

Health Reports

Missing teeth, mortality, and hospitalization: A population-based cohort analysis from the Canadian Health Measures Survey and linked databases

by Xue Feng Hu, Mohammad Moharrami, Kellie Murphy and
Janine Clarke

Release date: October 15, 2025



Statistics
Canada

Statistique
Canada

Canada

How to obtain more information

For information about this product or the wide range of services and data available from Statistics Canada, visit our website, www.statcan.gc.ca.

You can also contact us by

Email at infostats@statcan.gc.ca

Telephone, from Monday to Friday, 8:30 a.m. to 4:30 p.m., at the following numbers:

- Statistical Information Service 1-800-263-1136
- National telecommunications device for the hearing impaired 1-800-363-7629
- Fax line 1-514-283-9350

Standards of service to the public

Statistics Canada is committed to serving its clients in a prompt, reliable and courteous manner. To this end, the Agency has developed standards of service which its employees observe in serving its clients. To obtain a copy of these service standards, please contact Statistics Canada toll-free at 1-800-263-1136. The service standards are also published on www.statcan.gc.ca under “Contact us” > “[Standards of service to the public](#).”

Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

Published by authority of the Minister responsible for Statistics Canada

© His Majesty the King in Right of Canada, as represented by the Minister of Industry, 2025

Use of this publication is governed by the Statistics Canada [Open Licence Agreement](#).

An [HTML version](#) is also available.

Cette publication est aussi disponible en français.

Missing teeth, mortality, and hospitalization: A population-based cohort analysis from the Canadian Health Measures Survey and linked databases

by Xue Feng Hu , Mohammad Moharrami , Kellie Murphy and Janine Clarke

DOI: <https://www.doi.org/10.25318/82-003-x202501000001-eng>

ABSTRACT

Background

The association between oral health and general health is not yet fully understood. This study examines the association between missing teeth, mortality, and hospitalization outcomes.

Data and methods

This cohort study utilized time-to-event data from the Canadian Health Measures Survey Cycle 1 (2007 to 2009) linked to death and hospital discharge records. Participants with clinically assessed tooth counts were followed up to 2019. Cox proportional hazards models were used, treating missing teeth as either categorical or continuous exposures, adjusting for socioeconomic and health-related factors.

Results

In participants aged 20 to 79 years, 3,450 records were linked to mortality data (n=300 deaths) and 2,250 to hospitalization data (n=650 with at least one hospital stay). Missing teeth were associated with elevated all-cause and cancer mortality in unadjusted models, but not after covariate adjustment. After adjusting for key risk factors, including age and sex, participants with five or more missing teeth had a 76% higher risk of all-cause hospitalization (hazard ratio [HR] 1.76, 95% confidence interval [CI]: 1.41 to 2.20) and a 120% higher risk of circulatory-related hospitalization (HR 2.20, 95% CI: 1.09 to 4.45). Respiratory hospitalizations were also linked to missing teeth. No significant links were found with hospitalizations for digestive diseases or cancer.

Interpretation

Missing teeth is associated with hospitalization in Canadian adults. These findings highlight that oral health may play a role or serve as an indicator of overall health and health service use among Canadian adults.

Keywords

missing teeth, mortality, hospitalization, survival analysis, data linkage

AUTHORS

Xue Feng Hu, Mohammad Moharrami and Janine Clarke are with the Centre for Health Data Integration and Direct Measures at Statistics Canada. Mohammad Moharrami is also with the Faculty of Dentistry at the University of Toronto. Kellie Murphy is with the Health Analysis and Modelling Division at Statistics Canada.

What is already known on this subject?

- Tooth loss has been linked to systemic conditions, including cardiovascular disease, diabetes, and certain cancers.
- International studies suggest an association between tooth loss and a higher risk of mortality and hospitalization, but results from nationally representative Canadian data have been limited.

What does this study add?

- Missing teeth was significantly associated with an increased risk of all-cause, circulatory, and respiratory hospitalizations in Canadian adults.
- After adjusting for age and other risk factors, no significant relationship was found between missing teeth and mortality.
- Future research with larger sample sizes and longer follow-up is needed to clarify the role of missing teeth in predicting mortality and hospitalization risks.

Missing teeth serves as a cumulative indicator of lifelong oral health deterioration, primarily resulting from dental caries and periodontitis, though trauma and other factors may also contribute to this outcome.^{1,2} No major differences in tooth loss have been observed between the sexes; however, research has shown a progressive increase with age.² Edentulism (complete tooth loss) is an important oral health indicator. According to a 2022 World Health Organization report, the estimated average global prevalence of complete tooth loss is approximately 7% among individuals aged 20 years and older.³ Edentulism in Canadian adults decreased from 23.6% in 1970 to 1972, to 6.4% in 2007 to 2009, and further to 4.4% in 2023 to 2024.^{4,5} The Canadian Health Measures Survey (CHMS) Cycle 1 (2007 to 2009) and the forthcoming CHMS Cycle 7 (2022 to 2024) both include a clinical oral health component, which provides detailed per-tooth clinical examinations, including assessments of decayed, missing, and filled teeth.

Mortality and hospitalization rates are key indicators of population health and disease burden. Canadian statistics reveal a gradual upward trend of crude all-cause death from population growth and aging, with cancer and heart disease being the leading causes of death.⁶ Hospitalization rates have been generally dropping in Canada in recent years.⁷ The leading cause of hospitalization in 2019 to 2020 was childbirth, followed by respiratory and circulatory conditions.⁸

Recent research underscores a strong association between untreated dental conditions leading to tooth loss and adverse nutritional status⁹ and an increased risk of chronic systemic diseases,¹⁰⁻¹² which include impairments in cognitive function,¹³ cardiovascular diseases,¹⁴⁻¹⁶ diabetes,¹⁷ and certain types of cancer.^{18,19} Missing teeth may serve as a straightforward, non-invasive marker for overall health and service utilization, e.g., mortality and hospitalization. Numerous studies based on non-Canadian data have

underscored the potential of tooth loss in pinpointing groups at a heightened risk for these adverse health events.^{14,20-25}

The CHMS data have been linked to the Canadian Vital Statistics – Death Database (CVSD), the Canadian Cancer Registry, and the Discharge Abstract Database (DAD). Participants in the oral health module of the CHMS Cycle 1 (2007 to 2009) were followed for an average of 11 years within these linked datasets. The objective of this study was to examine the time-to-event associations between missing teeth and two key outcomes: (1) all-cause and cause-specific mortality, and (2) overall and cause-specific hospitalization, using population-representative data.

Data and methods

Study design and target population

This cohort study used data from the CHMS Cycle 1 (2007 to 2009) linked to multiple years of the CVSD and the DAD. The CHMS collects key information relevant to the health of Canadians, including direct physical measurements such as blood pressure, height, weight, physical fitness, and oral health status.²⁶ The target population for the CHMS Cycle 1 was the Canadian population aged 6 to 79 years living in private households. Excluded from the survey were First Nations people living on reserves, people living on Crown lands or in certain remote regions, the institutionalized population, and full-time members of the Canadian Forces. Approximately 96% of Canadians were represented. Only participants aged 20 to 79 years who had valid oral health examinations were included in this study.

