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ORIGINAL ARTICLE

Is tooth loss associated with multiple chronic conditions?

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ABSTRACT

Objectives: To examine the relationship between tooth loss and co-occurrence of multiple chronic conditions (MCC) among American adults at working age.

Materials and methods: Data was from the Behavioural Risk Factor Surveillance System 2018, a cross-sectional telephone-based, nationally representative survey of American adults. We included participants aged 25–64 years. The survey included sociodemographic data, reported diagnosis of chronic conditions, the number of missing teeth and health behaviours. An aggregate variable of chronic conditions was created which included heart attack, angina, stroke, cancer, chronic pulmonary disease, diabetes, asthma, arthritis, depression, and kidney diseases. The association between the number of missing teeth and the aggregate of chronic conditions was assessed adjusting for confounders.

Results: The analysis included 202,809 participants. The mean number of MCC was 0.86 (95% Confidence Interval 'CI':0.85,0.87). Tooth loss was significantly associated with MCC with rate ratio 1.18 (95% CI:1.15,1.21), 1.53 (95% CI:1.48,1.59) and 1.62 (95% CI:1.55,1.69) for those reporting losing 1–5 teeth, 6 or more but not all, and all teeth, respectively after adjusting for demographic, socioeconomic, and behavioural factors.

Conclusion: Tooth loss could be an early marker for the co-occurrence of multiple chronic conditions among adults of working age. The association could be attributed to common risk factors for oral and general health.

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Introduction

Multiple chronic conditions (MCC) are a major concern in public health. Individuals experiencing MCC have poorer health outcomes, such as deteriorated bodily and mental health performance [1,2]. Their need for medical care is also altered. Instead of a highly focused but isolated approach usually used for single disease treatment, MCC patients require a more complex and structured treatment plan [3]. This has a serious impact on disease administration, healthcare utilisation and costs [4]. Unsurprisingly, the occurrence of MCC increases the burden of disease and negatively impacts health status beyond the ability of the healthcare system to cope with every single condition [5]. The impact of MCC is particularly significant when it affects adults at working age as it will have financial consequences and affect the workforce and the productivity of the population [6]. The term multiple chronic conditions are commonly used in the literature along with other terms such as multimorbidity and comorbidity and are defined as the presence of two or more chronic diseases [2,7]. In this paper, the term multiple chronic conditions (MCC) indicates non-communicable diseases.

Oral health could be a neglected risk factor or an early marker of MCC. There is evidence that oral health is related to specific chronic conditions. A recent review highlighted the relationship between common oral conditions, particularly periodontal disease and tooth loss with several chronic conditions [8]. Other reviews demonstrated the association between tooth loss with stroke [9], and depression [10,11]. On the other hand, tooth loss was associated with each asthma, rheumatoid arthritis, emphysema, diabetes, cardiac and liver disease, and obesity in the same population of older adults [12]. Furthermore, another review highlighted the association between complete tooth loss and comorbidity [13]. Recently published papers also assessed this relationship in a large cohort of the Brazilian population and demonstrated that tooth loss was more common among those with multimorbidity [14,15].

The relationship between tooth loss and chronic conditions could be attributed to either nutritional or inflammatory pathways. The absence of teeth leads to an inability to chew and limits the selection of food, subsequently, this could have an effect on nutritional intake and impact general health [16–18]. Furthermore, tooth loss could have resulted from periodontal diseases which have been linked to inflammatory markers associated with systemic conditions [17,19,20]. Tooth loss also impacts appearance and ability to talk, it could lead to low self-esteem, isolation which in turn affects psychological and physical health [10]. These potential pathways aside, oral health and MCC relationship could be attributed to comorbidity due to common risk factors, including behavioural factors

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such as smoking, alcohol consumption and poor diet, which are all linked to poor socioeconomic factors.

Whether tooth loss is a maker of chronic conditions or a potential risk factor, its relationship with the co-occurrence of MCC has been scarcely addressed in the literature [13–15], although in two of these studies, oral health was the dependent variable [14,15]. Therefore, the objective of this study is to examine the relationship between tooth loss and MCC among American adults of working age, and whether this association, if existed, is independent from socioeconomic and behavioural factors.

Materials and methods

Data source and study population

This study used data from Behavioural Risk Factor Surveillance System (BRFSS) 2018, a nationally representative survey of non-institutionalised American adults. Telephone interview which involves both cell phone and landline interviews were used for data collection. The BRFSS has been used repeatedly to examine oral health [21], chronic conditions [22] and their relationship [23]. The 2018 survey was chosen because it is the latest existing survey that has comprehensive data relevant to the research question. This study included American adults of working age (25–64 years).

