

Mortality rate and oral health – a cohort study over 44 years in the county of Stockholm

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ABSTRACT

Objective: To study the association between oral health and all-cause mortality rate over 44 years. In addition, the specific relations between oral health and death caused by cardiovascular disease (CVD), cancer or other reasons were investigated.

Materials and Methods: An epidemiological investigation studying the oral health of the population consisting of 1393 randomly selected subjects was performed in the County of Stockholm. The individuals were invited to a clinical examination, an interview and a radiographic examination. The incidence of mortality during the years 1970–2014 as well as the causes of death according to the death certificate were registered in 2015. Cox regression survival analysis was used for investigating the effect of several variables upon the time to the outcome of death.

Results: Forty-six percent of the subjects were still alive at the end of the year 2014. Cancers caused 27% of the deaths, while 22% died due to CVD. The mortality risk was positively and significantly correlated to oral health when compensated for age, sex, smoking and social status. In addition, the mortality risk caused by CVD, cancer or other reasons was significantly increased for those with poor oral health.

Conclusions: Oral health was found to be a risk indicator of death caused by CVD and cancer as well as for all-cause mortality. Thus, the associations are unspecific. Harmful lifestyle factors impact dental health behavior as well as mortality risk. This might contribute to the association between oral health and mortality risk.

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Introduction

In recent years, the association between oral health and general health has been investigated in many epidemiological as well as clinical studies. The significant and positive correlation between diabetes and periodontal disease has been demonstrated and the scientific evidence is strong for this association [1]. Several studies have reported significant associations between periodontal disease and cardiovascular disease (CVD) [2]. A recently published longitudinal study found a significantly increased risk of future CVD for poor responders to periodontal treatment [3]. In addition, periodontal disease increases the risk of a first myocardial infarction according to a report from the PAROKRANK study [4]. Meta-analyses have reported significantly increased risk ratios for CVD and stroke for individuals with periodontitis [5]. The longitudinal studies indicate but do not prove that a causal relationship between periodontitis and CVD may exist. Cross-sectional studies indicate a significant association between periodontal disease and chronic obstructive pulmonary disease [6,7] and cohort studies have demonstrated that poor oral hygiene and periodontitis appear to be correlated to nosocomial pneumonia [6]. In addition, increasing evidence

indicates that several conditions are significantly associated to periodontitis such as rheumatoid diseases [8], osteoporosis [9], Parkinson's disease [10] and Alzheimer's disease [11]. Low-grade inflammation has been presented as one possible causal pathway between oral health and several systemic diseases [12].

Cardiovascular diseases, respiratory diseases and cancers are common causes of death in Sweden [13] as well as in other high-income countries [14]. Consequently, knowledge concerning the impact of oral health on mortality caused by these frequent diseases is of major importance. Cohort studies during the last decades predict an increased mortality risk caused by cardiovascular diseases [15–19], pneumonia [19–22] and cancers [17,23–27] for individuals with poor oral health. In addition, the association between oral status and all-cause mortality has been studied in several studies. Oral status has been found to have a significant effect on all-cause mortality in cohorts in Europe [28–30] and in the United States [31]. However, the results are not consistent and no significant association between periodontitis and all-cause mortality was found in a cohort including individuals aged 75+ years [16]. Furthermore, the relationship between oral health indicators and death caused by CVD was not significant in a 12-year follow-up study in Finland [32].

The relationship between oral status and general health may be stronger for older people. In addition, the oral health has been found to have a significant impact on quality of life [33]. Consequently, a growing number of older individuals in the population in the future emphasizes the need for deeper knowledge concerning the significance of oral health for a high quality of life.

The association between oral health and death caused by CVD as well as all-cause mortality rate over 26 years has been studied on a sample from the County of Stockholm in two earlier studies [15,29]. The main purpose of the present investigation was to follow-up the mortality rate over 44 years on the same cohort including more oral variables and potential confounders than in the earlier studies. Furthermore, the specific relations between oral health and death caused by CVD, cancer or other reasons were investigated.

Materials and methods

An epidemiological study investigating the oral health of the population consisting of 1393 randomly selected individuals aged 18–66 years was done during the years 1970–1971 in the County of Stockholm [34]. The individuals were invited to a clinical examination, an interview and a radiographic examination for 88% of the sample consisting of a full-mouth intraoral investigation including 18 radiographs in fully dentate persons.

