model for the 18-year follow-up, the significance of the number of teeth was lost for women (Table 7), although the univariate model demonstrated significant associations for both genders (Table 4).

The survival rate was higher with a greater number of remaining teeth at age 70 during the whole observation period. The mortality risk decreased by 4% during the first 7 years of follow-up for each remaining tooth at age 70, which supported the hypothesis set up. In cohort V, the effect was even stronger, 8% in women and 6% in men per each remaining tooth. The hazard ratio for the 18-year mortality had a somewhat lower value (2–3% in the cohort-adjusted data; Table 4). The total 7-year mortality risk decreased with 2% per later birth year, which is a reflection of a general decreasing mortality among elderly people in Sweden from 1970 onwards. The increasing life expectancy is nowadays mostly due to a decreasing mortality in elderly people (28). However, it was also found that in spite of a generally increased survival rate, edentulism is an increasing risk indicator of mortality, particularly in men

(Fig. 2). Thus, the survival rate in 70-year-old men born in 1922 was only 53% in edentulous subjects compared with 93% in those with ≥20 teeth. An explanation may be that when dental health is in general improving, edentulousness tends to be found more often in a select group of people with negative lifestyle, weak social network, and poor health, risk factors known to be associated with premature death. This has been indicated in previous studies of 70- and 75-year-old subjects (1, 20, 27, 29–31).

The explanations in earlier reports on a relationship between oral health and mortality have in general focused on associations between poor dental health and impairment of nutrition, limitations of functional capacities, smoking, and other lifestyle factors, which are known predictors of mortality (1–5). The associations found between edentulism and mortality in an Icelandic study (12) was dependent on smoking. They therefore concluded that the odontologic factors tested were not independent risk factors but surrogate markers for the risk from smoking. A study of a Chinese population sample found that the relationship between tooth loss and increased mortality was not limited to smokers (6). In the present study, the number of teeth was significantly associated with mortality independent of other common risk factors, including smoking. Smoking was in this study coded as two contrast factors comparing current and previous smokers versus nonsmokers. In the univariate analysis, current smoking was a significant predictor for the 7- and 18-year mortalities in both genders. However, in the multiple variable analyses, smoking was not an independent, significant ($P < 0.01$) factor for the 7-year mortality, and only in women for the 18-year mortality. The explanation may partly be due to selective survival up to 70 years of age, but may also be caused by multicollinearity between smoking and other covariates, for example the relation between low BMI and smoking and between general health status and smoking (26, 32). Also when the amount of tobacco used at age 70 was employed in the analyses, the results were the same: significant in women but not in men.

Disease and risk factors such as high levels of blood glucose and serum triglycerides have earlier been shown to be independent risk factors for mortality in our and other studies (24, 33). In the studied cohorts, low bone mineral density was shown to be an independent risk factor for mortality (relative risk 1.39, CI 1.25–1.56) in both genders indicating that functional parameters among elderly can be related to survival (24). The association between low bone density and increased mortality in women has been demonstrated earlier (34). Studies have also shown that impaired dental health/lower number of teeth was significantly associated with lower bone mass, lung volume, muscle strength, cognition, vision and hearing, as well as lower self-assessed health (1, 31). This is in line with results indicating that reduced grip strength is a single marker for frailty (35).

Data from this study and earlier presentations from our cohort studies indicate that the number of teeth is a robust predictor of general health, functional capacity, and a factor strongly associated with lifestyle factors such as smoking and physical inactivity (1, 20, 27, 30, 31). However, in the present study, the association between mortality and the number of teeth was to a large extent independent of established risk factors for mortality. These findings warrant further emphasis on preventive and conservative treatment, from childhood to adulthood, to help people to retain their teeth until the old age. Today, it is possible to give edentulous subjects a 'third dentition' by means of dental implants. It is not known if replacement of lost teeth with implants can reduce mortality the following years. However, implant treatment has been shown to improve the quality of life (36).

The causality of the independent association between the number of teeth and survival is obscure but might to some degree be dependent upon genetic or environmental factors. Studies have shown the same genetic factors for periodontal and cardiovascular disease (37).

In several studies, poor dental health and periodontal disease was found to be associated with increased mortality in cardiovascular disease (4, 8, 9, 37–39). However, in another study the association between oral health (including caries and periodontal status) and death in cardiovascular disease was reduced to statistical nonsignificance when adjustment for confounding factors was performed (40). It has also been suggested that the link between periodontal disease and CHD is weak (13, 14).

Of further interest in this context is the possible relationship between tooth loss, diet and cardiovascular disease. An extensive study in US women demonstrated that women with fewer teeth have less healthy diets, which could increase the risk of cardiovascular disease (41). This might be taken as an indirect support for an association between the number of teeth and mortality as death in cardiovascular disease is common. Indeed, after 70 years of age, death from cardiovascular disease is the predominant cause of death followed by cancer disease.