Outcome variable

The outcome variable was multiple chronic conditions. Participants were asked whether they were told they had any of the following conditions: heart attack, chronic heart disease or angina, stroke, cancer, chronic obstructive pulmonary disease (COPD) or chronic bronchitis, kidney disorder, diabetes, asthma, arthritis and depression. While there is no consensus on what should be included in MCC, as the definition indicates the presence of any two or more conditions [2,7], we included all chronic conditions available in BRFSS as they are also usually used in studies on multiple chronic conditions [24,25]. These ten conditions were added up to create a variable indicating co-occurrence of MCC varying from 0 (no disease) to 10 (all conditions).

Explanatory variable

The main explanatory variable was tooth loss categorised as not losing any tooth, losing 1–5 teeth, losing 6 teeth or more but not all, and edentulous. Tooth loss included permanent teeth removed due to gum disease, infection or dental caries. Participants who were not sure about the number of missing teeth were considered missing.

Covariates and confounders

Demographic variables included age and sex. Age was categorised as 25–34, 35–44, 45–54 and 55–64. Income groups were collapsed into 5 groups: lowest (less than US$15,000), second lowest (US$15,000 to less than 25,000), middle (US$25,000 to less than 35,000), second highest (US$35,000 to less than 50,000) and highest (US$50,000 or more). Education was grouped into less than high school, high school, some collage, and collage graduates. Race/ethnicity was categorised into Whites, Blacks, Hispanics, and Others. Smoking was categorised into never smoked, former smoker, and current smoker. Health insurance indicated whether participants had any public or private health insurance. Physical activity was categorised into yes and no according to if the participants are practicing any other bodily movement or workout other than work-related. Body Mass Index (BMI) was categorised into normal weight (<25), overweight (25–<30), and obese (≥ 30).

Statistical analysis

Stata 16 (StataCorp, College Station, TX, USA) (Stata Technical Support, 2019) was used. Sampling weights and survey commands were used throughout the analysis. First, a descriptive analysis of all variables included in the analysis was conducted, namely multiple chronic conditions (MCC), tooth loss, sex, age, race, education, annual income, health insurance, smoking status, BMI, and physical activity. The mean number of MCC was assessed within each variable. The binary associations between tooth loss and each of the ten chronic conditions were also calculated.

Finally, negative binomial regression was constructed with two models to assess the association between MCC and tooth loss. The first model was adjusted for age, sex, race/ethnicity, and tooth loss. The second model was additionally adjusted for education, income, health insurance, smoking, physical activity, and BMI.

We also conducted a sensitivity analysis including all age groups (18–65 and older), adjusting for all covariates included in the second model of the main analysis.

Results

The analysis included 202,809 participants who had complete data in all variables included in the analysis. Those excluded from the analysis were generally similar to the included sample in terms of demographic characteristics. Table 1 shows the distribution of all variables included in this study and the mean number of MCC within each variable. The mean number of chronic conditions in the whole sample was 0.86 (95% CI: 0.85, 0.86). Edentulous participants had the highest number of chronic conditions (2.17, 95% CI: 2.01, 2.24) followed by those who lost 6 or more teeth but not all (1.75: 95% CI: 1.70, 1.81). Number of chronic conditions were also higher among older participants, Black ethnicity, those with lower education and income, smokers, obese participants and those who did not participate in physical activities (Table 1).

Table 2 shows the association between tooth loss and each of the 10 chronic conditions included in the aggregate of MCC. There were associations between tooth loss and each of the chronic conditions. There was a gradient-like statistically significant relationship between tooth loss and each chronic condition with the prevalence of each condition higher among groups with a greater number of missing teeth. For example, the percentages of participants with a heart attack were 1.7,

Table 1. Distribution of all variables used in the analysis and mean number of multiple chronic conditions (MCC) among American adults aged 25–64, BRFSS 2018, $N = 202,809$.