At baseline in 1970 anamnestic, clinical and radiographic variables were registered [34]. Marginal bone loss (MBL) was measured mesially and distally at all (buccal wherever applicable) roots in percent (10 percent scale) of the distance apex-cementoenamel junction with a modified ruler [34]. If this ratio was less than 10 percent, then it was given the value 1. In the 10–20 percent interval, it was given the value 2, and so forth. The MBL index was defined as the mean of the MBL values at all measurable points in an individual.

Oral health score was defined as a score variable consisting of the sum of six quotients: (Number of lost teeth/maximum value) + (Marginal bone loss/maximum value) + (Russell's index/maximum value) + (Number of teeth with caries/maximum value) + (Number of teeth with apical lesions/maximum value) + (Plaque index/maximum value). Consequently, the range of each quotient is (0–1) and the calculated value of the score variable for the individuals of the sample is found in the interval (0–6).

The incidence of mortality during the years 1970–2014 as well as the causes of death according to the death certificate were registered in 2015 (outcome variable). These data were available in registers kept at the Swedish National Board of Health and Welfare. The International Statistical Classification of Diseases and related health problems (ICD-8, ICD-9 or ICD-10) was used to code cause of death. The causes of death were divided into three groups: CVD, cancer or other reason.

The study has been conducted in full accordance with the World Medical Association of Helsinki and was approved by the Regional Ethics Board in Stockholm (2015/541-31/1).

Table 1. Frequency distribution of the individuals according to gender and causes of death ($n = 1393$).

Sex	Cause of death			Alive <i>n</i>	Total <i>n</i>
	Cardiovascular diseases <i>N</i>	Cancers <i>n</i>	Other causes <i>n</i>		
Males	101	104	188	294	687
Females	63	100	196	347	706
Total	164	204	384	641	1393

The study followed the 'strengthening the reporting of observational studies in epidemiology' [35].

Statistical analysis

Descriptive statistics and statistical analyses were performed with a computer statistical package (IBM SPSS 21.0, SPSS Inc., Chicago, IL, USA). Pearson's correlation coefficient was calculated in order to examine the correlations between the independent variables. Cox regression survival analysis was used for investigating the effect of several variables upon the time to the outcome of death. Results were considered statistically significant at $p < .05$.

Results

The frequency distribution of the individuals according to gender and causes of death are presented in Table 1. Forty-six percent of the subjects were still alive at the end of the year 2014. Cancers caused 27% of the deaths, while 22% died due to CVD. The mortality rate was highest for males.

The distributions according to reason of death for age groups as well as means (standard deviation) for the dental variables and smoking at baseline for individuals alive or having died during the years 1970–2014 are presented in Table 2. Seventy-eight per cent of the subjects at age 18–30 yrs in 1970 were still alive at the end of the year 2014, while 28% were still alive in the age group 41–50 years.

The mean oral health score was higher for males within all social groups and was found to be highest for social group 3 (1.63), while the lowest mean value was calculated for social group 1 (1.34, Table 3). The oral health score was higher for older age groups and the mean score value was lowest for those individuals still alive within all age groups (Figure 1).

A high degree of multi-collinearity was found between all the six oral variables included in the oral health score (Figure 2). Three of those variables (the number of lost teeth, the percentage of tooth surfaces with caries and Plaque index) were significantly correlated to an increased all-cause mortality risk, while a tendency ($p = .054$) was found for marginal bone loss when adjusted for age, sex, social group and smoking (Table 4). One of the oral variables (number of lost teeth) was significantly correlated to mortality risk caused by CVD (odds ratio 1.04, $p < .001$), while mortality risk caused by cancer was significantly associated to four oral variables (MBL (odds ratio 1.37, $p = .001$), number of lost teeth (odds ratio 1.04, $p < .001$), the percentage of teeth with apical

Table 2. Mean (standard deviation) for the odontological variables and smoking for individuals alive or having died during the years 1970–2014 and at age 18–66 yrs in 1970.