The CVSD is an administrative database that includes demographic and cause-of-death information, collected annually from all provincial and territorial vital statistics registries.²⁷ Death records were obtained from the province or

territory in which the death occurred. Eligible records for linkage were provided for the years 2005 to 2019, but were included in this analysis if the death event occurred after the CHMS interview date and before December 2019. The underlying causes of death were coded using the International Classification of Diseases, Tenth Revision (ICD-10). Linkage between the CHMS and the CVSD (CHMS-CVSD) was performed using a probabilistic matching approach (further details are provided in the user guide, available upon request).

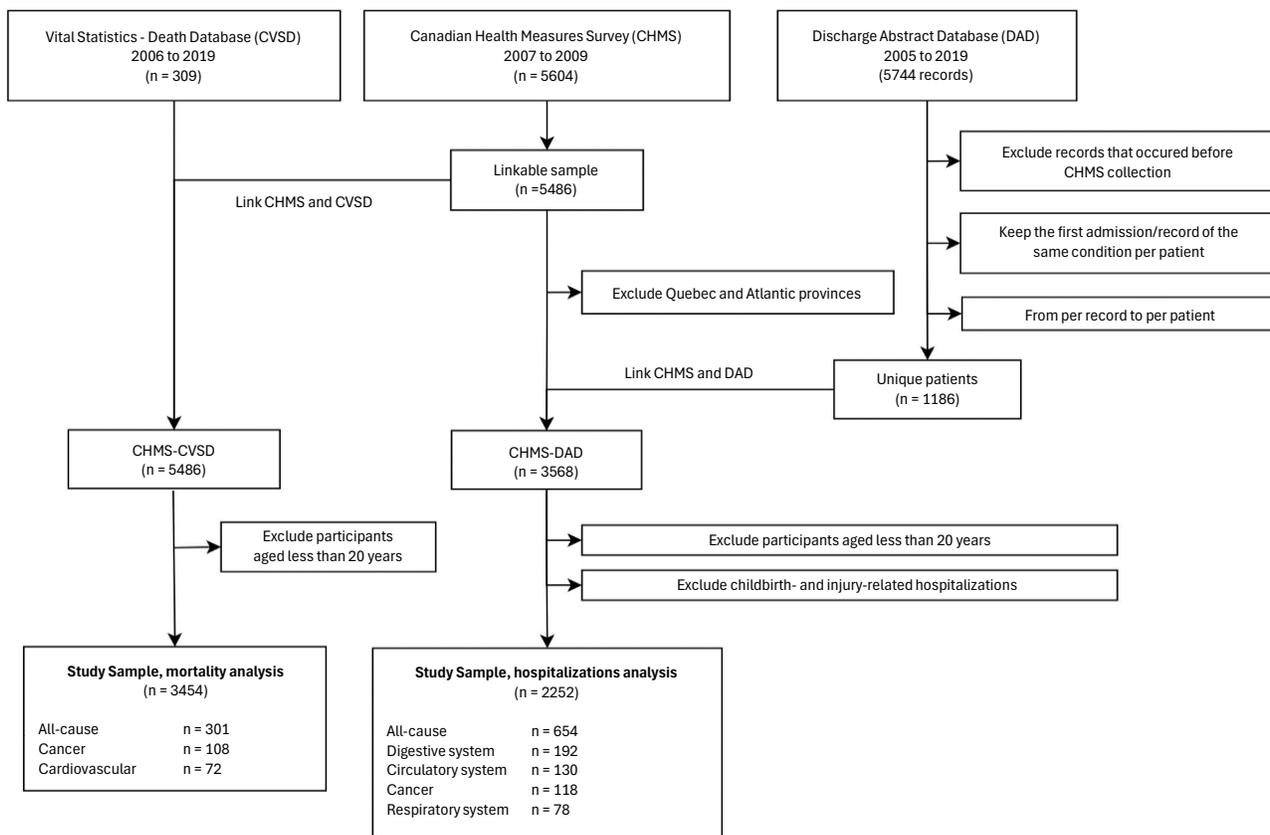
The DAD contains administrative, clinical, and demographic data on hospital discharges (including in-hospital deaths, sign-outs, and transfers) from all provinces and territories, except Quebec.²⁸ Eligible records for linkage included hospitalizations that took place from 2006 to 2019, but were defined in this analysis as occurring after the CHMS interview date and before the end of the 2019/2020 fiscal year (ending April 30, 2020). The CHMS and the DAD (CHMS-DAD) were linked using a deterministic matching approach (more details are provided in the user guide, available upon request). Participants from

Quebec and the Atlantic provinces were excluded from the hospitalization analysis because of the design of the CHMS Cycle 1 and the availability of DAD data.

Missing teeth

Oral health data were collected through household and respondent interviews, followed by a visit to a mobile examination centre (MEC). During the household interview, participants were asked about their satisfaction with their oral health and appearance, oral symptoms, and dental care habits. Clinical data collection at the MEC included measures of edentulism, tooth status, periodontal conditions, and other oral health symptoms. A participant was classified as edentulous if no natural teeth were present during the oral examination; otherwise, they were considered dentate. For dentate participants, tooth status was coded as decayed, missing, or filled, for each of the 28 teeth (wisdom teeth not recorded). Missing adult teeth (crowns) were recorded and summed.

Figure 1
Flow chart of data linkage for the study population



Notes: All numbers indicate the number of participants available in the 2007 to 2009 Canadian Health Measures Survey (CHMS) that link to mortality events in the Canadian Vital Statistics – Death Database (CVSD) from 2006 to 2019 or to hospitalization records in the Discharge Abstract Database (DAD) from 2005 to 2019.

Source: Statistics Canada, CHMS, Cycle 1 (2007 to 2009), linked to the CVSD and the DAD.

Table 1
Characteristics of the study population, Canadians aged 20 to 79 years from the Canadian Health Measures Survey (2007 to 2009) linked to the Canadian Vital Statistics – Death Database and the Discharge Abstract Database

Characteristic	CHMS-CVSD			CHMS-DAD		
	mean or percent	95% confidence interval		mean or percent	95% confidence interval	
		from	to		from	to
Socioeconomic variables						
Sex						
Male (%)	49.6	49.3	49.9	49.5	49.1	49.9
Female (%)	50.4	50.1	50.7	50.5	50.1	50.9
Age (years)	45.5	45.3	45.8	45.1	44.9	45.3
Total household income (\$1,000)	76.7	71.2	82.2	80.6	73.7	87.4
Highest household education						
Postsecondary (%)	72.6	65.5	78.7	71.9	60.8	80.9
Secondary or below (%)	23.8	18.3	30.3	24.8	16.8	35.1
Country of birth						
Born in Canada (%)	76.0	65.5	84.1	71.4	57.4	82.3
Born outside Canada (%)	24.0 [‡]	15.9	34.5	28.5 [‡]	17.7	42.5
Risk factor covariates						
Systolic blood pressure (mmHg)	112.8	111.5	114.1	112.5	110.6	114.3
Total cholesterol (mmol/L)	5.0	4.9	5.1	5.0	4.9	5.2
Body mass index (kg/m ²)	26.5	25.9	27.0	26.4	25.7	27.1
Smoking status						
Never or former Smoker (%)	78.3	75.9	80.6	79.3	76.2	82.1
Current Smoker (%)	21.7	19.4	24.1	20.7	17.9	23.8
Diabetes (%)	7.6	5.4	9.8	6.8 [‡]	4.2	9.4
Dentate						
No missing crown (%)	49.6	45.6	53.5	54.7	48.7	60.6
One to four missing crowns (%)	26.3	23.8	29.0	25.6	22.6	28.8
Five missing crowns and more (%)	17.5	15.5	19.6	14.7	12.8	16.9
Edentulous (%)	6.4	4.7	8.8	4.8 [‡]	2.6	8.7
Outcome measures						
All-cause mortality (%)	6.4	5.3	7.7	...	...	...
All-cause hospitalization (%)	...	...	...	27.1	23.4	31.0