During recent years, studies have demonstrated a strong relationship between inflammation markers and cardiovascular events (42). Periodontal disease is a major cause of tooth loss in elderly and is also related to long-standing inflammation, which can contribute to an increased risk of cardiovascular disease (9). Tobacco smoking is a causative risk factor for tooth loss but also for cardiovascular disease, cancer, and pulmonary disease, which contribute to the relation between the number of teeth and mortality. Our data showed that the correlation between remaining teeth and death in cardiovascular disease is almost at the same level as mortality in noncardiovascular causes. However, most elderly have several diseases at the time of death and there is a risk that certain diseases might be under-reported, which needs further investigation.

The cohort participation rate decreased substantially with time, and was 62% in the last cohort. The increasing unwillingness to participate in investigations is a trend observed lately in Scandinavia (43). This suggests that the conclusions should be interpreted with some caution. However, the only marked difference between participants and nonparticipants was prevalence of edentulism indicating that the variation in participation rate might have merely a minor influence on the results. Furthermore, an analysis of the nonresponders in cohort V showed that those reporting only natural teeth had an 18% higher 7-year survival rate than edentulous and partially edentulous subjects with removable dentures, thus also in line with the main results of the study.

Conclusions

- The results showed that each remaining tooth at age 70 decreased the mortality risk by 4% over 7 years and 2–3% over 18 years.
- The interaction of the number of teeth and birth year on mortality showed a trend against higher mortality among edentulous and a lower mortality among dentate subjects in later cohorts.
- The number of teeth was a significant predictor of mortality independent of health factors, socio-economic status and lifestyle. This was demonstrated in both genders for 7-year mortality but only in men for 18-year mortality.

Acknowledgments

The gerontological and geriatric population studies in Göteborg (H70) were supported by grants from the Ministry of Health and Social Welfare, Commission for Social Research, the Swedish Council for Planning and Coordination of Research, the Royal Society of Arts and Sciences in Göteborg, the Vilhelm and Martina Lundgren Foundation, the Swedish Medical Research Council, and the Dr Felix Neubergh Foundation. This part of the study was supported by grants from the Hjalmar Svenssons Foundation and the Public Dental Service, Göteborg.

References

1. Österberg T, Mellström D, Sundh V. Dental health and functional ageing. A study of 70-year-old people. Community Dent Oral Epidemiol 1990;18:313–8.
2. Appollonio I, Carabellese C, Frattola A, Trabucchi M. Dental status, quality of life and mortality in an older community population: a multivariate approach. J Am Geriatr Soc 1997;45:1315–23.
3. Shimazaki Y, Soh I, Saito T, Yamashita Y, Koya T, Miqazaki H et al. Influence of dentition status on physical disability, mental impairment and mortality in institutionalized elderly people. J Dent Res 2001; 80:340–5.
4. Jansson L, Lavstedt S, Frithiof L. Relationship between oral health and mortality rate. J Clin Periodontol 2002;29:1029–34.
5. Hämäläinen P, Meurman JH, Keskinen M, Heikkinen E. Relationship between dental health and 10-year mortality in a cohort of community-dwelling elderly people. Eur J Oral Sci 2003;111:291–6.
6. Abnet CC, Qiao YL, Dawsey SM, Dong ZW, Taylor PR, Mark SD. Tooth loss is associated with increased risk of total death and death from upper gastrointestinal cancer, heart disease, and stroke in a Chinese population-based cohort. Int J Epidemiol 2005;34: 467–74.
7. Cabrera C, Hakeberg M, Ahlqwist M, Wedel H, Bjorkelund C, Bengtsson C et al. Can the relation between tooth loss and chronic disease be explained by socio-economic status? A 24-year follow-up from the population study of women in Gothenburg, Sweden Eur J Epidemiol 2005;20:229–36.
8. Jansson L, Lavstedt S, Frithiof L, Theobald H. Relationship between oral health and mortality in cardiovascular diseases. J Clin Periodontol 2001;28: 762–8.
9. Ajwani S, Mattila KJ, Narhi TO, Tilvis RS, Ainamo A. Oral health status, c-reactive protein and mortality – a 10 year follow-up study. Gerodontology 2003;20: 32–40.