Age	N	Alive or cause of death	Relative frequency of smokers	Number of remaining teeth	Number of surfaces with restorations	Marginal bone loss index	Number of apical lesions	Number of surfaces with caries	Plaque index	Russell's periodontal index
18–30	406	Alive	0.57 (0.50)	27.7 (3.95)	36.8 (20.7)	1.15 (0.21)	0.69 (1.43)	6.60 (7.41)	1.3 (0.64)	1.31 (1.06)
		Cardiovascular disease	0.57 (0.51)	23.4 (7.25)	35.3 (21.2)	1.36 (0.47)	1.50 (1.88)	9.00 (6.21)	1.8 (0.70)	2.21 (1.20)
		Cancers	0.55 (0.50)	27.0 (5.81)	36.3 (20.2)	1.24 (0.36)	0.67 (1.41)	6.80 (7.94)	1.4 (0.65)	1.74 (1.38)
31–40	155	Other causes	0.68 (0.47)	26.8 (4.54)	35.4 (23.7)	1.21 (0.24)	0.65 (1.36)	8.77 (8.78)	1.5 (0.75)	1.47 (0.83)
		Alive	0.41 (0.49)	25.8 (4.63)	48.5 (22.8)	1.53 (0.52)	1.42 (1.97)	6.15 (8.17)	1.4 (0.69)	2.32 (1.61)
		Cardiovascular disease	0.67 (0.48)	19.6 (11.1)	35.4 (22.3)	1.74 (0.76)	1.67 (2.11)	4.06 (2.64)	1.5 (0.66)	2.46 (1.72)
41–50	72	Cancers	0.70 (0.46)	20.5 (9.21)	43.1 (23.3)	1.94 (0.77)	1.62 (2.34)	8.31 (10.3)	1.5 (0.74)	2.79 (1.74)
		Other causes	0.62 (0.49)	20.5 (9.47)	33.7 (23.4)	1.79 (0.53)	1.05 (1.82)	6.67 (5.61)	1.7 (0.72)	2.85 (1.80)
		Alive	0.34 (0.48)	24.7 (4.81)	51.6 (19.6)	1.91 (0.73)	1.30 (1.72)	4.51 (3.67)	1.4 (0.63)	2.72 (1.49)
51–66	92	Cardiovascular disease	0.48 (0.51)	18.4 (8.11)	39.5 (26.0)	2.17 (0.84)	1.49 (1.82)	7.15 (5.11)	1.9 (0.58)	3.45 (1.69)
		Cancers	0.52 (0.50)	19.2 (7.73)	40.7 (25.4)	2.23 (0.91)	1.62 (1.93)	5.80 (6.61)	1.9 (0.68)	3.29 (1.67)
		Other causes	0.52 (0.50)	19.9 (8.42)	45.1 (22.4)	2.08 (0.83)	1.35 (2.03)	6.75 (5.31)	1.7 (0.67)	2.98 (1.62)
18–66	181	Alive	0.00 (-)	14.5 (12.4)	15.0 (29.4)	1.60 (1.33)	2.33 (2.31)	1.50 (0.71)	1.5 (0.30)	3.71 (3.2)
		Cardiovascular disease	0.33 (0.47)	12.4 (9.8)	35.1 (21.6)	2.61 (1.19)	1.75 (2.47)	5.22 (4.01)	2.0 (0.62)	3.73 (1.70)
		Cancers	0.40 (0.49)	13.8 (11.1)	43.7 (26.2)	2.58 (1.18)	1.42 (2.07)	5.39 (3.87)	1.7 (0.74)	3.41 (1.80)
		Other causes	0.26 (0.44)	13.8 (9.86)	45.0 (26.4)	2.59 (1.17)	2.23 (2.77)	6.51 (5.61)	1.8 (0.69)	3.56 (1.8)

Table 3. Mean (standard deviations) for oral health score according to social group and sex.

Socio-economic group	Sex	N	Oral health score
1	Female	90	1.26 (0.62)
	Male	104	1.40 (0.76)
2	Female	357	1.26 (0.54)
	Male	258	1.59 (0.74)
3	Female	259	1.55 (0.64)
	Male	325	1.69 (0.70)

periodontitis (odds ratio 5.03, $p = .03$) and the percentage of tooth surfaces with caries (odds ratio 1.50, $p = .01$).