... not applicable

[‡] use with caution

Notes: CHMS-CVSD = Canadian Health Measures Survey linked to the Canadian Vital Statistics – Death Database, CHMS-DAD = Canadian Health Measures Survey linked to Discharge Abstract Database, mmHg = millimetres of mercury and mmol/L = millimoles per litre.

Source: Statistics Canada, Canadian Health Measures Survey, Cycle 1 (2007 to 2009), linked to the Canadian Vital Statistics – Death Database and the Discharge Abstract Database.

Mortality and hospitalization

The outcomes of interest for mortality were all-cause mortality, cancer mortality (ICD-10 codes C00 to D48), and mortality from diseases of the circulatory system (ICD-10 codes I00 to I99). For hospitalizations, only those occurring after the end date of a given CHMS collection site were considered, excluding those related to childbirth (ICD-10 codes O00 to O99) and injury (ICD-10 codes S00 to T88). The outcomes examined included all hospitalizations as well as hospitalizations specific to the digestive system (ICD-10 codes K00 to K99), the respiratory system (ICD-10 codes J00 to J99), cancer (ICD-10 codes C00 to D49), and the circulatory system (ICD-10 codes I00 to I99), as these were the most prevalent post-linkage and are reported annually by the Canadian Institute for Health Information.⁸ In cases where participants had multiple records for the same condition, only the first observed hospitalization event for each outcome was retained.

Socioeconomic status and risk factors

Baseline socioeconomic and health-related risk factors were considered in this study, as these factors have been documented to be associated with both oral and general health outcomes. Socioeconomic variables assessed included age, sex, country of birth, highest household education level, total household income, and smoking status, all of which were self-reported by participants. The risk factors included systolic blood pressure (SBP), measured as the average of six readings; body mass index (BMI), calculated as weight (in kilograms) divided by the square of height (in metres); measured total cholesterol levels (in millimoles per litre). Details of the measurement protocols are available upon request. Diabetes mellitus status was determined based on either a self-reported diagnosis or a fasting glucose of 7.0 millimoles per litre or more or a glycosylated hemoglobin of 6.5% or more.²⁹

Age, SBP, total cholesterol, BMI, and total household income were treated as continuous variables. The remaining variables were categorical, including sex (male or female), highest household education (postsecondary versus secondary or

below), country of birth (born in or outside Canada), smoking status (never or former smoker versus current smoker), and diabetes status (yes or no). Coefficients of control variables are not shown in the tables and are available upon request.

Statistical analysis

Descriptive statistics were used to assess participant characteristics, including frequencies, means, and 95% confidence intervals (CIs). Differences in participant characteristics and health outcomes were examined across missing teeth categories, which were divided into three groups for dentate participants (no missing teeth, one to four missing teeth, and five or more missing teeth), and the edentulous participants. Significance testing between groups was done using analysis of variance for continuous variables and the chi-square test for categorical variables.

Cox proportional hazards regression models were used to examine associations between missing teeth and mortality and hospitalization outcomes, adjusting for participant characteristics and risk factors. The main analysis was conducted in the dentate population (aged 20 to 79 years) to examine associations between missing teeth, mortality, and hospitalization outcomes. Missing teeth were investigated categorically (none missing, one to four missing, five or more missing) and continuously (number of missing teeth). To minimize the influence of age and socioeconomic status on the potential association, two sensitivity analyses were conducted by excluding the younger age group (20 to 39 years) and the older age group (60 to 79 years). Another sensitivity analysis was conducted to compare the edentulous and dentate populations. To account for the complex survey design and non-response in the CHMS, sampling weights were applied to the linked datasets to ensure population representativeness, and the bootstrap technique was used to obtain robust 95% CIs. Differences were considered statistically significant if $p < 0.05$. The number of degrees of freedom (DF) was taken into account for the CHMS-CVSD analysis (DF = 11) and for the CHMS-DAD analysis (DF = 7). This limited the number of covariates that could be included in the regressions. All statistical analyses were performed using R statistical software (version 4.2.3),³⁰ with Cox regression implemented using the “svycoxph” function to adjust for the survey design.

Results

Study population

Participants in the 2007 to 2009 CHMS were linked to the CVSD and the DAD (Figure 1). In the study population aged 20 to 79 years linked to the CVSD ($n = 3,454$), 301 deaths were recorded, with cancer ($n = 108$) and cardiovascular disease ($n = 72$) identified as the leading causes of death. Among the 2,252 participants aged 20 to 79 linked to the DAD, 654 individuals were hospitalized at least once. Hospitalizations related to the

digestive system ($n = 192$), the circulatory system ($n = 130$), cancer ($n = 118$), and the respiratory system ($n = 78$) were the most common reasons for hospitalization, excluding those related to childbirth and injury.

The characteristics of participants aged 20 to 79 years linked to the CVSD and the DAD are presented in Table 1. The mean age of participants in both datasets was 45 years, with an approximately equal representation of males and females. Approximately three-quarters of participants were born in Canada, had a postsecondary education, and were never (or former) smokers. Overall, 6.4% of the CHMS-CVSD participants and 4.8% of the CHMS-DAD participants were identified as edentulous. About half of participants had no missing teeth, one-quarter had one to four missing teeth, and around 15% had five or more missing teeth. The distribution of all socioeconomic and risk factor variables was similar across both datasets (Table 1).

Descriptive analysis

Participant characteristics by missing teeth categories in the CHMS-CVSD are presented in Table 2-A. Differences in sex, smoking status, and country of birth were not observed across missing teeth categories. Compared with those with no missing teeth, participants with a higher number of missing teeth were older, had lower total household income, and lower levels of household education. These participants also exhibited more unfavourable risk factors, including a higher prevalence of diabetes, elevated SBP, a higher BMI, and increased total cholesterol levels. Similar results are shown for the CHMS-DAD participant characteristics in Table 2-B, except that a higher proportion of participants born outside Canada had five or more missing teeth.

