

# Depression, periodontitis, caries and missing teeth in the USA, NHANES 2009–2014

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## ABSTRACT

**Purpose** This study aimed to investigate the association between self-reported depressive symptoms and oral diseases in US adults, including periodontitis, caries, missing teeth and untreated dental caries.

**Design** This study was designed as a secondary data analysis of a cross-sectional survey. We conducted descriptive, multivariable logistic and Poisson regression analyses on weighted data.

**Setting** US National Health and Nutrition Examination Survey 2009–2014 data.

**Participants** Individuals aged ≥30 years who completed a periodontal examination and depression screening (n=9799).

**Results** 21.6% (28.9 million) of adults aged ≥30 years reported depressive symptoms, with a higher prevalence among females, current smokers and participants with lower income and education status. More than half of the adults with moderate depressive symptoms had periodontal diseases, and more than one-third had teeth with untreated dental caries. After adjusting for sociodemographics, behavioural factors, having diabetes and psychotherapeutic medication use, depressive symptoms were associated with poorer oral health. Severe depressive symptoms were associated with higher odds of mild periodontitis (2.20; 99% CI 1.03 to 4.66). For those with mild depressive symptoms, the mean number of missing teeth was 1.20 (99% CI 1.06 to 1.37) times the average of non-symptomatic individuals; and 1.38 times (99% CI 1.15 to 1.66) among individuals with moderate depressive symptoms.

**Conclusions** Depressive symptoms were associated with mild periodontitis and a greater number of missing teeth, while having teeth with untreated dental caries was attributed to sociodemographic factors. Awareness of oral health status among patients with depressive symptoms can inform both dental and mental health providers to develop tailored treatment and help patients achieve overall wellness.

## INTRODUCTION

Depression is a diagnosable and treatable health condition distinct from experiences that occur normally from time to time such as feelings of fear, sadness or stress. Based on certain symptoms, depressive disorders are categorised into major depressive disorders,

## Key point

- Question: Is there an association between self-reported depressive symptoms and oral disease among US adults?
- Finding: Our research found that US adults with depressive symptoms tend to have poorer oral health.
- Meaning: Individuals with depressive symptoms may unnecessarily suffer from oral health-related outcomes that decrease their quality of life if not addressed. Both dental and mental health providers can work together to develop a tailored treatment plan and help patients achieve overall wellness.

persistent depressive disorders and specified or unspecified depressive disorders.<sup>1</sup> Symptoms of depression can include increased risk for social isolation, feelings of hopelessness, restlessness, difficulty performing any activity, aches or pains and substance abuse.<sup>2–5</sup> In severe cases, depression is associated with increased risk of suicidal ideation, suicide attempts and death.<sup>6</sup> As depressive symptoms are heterogeneous, not everyone who is depressed exhibits the same symptoms; hence, depression might manifest in different symptoms depending on an individual's age, ethnicity, lifestyle and other socio-demographic conditions.

WHO reported that, globally, more than 300 million people (4.4% of the world population) were living with depression in 2015, an increase of almost 18% from 2005.<sup>7</sup> According to the National Institute of Health, depression is the most common mental health disorder in the USA.<sup>8</sup> Using the Patient Health Questionnaire-9 (PHQ-9) to diagnose depression, the National Health and Nutrition Examination Survey (NHANES) cycle in 2018 showed 8.1% of adults aged 20 or older had depression in USA.<sup>5</sup> Depression was most prevalent among non-Hispanic whites (9.2%) and almost twice as prevalent among women (10.4%) than men (5.5%).<sup>5</sup>

Several studies have reported depressive symptoms to be associated with poorer health and physical illness such as coronary heart disease, obesity and sleep deprivation.<sup>9–11</sup> The association of depressive disorders with poor oral health has also been reported in the dental literature. Similar to the impact of oral disease, the consequences of depression affect the overall well-being of the individual, not just their mental health.<sup>12</sup> Nationally, data show a relationship between poor oral health and depressive symptoms, independent of inflammatory pathways associated with increased C reactive protein and/or obesity.<sup>13</sup> A positive association has been demonstrated between poor oral health (ie, untreated tooth decay and tooth loss) and depressive disorders. However, the studies used in this 2016 systematic review used small sample sizes and often presented self-reported oral diseases.<sup>14</sup> In 2018, a systematic review and meta-analysis consistently reported tooth decay, tooth loss and edentulism associated with depression.<sup>15</sup>

Our study addresses the gaps presented in the currently available literature by including objective, clinical dental examination data instead of solely self-reported oral diseases. Using the most recent NHANES data, we evaluate the associations among different severities of depressive symptoms with clinically assessed oral diseases and missing teeth in non-institutionalised US adults.