Variables		Percentage (95% CI)	Mean MCC (95% CI)	p value*
Sex	Male	51.6 (51.1, 51.9)	0.74 (0.73, 0.76)	<.001
	Female	48.4 (48.0, 48.8)	0.99 (0.97, 1.00)	
Age	25–34	25.9 (25.5, 26.3)	0.52 (0.51, 0.53)	Ref
	35–44	24.6 (24.2, 24.9)	0.65 (0.63, 0.67)	<.001
	45–54	24.5 (24.1, 24.8)	0.94 (0.92, 0.97)	<.001
	55–64	25.0 (24.6, 25.4)	1.34 (1.31, 1.36)	<.001
Race	White	62.7 (62.2, 63.1)	0.91 (0.89, 0.92)	Ref
	Black	12.2 (11.9, 12.5)	0.93 (0.90, 0.96)	.210
	Hispanic	17.1 (16.6, 17.5)	0.71 (0.68, 0.74)	<.001
	Others	8.0 (7.7, 8.3)	0.71 (0.68, 0.75)	<.001
Tooth loss	None	60.3 (59.8, 60.7)	0.63 (0.62, 0.64)	Ref
	1–5 teeth	29.1 (28.6, 29.4)	0.96 (0.94, 0.98)	<.001
	6 or more but not all	7.6 (7.4, 7.8)	1.75 (1.70, 1.81)	<.001
	All – edentulous	3.0 (2.8, 3.1)	2.17 (2.01, 2.24)	<.001
Education	<high school	11.3 (11.0, 11.7)	1.17 (1.12,1.22)	Ref
	High school	24.8 (24.3, 25.1)	0.94 (0.92, 0.96)	<.001
	Some collage	30.7 (30.2, 31.1)	0.95 (0.93, 0.97)	<.001
	Collage graduate	33.2 (32.8, 33.6)	0.61 (0.60, 0.62)	<.001
Annual income (US$)	<15,000	9.0 (8.7, 9.2)	1.63 (1.59, 1.68)	Ref
	15,000–<25,000	13.7 (13.4, 14.0)	1.22 (1.19, 1.25)	<.001
	25,000–<35,000	8.7 (8.4, 9.0)	0.94 (0.90, 0.97)	<.001
	35,000–<50,000	11.8 (11.5, 12.1)	0.82 (0.79, 0.85)	<.001
	50,000+	56.8 (56.3, 57.2)	0.65 (0.63, 0.66)	<.001
Health insurance	No	12.9 (12.5, 13.2)	0.74 (0.71, 0.77)	<.001
	Yes	87.1 (86.7, 87.4)	0.88 (0.87, 0.89)	
Smoking	Never smoked	58.1 (57.6, 58.5)	0.67 (0.66, 0.68)	Ref
	Former smoker	23.2 (22.8, 23.6)	1.02 (1.00, 1.04)	<.001
	Current smoker	18.7 (18.3, 19.0)	1.25 (1.25, 1.28)	<.001
Physical activity	No	22.3 (21.9, 22.6)	1.26 (1.23, 1.28)	<.001
	Yes	77.7 (77.3, 78.1)	0.75 (0.74, 0.76)	
BMI	Normal weight	29.8 (29.4, 30.2)	0.68 (0.66, 0.69)	Ref
	Overweight	35.7 (35.2, 36.1)	0.73 (0.71, 0.75)	<.001
	Obese	34.5 (34.1, 34.9)	1.15 (1.13, 1.17)	<.001
Mean number of multiple chronic conditions		0.86 (0.85, 0.87)		

*p value for difference in mean of multiple chronic conditions.

Table 2. Percentages of participants with chronic conditions by number of missing teeth among American adults aged 25–64, BRFSS 2018, $N = 202,809$.