The all-cause mortality risk was positively and significantly correlated to the oral health score when compensated for age, sex, smoking and social status ($p < .001$, Table 5). In addition, the mortality risk caused by CVD, cancer or other reasons was significantly increased for those with high oral health score (Table 6).

Discussion

The main finding of the present study was that the oral health score was found to be a risk indicator of death caused by CVD, cancer as well as by all-cause mortality. In addition, the number of lost teeth, the percentage of tooth surfaces with caries and Plaque index were identified as potential risk indicators of all-cause mortality.

Two earlier studies on the same epidemiological material [15,29] have investigated the influence of oral health on the mortality risk. These studies followed up the mortality incidences for 26 yrs, while the present study followed the same sample over 44 yrs. In addition, the independent variables age, sex and social group were included in the regression models as potential confounders irrespective of their p -values. The oral health score in the earlier studies [15,29] contained the variables number of lost teeth, marginal bone loss, number of teeth with caries and number of teeth with

apical lesions. In the present study, Plaque index and Russell's index were added.

The predictor variables of the oral health score are strongly correlated to each other indicating multi-collinearity. This means that the individual predictors in the model may not give valid results, while the summary variable oral health score is a measure of the total impact on mortality risk of the oral variables after standardization of the examined variables.

In regression models, it is important to control for confounding variables. In the present study, the effects of age, sex, smoking and social group were compensated. However, lifestyle factors such as alcohol consumption and obesity were not included in the regression models. Consequently, these types of follow-up studies may not prove causal relationships but describe significant associations between variables.

The definition of periodontitis varies between studies investigating on one hand, the associations between oral health and systemic disease and on the other hand, oral health and mortality [36]. This heterogeneity in the definitions complicates the comparisons between studies and to perform valid meta-analyses.

In the present study, oral health was significantly associated to all-cause mortality. This result is in accordance with several earlier studies [28–31,37–39]. Four out of those studies [30,37–39] found a significant correlation between periodontal disease and all-cause mortality, while the others described a significantly increased all-cause mortality risk for subjects with poor oral health. However, a study involving an elderly population in Finland did not find a significant association between periodontal disease and all-cause mortality [16]. On the other hand, CVD-related mortality was significantly associated to periodontitis in that study. In contrast, another study [31] found that oral health conditions were significantly associated to all-cause mortality, while no significant correlation between periodontitis and death risk was found.

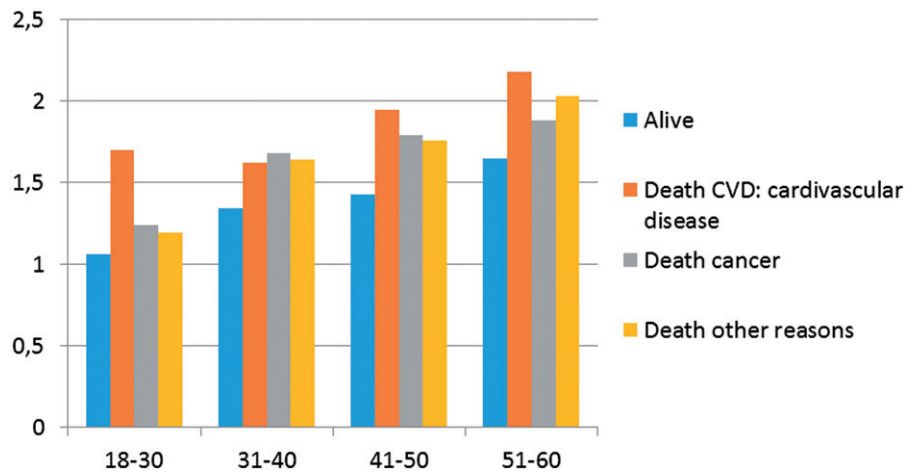


Figure 1. Oral health score according to age groups and reasons of death.