The unadjusted mortality rate increased with the number of missing teeth (Chart 1-A). The overall all-cause mortality rate was 6.4% (95% CI: 5.4 to 7.5), ranging from 1.6% (95% CI: 1.0 to 2.4) in participants with no missing teeth to 23.2% (95% CI: 16.3 to 31.7) in edentulous individuals. Cancer mortality rates followed a similar trend, increasing from 0.8% (95% CI: 0.6 to 1.2) in participants with no missing teeth to 6.7% (95% CI: 4.0 to 11.0) in edentulous individuals. A similar pattern was observed for unadjusted hospitalizations (Chart 1-B). Among the top four causes of hospitalization, the rate for digestive system diseases was highest at 8.2% (95% CI: 6.6 to 10.3), followed by cancer at 4.7% (95% CI: 3.8 to 6.1), circulatory system diseases at 4.3% (95% CI: 3.3 to 5.6), and respiratory system diseases at 3.3% (95% CI: 2.4 to 4.5). Hospitalization rates for all causes increased with the number of missing teeth. Proportionally, hospitalizations from respiratory system diseases showed the steepest increase, followed by those from circulatory system diseases. The overall all-cause hospitalization rate (excluding those related to childbirth and injury) was 27.1% (95% CI: 24.1 to 30.4), increasing from 20.3% (95% CI: 16.7 to 24.5) in participants with no missing teeth to 46.0% (95% CI: 37.0 to 55.3) in edentulous individuals.

Table 2-A
Characteristics of the study population, by missing teeth categories, Canadians aged 20 to 79 years from the Canadian Health Measures Survey (2007 to 2009) linked to the Canadian Vital Statistics – Death Database

Characteristic	Dentate population										Edentulous population		
	No missing teeth [‡]			One to four missing teeth			Five or more missing teeth			mean or percent	95% confidence interval		
	mean or percent	95% confidence interval from	to	mean or percent	95% confidence interval from	to	mean or percent	95% confidence interval from	to		mean or percent	95% confidence interval from	to
Socioeconomic variables													
Sex													
Male (%)	51.6	49.6	53.4	47.5	44.0	50.9	48.0	41.9	54.0	48.8	42.1	55.5	
Female (%)	48.4	46.5	50.3	52.5	49.1	56.0	52.0	46.0	58.1	51.2	44.5	57.9	
Age (years)	36.6	35.5	37.6	48.9 **	47.8	50.1	59.0 **	57.1	61.0	64.3 **	62.5	66.1	
Total household income (\$1,000)	88.2	81.2	95.3	73.2 **	68.9	77.6	60.7 **	52.8	68.5	45.7 **	37.8	53.5	
Highest household education													
Postsecondary (%)	83.9	76.8	90.9	71.8 **	65.5	78.1	64.2 **	57.1	71.3	51.7 **	42.0	61.4	
Secondary or below (%)	16.1 [‡]	9.1	23.2	28.2	21.9	34.5	35.8	28.6	42.9	48.3	38.6	58.0	
Country of birth													
Born in Canada (%)	78.1	68.4	87.8	71.9	62.1	81.8	73.9	62.3	85.5	81.9	73.5	90.3	
Born outside Canada (%)	21.9 [‡]	12.2	31.6	28.1	18.2	37.9	26.1 [‡]	14.5	37.7	18.1	9.7	26.5	
Risk factor covariates													
Systolic blood pressure (mmHg)	108.6	106.8	110.3	113.7 **	112.3	115.2	119.2 **	117.9	120.5	124.1 **	120.3	127.9	
Total cholesterol (mmol/L)	4.9	4.8	5.0	5.2 **	5.1	5.3	5.1 **	5.0	5.3	5.2 *	5.0	5.3	
Body Mass Index (kg/m ²)	25.8	25.1	26.5	27.0 **	26.5	27.6	27.1 **	26.6	27.7	27.6 *	26.6	28.5	
Smoking status													
Never or former Smoker (%)	80.8	77.0	84.6	74.7	69.8	79.6	78.7	73.4	83.8	74.0	65.3	82.8	
Current Smoker (%)	19.2	15.4	23.0	25.3	20.4	30.2	21.3	16.2	26.4	26.0	17.2	34.7	
Diabetes (%)	3.4 [‡]	1.2	5.6	6.9 [‡]	3.9	9.8	16.6 **	12.3	20.9	18.4 ^{E**}	10.2	26.6	

^E use with caution

* significantly different from reference category (p < 0.05)

** significantly different from reference category (p < 0.01)

[‡] reference group

Notes: MmHg = millimetres of mercury and mmol/L = millimoles per litre.

Source: Statistics Canada, Canadian Health Measures Survey, Cycle 1 (2007 to 2009), linked to the Canadian Vital Statistics – Death Database.

Table 2-B
Characteristics of the study population, by missing teeth categories, Canadians aged 20 to 79 years from the Canadian Health Measures Survey 2007-2009 linked to the Discharge Abstract Database (DAD)

Characteristic	Dentate population										Edentulous population		
	No missing teeth [‡]			One to four missing teeth			Five or more missing teeth			mean or percent	95% confidence interval		
	mean or percent	95% confidence interval from	to	mean or percent	95% confidence interval from	to	mean or percent	95% confidence interval from	to		mean or percent	95% confidence interval from	to
Socioeconomic variables													
Sex													
Male (%)	50.7	49.1	52.3	49.4	45.4	53.4	47.0	40.7	53.3	45.4	35.1	55.8	
Female (%)	49.3	47.7	50.9	50.6	46.6	54.6	53.0	46.7	59.3	54.6	44.2	64.9	
Age (years)	37.3	36.2	38.5	49.5 **	48.0	51.0	59.6 **	57.0	62.1	65.6 **	62.2	68.9	
Total household income (in \$1,000s)	90.8	82.1	99.6	74.6 **	70.1	79.0	63.3 **	55.8	70.8	48.3 **	38.1	58.5	
Highest household education													
Postsecondary (%)	83.3	73.9	92.6	68.1 *	59.3	76.9	59.9 **	50.7	69.2	45.7 **	30.6	60.8	
Secondary or below (%)	16.7 [‡]	7.4	26.1	31.9	23.1	40.7	40.1	30.8	49.3	54.3	39.2	69.4	
Country of birth													
Born in Canada (%)	76.0	64.2	87.9	67.9	56.0	79.8	61.4 *	44.9	77.8	67.8	50.0	85.7	
Born outside Canada (%)	24.0 [‡]	12.1	35.8	32.1 [‡]	20.2	44.0	38.6 [‡]	22.2	55.1	32.2 [‡]	14.3	50.0	
Risk factor covariates													
Systolic blood pressure (mmHg)	108.9	106.6	111.2	114.1 **	112.1	116.1	119.1 **	117.0	121.2	124.1 **	119.8	128.3	
Total cholesterol (mmol/L)	4.9	4.8	5.1	5.2 **	5.0	5.3	5.1	4.9	5.4	5.2	5.0	5.5	
Body Mass Index (kg/m ²)	25.8	25.0	26.7	27.1 *	26.4	27.9	27.1 *	26.2	27.9	27.0	25.7	28.4	
Smoking status													
Never or former Smoker (%)	82.3	77.6	87.1	73.1	66.3	80.0	80.3	74.6	86.0	74.7	62.1	87.3	
Current Smoker (%)	17.7	12.9	22.4	26.9	20.0	33.7	19.7	14.0	25.4	25.3 [‡]	12.7	37.9	
Diabetes (%)	0.0 [‡]	0.0	0.1	0.1 [‡]	0.0	0.1	0.2 **	0.1	0.2	0.2 ^{E*}	0.1	0.3	