		Percentages (95%CI) within number of missing teeth groups				
Chronic condition	Overall percentage (95% CI)	None	1–5	6 or more, but not all	All-edentulous	Significance*
Heart attack	3.2 (3.1, 3.4)	1.7 (1.5, 1.9)	4.1 (3.7, 4.6)	8.1 (7.4, 8.8)	13.9 (12.1, 15.9)	<.001
Angina or CHD[a]	2.9 (2.8, 3.1)	1.5 (1.4, 1.7)	3.7 (3.3, 4.2)	7.7 (7.0, 8.4)	11.6 (10.0, 13.4)	<.001
Stroke	2.4 (2.3, 2.5)	1.3 (1.2, 1.4)	2.6 (2.3, 2.8)	7.5 (6.7, 8.4)	9.6 (8.5, 10.7)	<.001
Asthma	14.6 (14.3, 14.9)	13.5 (13.1, 13.9)	14.3 (13.7, 14.8)	20.7 (19.5, 21.9)	23.7 (21.9,25.5)	<.001
Cancer[b]	4.7 (4.5, 4.9)	3.6 (3.4, 3.7)	5.2 (4.9, 5.5)	9.6 (8.6, 10.6)	11.1 (9.9, 12.3)	<.001
Pulmonary disease	5.6 (5.4, 5.8)	2.8 (2.6, 3.0)	5.9 (5.6, 6.3)	18.2 (17.1, 19.4)	28.2 (26.3, 30.1)	<.001
Arthritis	22.0 (21.6, 22.3)	15.7 (15.4, 16.1)	25.8 (25.1, 26.5)	45.5 (44.1, 47.0)	51.3 (49.1, 53.5)	<.001
Depression	19.7 (19.4, 20.1)	16.5 (16.1, 16.9)	20.9 (20.3, 21.6)	33.5 (32.1, 34.8)	39.8 (37.6, 41.9)	<.001
Diabetes	9.2 (9.0, 9.5)	5.7 (5.5, 6.0)	12.1 (11.5, 12.7)	20.4 (19.2, 21.7)	23.4 (21.7, 25.2)	<.001
Kidney disease	2.3 (2.2, 2.4)	1.5 (1.4, 1.7)	2.6 (2.4, 2.9)	5.6 (4.9, 6.4)	6.5 (5.6, 7.6)	<.001

*p value from Chi-Square.
[a]Angina or coronary heart disease (CHD).
[b]Any cancer.

4.1, 8.1 and 13.9 for persons with zero, 1–5, 6 or more missing teeth and edentulous, respectively (Table 2).

Tooth loss was significantly associated with greater rates of MCC. Those who lost 1–5 teeth, 6 or more teeth but not all, and edentates had higher rate ratio of MCC of 1.39 (95% CI: 1.36, 1.43), 2.25 (95% CI 2.17, 2.33) and 2.65 (95% CI 2.55, 2.76), respectively compared to those who did not lose any teeth in a model adjusting for age, sex, and ethnicity (Table 3). After further adjustment for socioeconomic, behavioural factors and BMI, the associations between tooth loss and MCC were attenuated but remained significant. Other factors significantly associated with MCC in the fully adjusted model included lower income, smoking, lack of physical activities and obesity, older age and gender (females) (Table 3).

In the sensitivity analysis which included all age groups and adjusted for all variables included in Table 3 in the main analysis, rates of multiple chronic conditions were significantly higher among those who lost teeth than those who did not lose any tooth with rate ratios 1.19 (95% CI:1.16, 1.21), 1.45 (95% CI:1.41, 1.49) and 1.48 (95% CI: 1.44, 1.53) for those who lost 1–5, 6 or more but not all and all teeth, respectively.

Discussion

This study exclusively examined the association between tooth loss and co-occurrence of multiple chronic conditions, namely heart attacks, heart diseases or angina, stroke, cancer,

Table 3. Results of negative binomial regression analysis showing rate ratios and 95% CI for factors associated with multiple chronic conditions (MCC) among American adults aged 25–64, BRFSS 2018, $N = 202{,}809$.

		Rate Ratio for multiple chronic conditions (95% CI)	
Variables		Model 1	Model 2
Sex (Ref: male)		1.32*** (1.29, 1.35)	1.28*** (1.25, 1.31)
Age (Ref: 25–34)	35–44	1.16*** (1.12, 1.20)	1.18*** (1.14, 1.22)
	45–54	1.55*** (1.50, 1.60)	1.57*** (1.52, 1.63)
	55–64	1.98*** (1.91, 2.05)	2.00*** (1.93, 2.07)
Race (Ref: white)	Black	1.01 (0.97, 1.04)	0.88*** (0.85, 0.91)
	Hispanic	0.86*** (0.82, 0.89)	0.76*** (0.73, 0.79)
	Others	0.85*** (0.81, 0.89)	0.88*** (0.84, 0.93)
Tooth loss (Ref: none)	1–5 teeth	1.39*** (1.36, 1.43)	1.18*** (1.15, 1.21)
	6 or more but not all	2.25*** (2.17, 2.33)	1.53*** (1.48, 1.59)
	All – edentulous	2.65*** (2.55, 2.76)	1.62*** (1.55, 1.69)
Education (Ref: <high school)	High school		0.92** (0.89, 0.96)
	Some collage		1.07** (1.03, 1.12)
	Collage graduate		0.96 (0.91, 1.00)
Income (Ref: <15,000) (US$)	15,000–<25,000		0.83*** (0.80, 0.86)
	25,000–<35,000		0.69*** (0.66, 0.72)
	35,000–<50,000		0.60*** (0.57, 0.63)
	50,000+		0.50*** (0.48, 0.52)
Health insurance (Ref: no)			1.27*** (1.22, 1.32)
Smoking (Ref: never smoked)	Former smoker		1.28*** (1.25, 1.32)
	Current smoker		1.43*** (1.33, 1.48)
Physical activity (Ref: no)			0.84*** (0.82, 0.86)
BMI (Ref: normal weight)	Overweight		1.08*** (1.05, 1.11)
	Obese		1.53*** (1.49, 1.58)