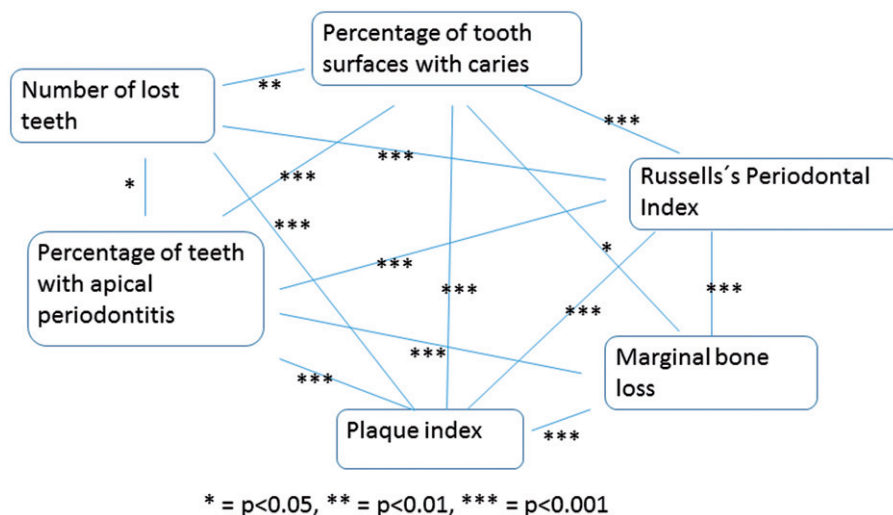


Figure 2. Correlations between the variables of the oral health score.

Consequently, the results are not consistent between the studies.

The association between oral variables, especially periodontitis, and the risk of fatal cardiovascular events have been investigated for many years. Cohort studies report significant associations between mortality caused by CVD and tooth loss [18,19,23], periodontitis [16,30,37,40] and general oral status [14]. These results are in accordance with the present study. However, the correlation between the oral variable Russell's periodontal index and CVD was not significant, while a strong tendency ($p = .054$) was found for marginal bone loss. An earlier report from Finland has shown significant associations in univariate analyses between oral health indicators and death caused by coronary heart disease [32]. However, after adjustment for known confounding factors, the associations were found to be non-significant. In a recent Swedish follow-up study [3], individuals who did not respond well to periodontal treatment had a significantly increased risk of fatal/nonfatal incidence rate of CVD.

Many studies have focused on associations between periodontal disease and CVD [2,4,5]. However, reports on the potential relationship between oral health and cancer are sparse. In the present study, four of the oral variables

(marginal bone loss, number of lost teeth, the percentage of teeth with apical periodontitis and the percentage of tooth surfaces with caries) were associated to death due to cancer. In a study of a US population, periodontitis was found to be significantly associated to an increased risk of death caused by lung cancer [41] and a recent meta-analysis supports this result [42]. However, the authors discussed whether this association is spurious due to an unmeasured aspect of the smoking history, despite the unconfounded association [41]. Tooth loss was a significant predictor of gastrointestinal cancer death [17] and esophageal/gastric cancers [23] in China as well as gastric non-cardia adenocarcinoma [25] and pancreatic cancer [24] in Finnish smokers. In a prospective cohort study of male health professionals [26], periodontal disease history was significantly associated to an increased risk of total cancer. Thus, oral conditions have been found to be associated to specific cancers as well as to total cancer risk.

Tooth loss may be caused by periodontal disease as well as by caries. Thus, it is an unspecific indicator of oral health. This might explain the fact that tooth loss was the most significant oral variable and was found to be highly significant ($p < .001$) as a risk indicator for all-cause mortality and mortality caused by cardiovascular and cancers. The number of

Table 4. Six cox regression analyses for dentate individuals using the mortality risk between the years 1970 and 2014 as the dependent variable (adjusted for age, sex, social group, and smoking) and the oral variables of the oral health score as independent variables.

Independent variable	Odds ratio (95% confidence interval)	<i>p</i>
Marginal bone loss	1.10 (1.00; 1.21)	.054
Number of lost teeth	1.03 (1.02; 1.04)	<.001
The percentage of teeth with apical periodontitis	1.32 (0.79; 2.22)	.29
The percentage of tooth surfaces with caries	1.37 (1.18; 1.58)	<.001
Russell's periodontal index	1.03 (0.98; 1.08)	.30
Plaque index	1.26 (1.10; 1.43)	.001

Table 5. Results of Cox regression analysis for dentate individuals using the mortality risk between the years 1970 and 2014 as the dependent variable. *N* = 1225.