10. Joshipura KJ, Hung HC, Rimm EB, Willett WC, Ascherio A. Periodontal disease, tooth loss, and incidence of ischemic stroke. Stroke 2003;34: 47–52.
11. Hung HC, Joshipura KJ, Colditz G, Manson JE, Rimm EB, Speizer FE et al. The association between tooth loss and coronary heart disease in men and women. J Public Health Dent 2004;64:209–15.
12. Ragnarsson E, Eliasson ST, Gudnason V. Loss of teeth and coronary heart disease. Int J Prosthodont 2004;17:441–6.
13. Hujoel PP. Does chronic periodontitis cause coronary heart disease? A review of the literature J Am Dent Assoc 2002;133(Suppl.):31S–6S.
14. Hujoel PP, Drangsholt M, Spiekerman C, Derouen TA. Examining the link between coronary heart disease and the elimination of chronic dental infections. J Am Dent Assoc 2001;132:883–9.
15. Khader YS, Albashairch ZS, Alomari MA. Periodontal diseases and the risk of coronary heart and cerebrovascular diseases: a meta-analysis. J Periodontol 2004;75:1046–53.
16. Meurman JH, Sanz M, Janker S. Oral health, arteriosclerosis, and cardiovascular disease. Crit Rev Oral Biol Med 2004;15:403–13.
17. Joshipura K, Ritchie C, Douglass C. Strength of evidence linking oral conditions and systematic disease. Compend Contin Educ Dent Suppl 2000;30:12–23.
18. Hujoel PP, Cunha-Cruz J, Kressin NR. Spurious associations in oral epidemiological research: the case of dental flossing and obesity. J Clin Periodontol 2006;33:520–3.
19. Rinder L, Roupe S, Steen B, Svanborg A. 70-year-old people in Gothenburg. A population study in an industrialized Swedish city. General design of the study. Acta Med Scand 1975;198:397–407.
20. Österberg T. Odontologic studies in 70-year-old people in Göteborg, Thesis. Göteborg University, Göteborg; 1981.
21. Eriksson BG, Mellström D, Svanborg A. Medical-social intervention in a 70-year-old Swedish population. A general presentation of methodological experience. Compr Gerontol 1987;1:49–56.
22. Steen B, Djurfelt H. The gerontological and geriatric population studies in Gothenburg, Sweden. Z Gerontol 1993;26:163–9.
23. Steen B. The elderly yesterday, today and tomorrow. Aspects on cohort differences from the Gerontological and geriatric population studies in Göteborg, Sweden (H70). Arch Gerontol Geriatr 2002;8(Suppl.): 359–70.
24. Johansson C, Black D, Johnell O, Odén A, Mellström D. Bone mineral density is a predictor of survival. Calcif Tissue Int 1998;63:190–6.
25. Ljungquist B, Berg S, Steen B. Prediction of survival in 70-year olds. Arch Gerontol Geriatr 1995;20:295–307.
26. Wilhelmson K, Allebeck P, Steen B. Improved health among 70-year olds: Comparison of health indicators in three different birth cohorts. Aging Clin Exp Res 2002;14:362–70.
27. Österberg T, Johanson C, Sundh V, Steen B, Birkhed D. Secular trends of dental status in five 70-year-old cohorts between 1971 and 2001. Community Dent Oral Epidemiol 2006;34:446–54.
28. Statistics Sweden. Population projection for Sweden 2002–2050. Stockholm: Statistics Sweden; 2002. BE 18 SM 0201.
29. Johansson C, Mellström D, Lerner U, Österberg T. Coffee drinking: a minor risk factor for bone loss and fracture. Age Ageing 1992;21:20–6.
30. Österberg T, Mellström D. Tobacco smoking: a major risk factor for loss of teeth in three 70-year old cohorts. Community Dent Oral Epidemiol 1986;14:367–70.
31. Österberg T, Era P, Gause-Nilsson I, Steen B. Dental state and functional capacity in 75-year-olds in three Nordic localities. J Oral Rehabil 1995;22:653–60.
32. Dey DK, Rothenberg E, Sundh V, Bosaeus I, Steen B. Height and body weight in elderly adults: a 21-year population study on secular trends and related factors in 70-year-olds. J Gerontol A Biol Sci Med Sci 2001;56:M780–4.
33. Port SC, Boyle NG, Hsueh WA, Quinones MJ, Jennrich RI, Goodarzi MO. The predictive role of blood glucose for mortality in subjects with cardiovascular disease. Am J Epidemiol 2006;163:342–51.
34. Browner WS, Seeley DG, Vogt TM, Cummings SR. Non-trauma mortality in elderly women with low bone mineral density. Study of Osteoporotic Fractures Research Group. Lancet 1991;338:355–8.
35. Syddall H, Cooper C, Martin F, Briggs R, Aihie Sayer A. Is grip strength a useful single marker of frailty? Age Ageing 2003;32:650–6.
36. Heydecke G, Locker D, Awad MA, Lund JP, Feine JS. Oral and general health-related quality of life with conventional and implant dentures. Community Dent Oral Epidemiol 2003;31:161–8.
37. Kornman KS, Duff GW. Candidate genes as potential links between periodontal and cardiovascular diseases. Ann Periodontol 2001;6:48–57.
38. Morrison HI, Ellison LF, Taylor GW. Periodontal disease and risk of fatal coronary heart and cerebrovascular diseases. J Cardiovasc Risk 1999;6:7–11.
39. Ajwani S, Mattila KJ, Tilvis RS, Ainamo A. Periodontal disease and mortality in an aged population. Spec Care Dentist 2003;23:125–30.
40. Tuominen R, Reunanen A, Paunio M, Paunio I, Aromaa A. Oral health indicators poorly predict coronary heart disease deaths. J Dent Res 2003;82:713–8.
41. Hung H, Colditz G, Joshipura K. The association between tooth loss and the self-reported intake of selected CVD-related nutrients and foods among US women. Community Dent Oral Epidemiol 2005;33:167–73.
42. Willerson JT, Ridker PM. Inflammation as a cardiovascular risk factor. Circulation 2004;109(21 Suppl. 1): II2–10.
43. Johansson A, Unell L, Carlsson GE, Söderfeldt B, Halling A. Gender differences in symptoms related to temporomandibular disorders in a population of 50-year-old subjects. J Orofac Pain 2003;17:29–35.