^E use with caution

* significantly different from reference category (p < 0.05)

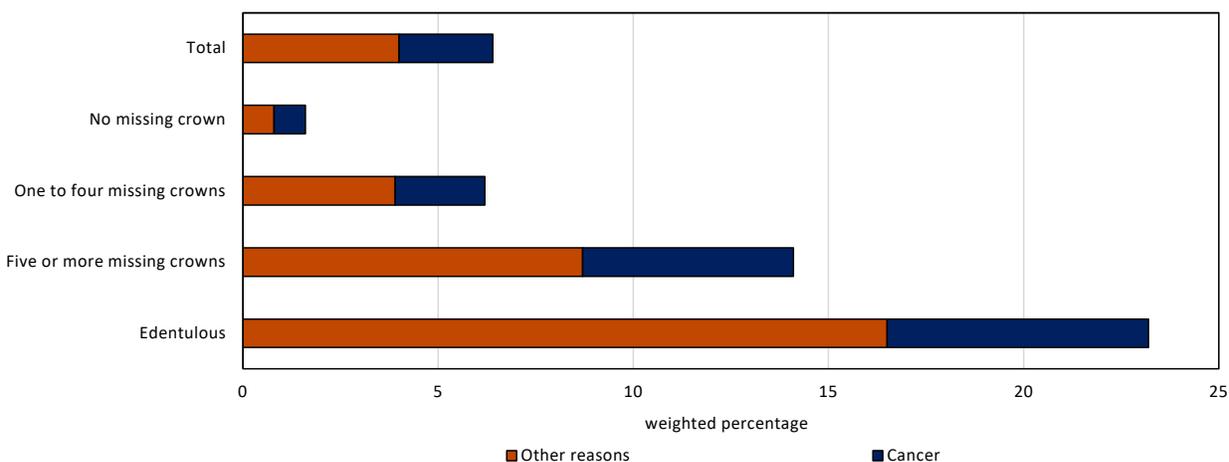
** significantly different from reference category (p < 0.01)

[‡] reference group

Notes: MmHg = millimetres of mercury and mmol/L = millimoles per litre.

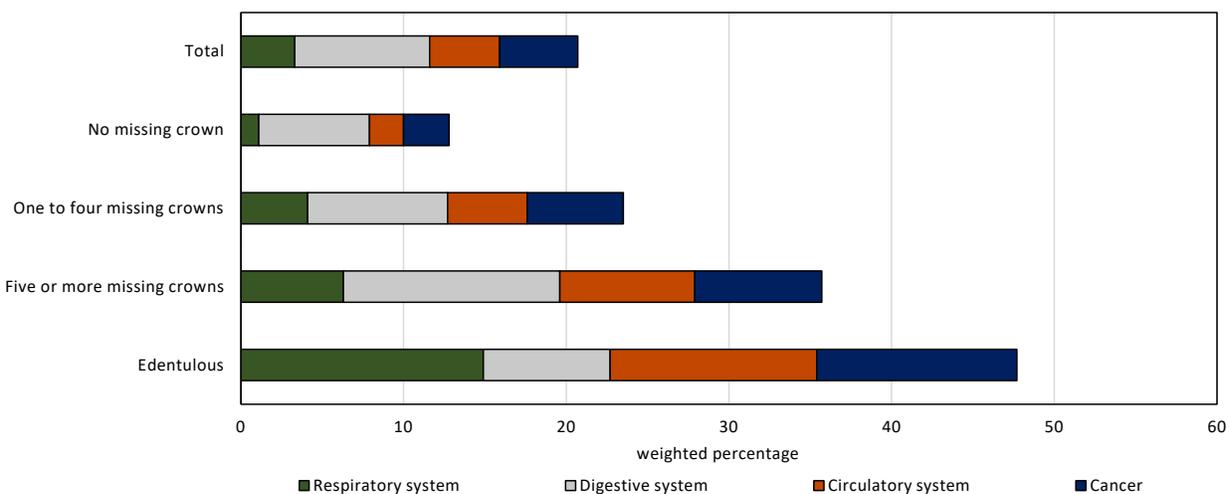
Source: Statistics Canada, Canadian Health Measures Survey, Cycle 1 (2007 to 2009), linked to the Discharge Abstract Database.

Chart 1-A
Mortality outcomes by missing teeth categories



Notes: The numbers represent the weighted percentages of participants who died up to 2019.
Source: Statistics Canada, Canadian Health Measures Survey, Cycle 1 (2007 to 2009), linked to the Canadian Vital Statistics – Death Database.

Chart 1-B
Hospitalization outcomes by missing teeth categories



Notes: The numbers represent the weighted percentages of participants who were hospitalized up to 2019.
Source: Statistics Canada, Canadian Health Measures Survey, Cycle 1 (2007 to 2009), linked to the Discharge Abstract Database.

Missing teeth, mortality, and hospitalization

Based on univariate Cox regression models, a significant gradient in all-cause and cancer mortality was observed across missing teeth categories in participants aged 20 to 79 years and those aged 40 to 79 years (Table 3). This trend was further supported by analyses treating missing teeth as a continuous variable and by comparisons between the edentulous and dentate populations. Each additional missing tooth was associated with an approximately 16% increase in all-cause mortality (hazard ratio [HR] 1.16, 95% CI: 1.09 to 1.25) and cancer mortality (HR=1.16, 95% CI: 1.09 to 1.23) among 20-to 79-year-olds. The estimates were robust when younger or older age groups were excluded from the analysis. However, after

adjusting for socioeconomic variables and risk factors, the gradient of association persisted but lost statistical significance and showed a reduced magnitude.

Cox regression results for missing teeth and hospitalization outcomes are presented in Table 4. A clear dose-response association was identified between missing teeth categories and hospitalization outcomes in univariate (data not shown) and adjusted models. In participants aged 20 to 79 years, after adjusting for age, sex, smoking status, and diabetes, those with five or more missing teeth demonstrated a 76% increase in the risk of all-cause hospitalization (HR=1.76, 95% CI: 1.41 to 2.20) and a 120% increase in the risk of hospitalization from circulatory system diseases (HR=2.20, 95% CI: 1.09 to 4.45).

Positive associations between missing teeth and hospitalizations from respiratory system disease were also observed, with an HR of 3.62 (95% CI: 1.35 to 9.77) for participants with one to four missing teeth compared with participants with no missing teeth, and among the dentate participants (HR=3.33, 95% CI: 1.17 to 9.47) compared with edentulous participants. No significant associations were observed between missing teeth and hospitalizations from digestive system diseases or cancer. The estimates were robust when younger or older age groups were excluded from the analysis.