Model 1 adjusted for age, sex, race and number of missing teeth.
Model 2 additionally adjusted for education, income, insurance, smoking, physical activity, and BMI.
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

COPD or chronic bronchitis, kidney disorder, diabetes, asthma, arthritis, and depression among American adults aged 25–64 years. Multiple chronic conditions were significantly associated with tooth loss. The relationship between tooth loss and MCC persisted even after accounting for socioeconomic factors, health insurance, behavioural factors and BMI. Tooth loss was also significantly associated with each chronic condition, with the prevalence of the condition successively higher at each group with greater tooth loss.

Two recent studies demonstrated an association between MCC and oral health [14,15], but oral health was used as a dependent variable. However, the current analysis is different as tooth loss was used as an exposure and MCC as the dependent variable. There are also several studies that demonstrated relationships between individual chronic conditions, mortality and tooth loss [9,26–31]. Furthermore, oral health was shown to be associated with frailty index [17] which overlaps with MCC [32]. While previous studies mainly examined the relationship between tooth loss and individual chronic conditions [8], the current analysis demonstrated a persistent and strong association between tooth loss and co-occurrence of MCC among adults of working age.

There are several mechanisms that can explain the relationship between oral health and chronic conditions. The first plausible mechanism is a nutritional pathway including food intake and food selection. Having fewer or no teeth could possibly result in decreased intake of fruits and vegetables and less consumption of micronutrients and proteins and an increased intake of carbohydrates due to the inability to chew, leading to the deterioration of general health [33]. Given that this is cross-sectional data, it is also possible that poor diet is the underlying cause of both MCC and tooth loss.

The second possible link is an inflammatory pathway. Tooth loss could have resulted from gingivitis and periodontitis. Inflammation in the periodontal tissue could be linked to general health [19,20,34]. The third pathway could be through a psychological link, as oral health has an impact on social interactions, isolation, and self-esteem, which in turn have an effect on general health and well-being [35]. Most importantly, the association between tooth loss and co-occurrence of MCC could be a comorbidity due to common risk factors. Behavioural factors such as poor dietary intake, smoking and excessive alcohol consumption are all known risk factors for chronic conditions and oral health, particularly tooth loss. Furthermore, health-risk behaviours tend to cluster among those at the lower end of the social hierarchy [36]. Therefore, poorer socioeconomic conditions undoubtedly contribute to the observed association between tooth loss and the co-occurrence of MCC.

The strengths of this study are in using a large nationally representative sample of American adults, measuring tooth loss among working-age adults and accounting for several confounders for the association between MCC and tooth loss. Additionally, different types of chronic conditions that are usually used in studies about the co-occurrence of multiple chronic conditions [24,25] were aggregated and used. Finally, this is the first study that assessed this association among the working-age population in the USA. The findings suggest that oral health could be an early marker of MCC and should be incorporated in the risk assessment for MCC. Furthermore, oral health promotion and intervention should also be integrated with health promotion targeting populations at risk of MCC.

There are a few limitations of this analysis that needs to be mentioned. The cross-sectional nature of the survey does

not allow a conclusion on temporality or causality. Data on chronic conditions and oral health were self-reported and subjected to recall bias. Due to data limitation, physical activity was categorised into 'yes' versus 'no' which does not reflect its frequency and intensity. Furthermore, there are other risk factors for chronic conditions which were not available in the BRFSS. The current research relied on data collected through telephone interviews, which is considered a more efficient way to collect data and is usually comparable to data collected in face-to-face interviews. However, telephone interviews have some limitations such as a lack of visual aid that could be used in a face-to-face interview. Individuals could also respond differently in telephone and face-to-face interviews [37].

This study has shown that there is a significant association between tooth loss and co-occurrence of multiple chronic conditions, which persisted even after adjusting for socioeconomic, behavioural factors and BMI. Tooth loss could be an early marker for the co-occurrence of multiple chronic conditions among American adults of working age. The association could be attributed to common risk factors for oral and general health.

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