Independent variable	Odds ratio (95 & confidence interval)	<i>p</i>
Age(years)	1.09 (1.09; 1.11)	<.001
Sex(0 = female, 1 = male)	1.36 (1.12; 1.65)	.002
Social groups:		
Social group 1	0.75 (0.56; 1.01)	.14
Social group 2	0.86 (0.70; 1.07)	.06
Social group 3	1	.17
Smoking (0 = no, 1 = yes)	1.41 (1.16; 1.71)	.001
Oral health score	1.27 (1.08; 1.49)	.004

Table 6. Cox regression analyses for dentate individuals using the mortality risk (caused by A: cardiovascular disease, B: cancer or C: other reasons) between the years 1970 and 2014 as the dependent variable (adjusted for age, sex, social group and smoking) and oral health score as independent variable.

Independent variable	Odds ratio (95 & confidence interval)	<i>p</i>
A. Death caused by cardiovascular disease <i>N</i> = 708		
Age (years)	1.17 (1.14; 1.20)	<.001
Sex (0 = female, 1 = male)	1.69 (1.08; 2.65)	.02
Social groups:		
Social group 1	0.63 (0.34; 1.20)	.19
Social group 2	0.67 (0.42; 1.07)	.16
Social group 3	1	.10
Smoking (0 = no, 1 = yes)	1.82 (1.7; 2.82)	.008
Oral health score	1.45 (1.01; 2.10)	.04
B. Death caused by cancer. <i>N</i> = 744		
Age (years)	1.13 (1.11; 1.15)	<.001
Sex(0 = female, 1 = male)	1.00 (0.69; 1.45)	.99
Social groups:		
Social group 1	0.71 (0.39; 1.29)	.32
Social group 2	0.76 (0.51; 1.12)	.26
Social group 3	1	.17
Smoking (0 = no, 1 = yes)	1.49 (1.03; 2.15)	.03
Oral health score	1.58 (1.14; 2.17)	.005
C. Death not caused by cardiovascular or cancer. <i>N</i> = 902		
Age (years)	1.11 (1.09; 1.12)	<.001
Sex(0 = female, 1 = male)	1.48 (1.13; 1.94)	.004
Social groups:		
Social group 1	0.81 (0.54; 1.22)	.54
Social group 2	0.88 (0.65; 1.18)	.31
Social group 3	1	.38
Smoking (0 = no, 1 = yes)	1.46 (1.11; 1.91)	.007
Oral health score	1.27 (1.01; 1.59)	.04

teeth has also been found to be an important factor influencing the quality of life besides age and cultural background in dentate adults from UK and Australia [43]. In a study on a Chinese population, tooth loss was significantly associated to total death and death caused by gastro-intestinal cancer, heart disease and stroke [17], while mortality data from older Japanese showed that tooth loss significantly predicted death caused by CVD disease and respiratory disease [19]. A study

on elderly community-dwelling individuals in central Finland [44] found that tooth loss increased the risk of death and a Swedish cohort with a follow-up period of 12 years revealed a dose-dependent relationship between number of missing teeth and all-cause mortality [18].

Many studies investigating the association between oral health and mortality have been performed in Western countries. The lifestyle and factors such as dietary habits and alcohol consumption might vary depending on population. This emphasizes the need for studies from different parts of the world. Poor oral health affects the quality of life in a growing elderly population [45,46]. Consequently, prevention of oral diseases such as caries and periodontitis is important to strengthen general health and improve the quality of life for older people. However, a more effective approach might be to affect risk factors common to many chronic diseases such as diet, hygiene, alcohol use, stress and smoking [47] as an unhealthy lifestyle has been found to be related to a higher prevalence of caries and periodontitis [48]. Oral diseases and general chronic diseases share many common risk factors related to lifestyle. In the studies investigating the relationship between oral health and general health, the analyses try to compensate for confounding variables. However, several unknown, common lifestyle factors might not have been taken into account in the multivariable analyses.

In conclusion, the oral health score was found to be a risk indicator of death caused by CVD and cancer as well as for all-cause mortality. Besides, the oral variables number of lost teeth, the percentage of tooth surfaces with caries and Plaque index were found to be risk indicators of all-cause mortality. Thus, the associations are unspecific. Harmful lifestyle factors impact dental health behavior as well as mortality risk. This might contribute to the association between oral health and mortality risk.

Disclosure statement

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