Discussion

This study is the first to provide time-to-event evidence on clinically measured oral health and its association with hospitalization and mortality outcomes in Canada. Additionally, it is among the first studies using the multiple linkage datasets from the CHMS. The results demonstrated that missing teeth was significantly associated with all-cause, respiratory, and circulatory hospitalizations in the Canadian population living in the provinces (except Quebec and the Atlantic provinces) aged 20 to 79 years. This association remained robust across various sensitivity analyses, including stratification by age groups, treating missing teeth as continuous

or categorical variables, and extreme scenarios (e.g., comparing edentulous participants to dentate participants). Missing teeth was associated with all-cause and cancer mortality in univariate analyses, but not in fully adjusted models.

Several studies have investigated the association between tooth loss and mortality across various countries.^{23,25} However, it is noteworthy that no study using nationally representative Canadian data has been conducted until now. Though this current study did not observe a significant association between missing teeth—whether measured as an absolute number or in categorized brackets—and all-cause or cause-specific mortality in adjusted models, this is in line with some other studies suggesting that the apparent association between tooth loss and mortality diminishes after adjusting for key covariates, such as age, sex, smoking status, health behaviours, and baseline chronic diseases.^{31 to 36} It is plausible that missing teeth is associated with mortality; however, its association is not as strong as factors such as age, health behaviours, and socioeconomic status. It is also plausible that missing teeth could be an indicator of poor health and low socioeconomic status, instead of an independent risk factor of increased mortality. Future studies could employ directed acyclic graphs and path analysis to further assess potential causal relationships and quantify direct, indirect, mediating, and moderating effects.

Table 3
Hazard ratios and 95% confidence intervals from Cox proportional hazards regression models for mortality, by type of mortality, Canadians aged 20 to 79 years (40 to 79 years and 20 to 59 years) from the Canadian Health Measures Survey (2007 to 2009) linked to the Canadian Vital Statistics – Death Database

	All-cause mortality						Cancer mortality					
	Univariable model			Multivariable model ¹			Univariable model			Multivariable model ¹		
	Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval	
		from	to		from	to		from	to		from	to
In participants aged 20 to 79 years												
Within the dentate population												
No missing crowns	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
One to four missing crowns	3.98 **	2.09	7.58	1.29	0.32	5.18	2.87	0.85	9.68	1.11	0.04	31.00
Five or more missing crowns	9.70 **	3.38	27.80	1.72	0.88	3.37	7.13 *	1.43	35.50	1.60	0.05	53.50
Number of missing crowns	1.16 **	1.09	1.25	1.04	0.98	1.10	1.16 **	1.09	1.23	1.05	0.97	1.13
Edentulous versus dentate populations												
Dentate	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Edentulous	5.01 **	3.32	7.58	1.35	0.93	1.95	3.61 **	2.02	6.46	0.99	0.30	3.29
In participants aged 40 to 79 years												
Within the dentate population												
No missing crowns	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
One to four missing crowns	4.54	0.65	31.80	2.11	0.66	6.76	3.53	0.10	127.00	1.66	0.06	42.60
Five or more missing crowns	8.98 **	4.05	19.90	2.56	0.59	11.20	7.05	0.30	164.00	2.13	0.08	59.10
Number of missing crowns	1.12 **	1.06	1.19	1.04	0.96	1.12	1.12 **	1.04	1.21	1.04	0.88	1.23
Edentulous versus dentate populations												
Dentate	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Edentulous	3.31 **	2.16	5.08	1.35	0.86	2.13	2.46 **	1.37	4.43	0.98	0.46	2.10
In participants aged 20 to 59 years												
Within the dentate population												
Number of missing crowns	1.15 **	1.05	1.26	1.07	0.95	1.20	1.17 **	1.03	1.33	1.05	0.78	1.40

... not applicable

* significantly different from reference category (p < 0.05)

** significantly different from reference category (p < 0.01)

1. The multivariable modeled controlled for age, sex, country of birth, smoking status, body mass index, systolic blood pressure, total cholesterol, and diabetes.

Source: Statistics Canada, Canadian Health Measures Survey, Cycle 1 (2007 to 2009), linked to the Canadian Vital Statistics – Death Database.

This study found a significant relationship between missing teeth and all-cause hospitalizations and hospitalizations from respiratory conditions, whether missing teeth was considered as a continuous or categorical variable. Periodontal disease, a major cause of tooth loss, contributes to systemic inflammation and immune dysregulation, increasing susceptibility to infections and worsening pre-existing conditions.^{17,31} Furthermore, poor oral health can impair nutrition and overall immunity, further exacerbating health issues that may lead to hospitalization.^{9,34} The relative lack of hospitalization data compared with mortality data helps explain the limited evidence and highlights the need for further research on this topic.^{14,24}

When comparing the results of this study with others in the literature, the inconsistencies observed in the relationship between tooth loss and clinical outcomes may be attributed to significant variations in how tooth loss is measured and analyzed across studies. The definition and assessment of tooth count vary widely, from simple measures such as the absolute number of remaining and missing teeth and edentulous status to more complex measures such as functional masticatory status.^{23,25} In the calculation of tooth count, some studies include dentures, while others restrict it to natural teeth only,

introducing further inconsistency.^{37,38,39} In the CHMS Cycle 1, the status of wisdom teeth was not recorded; therefore, the maximum number of teeth for an individual in this study was 28. Tooth loss was reported based on the number of missing teeth rather than the number of remaining teeth. Beyond measurement differences, analytical approaches to tooth loss also lack uniformity and are often reported unclearly. Studies have treated tooth count as either a continuous or categorical variable, with no consensus on appropriate categories.^{23,25} For instance, one study with a 57-year follow-up found that missing teeth was significantly associated with mortality when treated as a categorical variable, but not when treated as a continuous variable.⁴⁰ To address these issues, different versions of regression analyses were performed in this study, incorporating tooth loss as a continuous variable, a categorical variable, and as dentate versus edentulous status. In addition, existing studies included different covariates in their analyses, contributing to inconsistent findings.

Another source of difference could be the reliance on self-reported tooth loss in some of the previous studies,^{41,42} as opposed to this study, which used direct clinical measurements. Self-reported oral health data, while common in large epidemiological studies, may be prone to some biases.^{43,44}

Table 4
Hazard ratios and 95% confidence intervals from multivariate Cox proportional hazards regression models for hospitalizations, by type of hospitalization, Canadians aged 20 to 79 years (20 to 59 years and 40 to 79 years) from the Canadian Health Measures Survey (2007 to 2009) linked to the Discharge Abstract Database

	All hospitalizations			Digestive system hospitalizations			Respiratory system hospitalizations			Cancer hospitalizations			Circulatory system hospitalizations		
	Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval	
		from	to		from	to		from	to		from	to		from	to
In participants aged 20 to 79 years															
Within the dentate population															
No missing crowns	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
One to four missing crowns	1.44 **	1.11	1.88	1.36	0.59	3.14	3.62 *	1.35	9.77	1.72	0.54	4.78	1.88	0.74	4.78
Five or more missing crowns	1.76 **	1.41	2.20	2.32	0.49	11.02	4.62	0.63	34.20	1.85	0.51	6.68	2.20 *	1.09	4.45
Number of missing crowns	1.05	0.99	1.09	1.09	0.93	1.24	1.12	0.96	1.29	1.08	0.97	1.20	1.03	0.98	1.09
Edentulous versus dentate populations															
Dentate	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Edentulous	1.39	0.98	1.83	0.84	0.44	1.43	3.33 *	1.17	9.47	1.63	0.49	5.37	1.48	0.66	3.33
In participants aged 40 to 79 years															
Within the dentate population															
No missing crowns	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
One to four missing crowns	1.46	0.89	2.40	1.29	0.56	2.97	8.03 *	1.20	53.60	1.38	0.32	5.85	1.07	0.62	1.86
Five or more missing crowns	1.64	0.81	3.32	1.98	0.40	9.82	10.20	0.78	134.00	1.41	0.45	4.43	1.07	0.52	2.20
Number of missing crowns	1.04	0.99	1.09	1.07	0.93	1.24	1.11 *	1.02	1.22	1.05	0.95	1.17	0.99	0.95	1.03
Edentulous versus dentate populations															
Dentate	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Edentulous	1.34	0.98	1.83	0.79	0.44	1.43	3.09 *	1.05	9.13	1.51	0.34	6.75	1.41	0.76	2.62
In participants aged 20 to 59 years															
Within the dentate population															
No missing crowns	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
One to four missing crowns	1.16	0.74	1.81	1.06	0.59	1.91	3.98 **	1.39	11.35	1.07	0.59	1.95	1.16	0.44	3.05
Five or more missing crowns	1.91 **	1.23	2.96	2.38 *	1.03	5.45	4.32 *	1.13	16.55	1.46	0.22	9.69	2.10	0.41	10.66
Number of missing crowns	1.08 *	1.02	1.14	1.11	0.99	1.24	1.15	0.94	1.39	1.10	0.87	1.38	1.05	0.90	1.24

... not applicable

* significantly different from reference category (p < 0.05)

** significantly different from reference category (p < 0.01)

Note: The multivariate model controlled for age, sex, smoking status, and diabetes. Pregnancy- and injury-related hospitalizations were excluded from all hospitalizations.

Source: Statistics Canada, Canadian Health Measures Survey, Cycle 1 (2007 to 2009), linked to the Discharge Abstract Database.

Therefore, where possible, comparisons should prioritize studies that performed direct clinical assessments. Additionally, the length of the follow-up appears to influence the reported associations between tooth loss and mortality. Some studies observed associations at shorter follow-up periods, while others found these associations only with longer follow-up times.²⁵ In this study, the follow-up period spanned 10 years. While this is substantial, it is still shorter than the average follow-up time of 13.6 years (with a standard deviation of 12.1) reported in previous studies.²³ This follow-up duration resulted in 300 mortality events. Encouraging further data linkage in future studies could increase the number of events, potentially narrowing CIs and yielding statistically significant results.

Strengths and limitations

The biggest strength of this study lies in it being the first to provide time-to-event data on the association between tooth loss, mortality, and hospitalization in Canada at the national level. As part of the analysis, common risk factors were adjusted for in the models to ensure robust findings. Another key strength is that tooth loss was assessed through direct clinical measures rather than self-reported data. The characteristics of Canadians with different missing teeth categories were described and compared systematically. Additionally, missing teeth was analyzed as a continuous and as a categorical variable, using different cut-off points informed by the data and previous literature. Multiple sensitivity analyses were conducted to ensure the robustness of the study findings. These included stratification by age group and comparisons between edentulous and dentate participants.

Several limitations of this study should be acknowledged. The sample size from the CHMS and its linked datasets imposed constraints on the scope of the analyses. For instance, the Canadian Cancer Registry was not used, and more detailed cause-specific analyses—such as deaths or hospitalizations from coronary heart disease, stroke, or specific types of cancer—were not feasible. Additionally, the exclusion of

participants from Quebec and the Atlantic provinces further reduced the sample size and degrees of freedom for analyses using the DAD, thus limiting the feasibility of detailed cause-specific hospitalization analyses and the number of covariates that could be adjusted in the models. Furthermore, because of the sampling design and degrees of freedom, only a limited number of control variables could be included in the current analysis, potentially leading to either overestimates or underestimates of the true association. While this study identified an association, future research should explore mediating factors, such as filling status or other periodontal conditions, that may influence the relationship between tooth loss, mortality, and hospitalization.

Conclusion

The present study contributes to the increasing body of literature on the link between oral health and general health using the best available Canadian data. More specifically, missing teeth was found to be associated with increased all-cause hospitalizations, and circulatory and respiratory hospitalizations after adjusting for key risk factors. Tooth loss is associated with all-cause and cancer mortality in the unadjusted analysis, but not after adjustment.

Future research could benefit from longer follow-up periods through continued data linkage, as this may better capture the incubation periods and the occurrence of events of interest, thereby confirming marginally significant findings, such as all-cause mortality. It would also be valuable to disaggregate tooth loss based on its causes, such as periodontal disease versus other conditions, to identify which type of tooth loss serves as a stronger signal. Furthermore, as other measured oral health outcomes, oral health hygiene behaviours, and information on socioeconomic status were available in the CHMS, it may be worth exploring how different oral health outcomes and oral hygiene behaviours interact with and impact key clinical outcomes.

References

- Griffin SO, Jones JA, Brunson D, et al. Burden of oral disease among older adults and implications for public health priorities. *Am J Public Health*. 2012 Mar;102(3):411–8.
- Kassebaum NJ, Bernabé E, Dahiya M, et al. Global burden of severe tooth loss: a systematic review and meta-analysis. *J Dent Res*. 2014 Jul;93(7 Suppl):20S–8S.
- World Health Organization. Oral health [Internet]. Geneva: World Health Organization; 2024 Nov 6 [cited 2024 Dec 10]. Available from: <https://www.who.int/news-room/fact-sheets/detail/oral-health>
- Cooney P. Report on the findings of the oral health component of the Canadian Health Measures Survey 2007–2009. Ottawa: Health Canada; 2010. p 1–111. Available from: http://publications.gc.ca/collections/collection_2010/sc-hc/H34-221-2010-eng.pdf
- Statistics Canada. Self-reported oral health problems in the Canadian population living in the provinces, November 2023 to March 2024 [Internet]. Ottawa: Statistics Canada; 2024 Oct 23 [cited 2025 Mar 3]. Available from: <https://www150.statcan.gc.ca/n1/daily-quotidien/241023/dq241023b-eng.htm>
- Statistics Canada. Deaths, 2019 [Internet]. Ottawa: Statistics Canada; 2020 Nov 26 [cited 2024 Dec 10]. Available from: <https://www150.statcan.gc.ca/n1/daily-quotidien/201126/dq201126b-eng.htm>
- Canadian Institute for Health Information. Hospital stays in Canada [Internet]. Ottawa (ON): CIHI; [cited 2024 Dec 10]. Available from: <https://www.cihi.ca/en/hospital-stays-in-canada-series>
- Canadian Institute for Health Information. Inpatient Hospitalization, Surgery and Newborn Statistics, 2019–2020. Ottawa (ON): CIHI; 2021.
- Kaurani P, Kakodkar P, Bhowmick A, et al. Association of tooth loss and nutritional status in adults: an overview of systematic reviews. *BMC Oral Health*. 2024 Jul 24;24(1):838.
- Hag Mohamed S, Sabbah W. Is tooth loss associated with multiple chronic conditions? *Acta Odontol Scand*. 2023 Aug 18;81(6):443–8.
- Parker ML, Thornton-Evans GO, Wei L, Griffin SO. Prevalence of and changes in tooth loss among adults aged ≥ 50 years with selected chronic conditions—United States, 1999–2004 and 2011–2016. *MMWR Morb Mortal Wkly Rep*. 2020;69:641–6.
- Zhang Y, Leveille SG, Shi L. Multiple chronic diseases associated with tooth loss among the US adult population. *Front Big Data*. 2022 Jul 1;5:932618.
- Gao W, Wang X, Wang X, et al. Association of cognitive function with tooth loss and mitochondrial variation in adult subjects: a community-based study in Beijing, China. *Oral Dis*. 2016 Oct;22(7):697–702.
- Joshy G, Arora M, Korda RJ, et al. Is poor oral health a risk marker for incident cardiovascular disease hospitalisation and all-cause mortality? Findings from 172 630 participants from the prospective 45 and Up Study. *BMJ Open*. 2016 Aug 1;6(8):e012386.
- Iwasaki M, Sato M, Yoshihara A, et al. Association between tooth loss and medical costs related to stroke in healthy older adults aged over 75 years in Japan. *Geriatr Gerontol Int*. 2017 Feb;17(2):202–10.
- Joshiyura K. The relationship between oral conditions and ischemic stroke and peripheral vascular disease. *J Am Dent Assoc*. 2002 Jun;133 Suppl:23S–30S.
- Chatzopoulos GS, Jiang Z, Marka N, Wolff LF. Periodontal disease, tooth loss, and systemic conditions: an exploratory study. *Int Dent J*. 2024 Apr 1;74(2):207–15.
- Wang Y, Peng J, Li Y, et al. Association between tooth loss and risk of oesophageal cancer: a dose–response meta-analysis. *Springerplus*. 2016 Jul 8;5(1):1020.
- Yin XH, Wang YD, Luo H, et al. Association between tooth loss and gastric cancer: a meta-analysis of observational studies. *PLoS One*. 2016 Mar 2;11(3):e0149653.
- Del Brutto OH, Recalde BY, Rumbela DA, Mera RM. Severe tooth loss and mortality risk: a population-based, longitudinal prospective study in a rural setting. *Int Health*. 2023 Sep;15(5):611–3.
- Dai M, Song Q, Lin T, et al. Tooth loss, denture use, and all-cause and cause-specific mortality in older adults: a community cohort study. *Front Public Health*. 2023 Jun 5;11:1194054.
- Izuora K, Yousif A, Allenback G, et al. Relationship between dental loss and health outcomes among hospitalized patients with and without diabetes. *J Investig Med*. 2019 Mar;67(3):669–73.
- Peng J, Song J, Han J, et al. The relationship between tooth loss and mortality from all causes, cardiovascular diseases, and coronary heart disease in the general population: systematic review and dose–response meta-analysis of prospective cohort studies. *Biosci Rep*. 2019 Jan;39(1):BSR20181773.
- Saito M, Shimazaki Y, Nonoyama T, Tadokoro Y. Associations of number of teeth with medical costs and hospitalization duration in an older Japanese population. *Geriatr Gerontol Int*. 2019 Apr;19(4):335–41.
- Koka S, Gupta A. Association between missing tooth count and mortality: a systematic review. *J Prosthodont Res*. 2018;62(2):134–51.
- Tremblay MS, Wolfson M, Gorber SC. Canadian Health Measures Survey: rationale, background and overview. *Health Rep*. 2007 Dec;18 Suppl:7–20. Report no. 82-003-SPE.
- Statistics Canada. Vital Statistics—Death Database (CVSD) [Internet]. Ottawa: Statistics Canada; [cited 2024 Dec 10]. Available from: <http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=1290799>
- Canadian Institute for Health Information. Discharge Abstract Database Metadata [Internet]. Ottawa (ON): CIHI; [cited 2024 Dec 10]. Available from: <https://www.cihi.ca/en/discharge-abstract-database-metadata>

29. Diabetes Canada Clinical Practice Guidelines Expert Committee. Diabetes Canada 2018 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada. *Can J Diabetes*. 2018;42 Suppl 1:S1–S325.
30. R Core Team. *R: A language and environment for statistical computing* [Internet]. Vienna: R Foundation for Statistical Computing; 2023 [cited 2025 Jun 16]. Available from: <https://www.R-project.org>
31. Garcia RI, Krall EA, Vokonas PS. Periodontal disease and mortality from all causes in the VA Dental Longitudinal Study. *Ann Periodontol*. 1998 Jul;3(1):339–49.
32. Kim JK, Baker LA, Davarian S, Crimmins E. Oral health problems and mortality. *J Dent Sci*. 2013 Jun;8(2):115–20.
33. 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 Nov;45(11):1315–23.
34. Saarela RK, Soini H, Hiltunen K, et al. Dentition status, malnutrition and mortality among older service housing residents. *J Nutr Health Aging*. 2014 Jan 1;18(1):34–8.
35. Ragnarsson E, Eliasson ST, Gudnason V. Loss of teeth and coronary heart disease. *Int J Prosthodont*. 2004 Jul-Aug;17(4).
36. Tuominen R, Reunanen A, Paunio M, et al. Oral health indicators poorly predict coronary heart disease deaths. *J Dent Res*. 2003 Sep;82(9):713–8.
37. Watt RG, Tsakos G, de Oliveira C, Hamer M. Tooth loss and cardiovascular disease mortality risk—results from the Scottish Health Survey. *PLoS One*. 2012 Feb 20;7(2):e30797.
38. Paganini-Hill A, White SC, Atchison KA. Dental health behaviours, dentition, and mortality in the elderly: the leisure world cohort study. *J Aging Res*. 2011;2011:156061.
39. Marín-Zuluaga DJ, Sandvik L, Gil-Montoya JA, Willumsen T. Oral health and mortality risk in the institutionalised elderly. *Med Oral Patol Oral Cir Bucal*. 2012 Jul;17(4):e618.
40. Tu YK, Galobardes B, Smith GD, et al. Associations between tooth loss and mortality patterns in the Glasgow Alumni Cohort. *Heart*. 2007 Sep 1;93(9):1098–103.
41. Hung HC, Joshipura KJ, Colditz G, et al. The association between tooth loss and coronary heart disease in men and women. *J Public Health Dent*. 2004 Dec;64(4):209–15.
42. Österberg T, Carlsson GE, Sundh V, Steen B. Number of teeth—a predictor of mortality in the elderly? A population study in three Nordic localities. *Acta Odontol Scand*. 2007 Jan 1;65(6):335–40.
43. Liu H, Maida CA, Spolsky VW, et al. Calibration of self-reported oral health to clinically determined standards. *Community Dent Oral Epidemiol*. 2010 Dec;38(6):527–39.
44. Vered Y, Sgan-Cohen HD. Self-perceived and clinically diagnosed dental and periodontal health status among young adults and their implications for epidemiological surveys. *BMC Oral Health*. 2003 Dec;3:1–6.