## MATERIALS AND METHODS

### Study design and population

We used pooled NHANES data from 2009 to 2014. NHANES is a cross-sectional, nationally representative survey of the non-institutionalised US population that collects data via self-reported questionnaires, laboratory assessments and clinical exams.<sup>16</sup> Participants in the analytical sample were at least 30 years old and had completed an NHANES oral examination and a nine-item screening and diagnostic tool for depression called the PHQ-9.<sup>16</sup> The PHQ-9 is designed to measure depressive symptoms within a 2-week period before the survey that align with the American Psychiatric Association's diagnostic criteria for depressive disorders.<sup>17–19</sup> While a diagnosis of depression typically does not rely solely on a single questionnaire, cut-off scores for the diagnosis of severe depression have been developed and validated using the PHQ-9.<sup>20</sup>

The total sample size included 9799 participants in the three pooled cycles with periodontal examination data from 2009 to 2014 as well as 7011 participants in the two pooled cycles with clinical data recording dental caries and missing teeth from 2011 to 2014. The unweighted response rate of the examined sample was 77% from 2009 to 2010, 69.5% from 2011 to 2012, and 68.5% from 2013 to 2014. Written informed consent was obtained from all participants.

### Clinical assessment of oral diseases

Calibrated dental examiners performed all clinical examinations of periodontal and dental status for NHANES participants. Using the definitions from the Centers for Disease Control and Prevention and the American Academy of Periodontics /, periodontal status was categorised into three groups: severe, moderate and mild. Periodontitis was deemed severe if there were two or more interproximal sites with  $\geq 6$  mm of loss of attachment (not on the same tooth) and one or more interproximal sites with probing depths of  $\geq 5$  mm. Moderate periodontitis was defined as two or more interproximal sites with  $\geq 4$  mm of loss of attachment (not on the same tooth) or two or more interproximal sites with probing depths of  $\geq 5$  mm (not on the same tooth). Mild periodontitis was defined as either two or more interproximal sites with  $\geq 3$  mm of loss of attachment and two or more interproximal sites with  $\geq 4$  mm of probing depths (not on the same tooth) or one or more interproximal sites with probing depths of  $\geq 5$  mm.

The presence of any periodontitis at all was also recorded as an aggregate measure.<sup>21</sup> Additionally, we assessed the prevalence of participants with untreated dental caries, the number of teeth with untreated dental caries and the number of missing teeth.

### Definition of depression and confounding factors

The severity of depressive symptoms was measured using the PHQ-9, a nine-item screening instrument that measures the frequency of self-reported depression-related symptoms over the 2 weeks preceding the questionnaire. Based on the frequency of the symptoms, participants responded to each question by ranking symptom frequency: 0 for 'not at all,' 1 for 'several days,' 2 for 'more than half the days' and 3 for 'nearly every day.' The PHQ-9 classifies the severity of depressive symptoms based on the total score. A total score in the range of 0–4 classifies depressive symptoms as minimal; 5–9 classifies depressive symptoms as mild; 10–14, moderate and 15–27, severe.<sup>17–18</sup>

Other independent variables we included in the analysis were: age (30–34, 35–49, 50–64, 65+), sex (male or female), family income ratio to the federal poverty level (<100%, 100%–199%, 200%–499%, 500%+), education level (less than high school, completed high school/GED and education beyond high school), race/ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic other and Hispanic), smoking status (never, former or current smoker), current heavy alcohol consumption ( $\geq 2.5$  drinks/day for men,  $\geq 1.5$  drinks/day for women), use of psychotherapeutic medications (taking antidepressant and/or antipsychotic medication, not taking psychotherapeutic medications) and report of diagnosed diabetes mellitus (diabetic, non-diabetic).

### Statistical analysis

We obtained descriptive statistics to examine the prevalence of depressive symptoms for each independent

factor; then, we estimated the overall prevalence and severity of oral diseases among the four levels of depressive symptoms. With the corresponding 99% CI, we reported the prevalence of periodontitis, the presence of untreated dental caries, the average number of teeth with untreated dental caries, and the number of missing teeth. Weighted percentages were used to report nationally representative results. We also performed analyses on pooled data across cycles of NHANES and recalibrated the weights by dividing them by the number of cycles; then, we used these recalibrated weights to accurately extrapolate the population counts. For SE estimations, we used Taylor linearisation methods in the survey procedures with the provided masked variance pseudostratum and masked variance pseudoprimary sampling units.

We used logistic regression models for binary oral disease regarding mild to moderate to severe periodontitis and the presence of untreated dental caries. Poisson regression models were used for the mean numbers of missing teeth and teeth with untreated dental caries to estimate crude and adjusted measures of association between depressive symptoms and study endpoints. To determine OR, we applied simple and multivariable logistic regressions to estimate the crude and adjusted OR of periodontal diseases and untreated dental caries, comparing the levels of the severity of depressive symptoms to individuals with no reported depressive symptoms. Additionally, we used Poisson regressions to estimate the mean ratio of missing teeth and teeth with untreated dental caries to the severity level of reported depressive symptoms, using individuals without depressive symptoms as a reference. We controlled for the independent confounding factors in all multivariable regression models for the adjusted estimates, the directed acyclic graph (online supplemental figure 1) provides a visual model for our assumptions. The results were deemed statistically significant at  $p < 0.01$ , and all statistical analyses were performed using Stata/MP V.16.1 (StataCorp).

## RESULTS

Among non-institutionalised US adults aged  $\geq 30$  years, 21.6% of them reported having at least mild depressive symptoms within the last 2 weeks on the PHQ-9 (table 1). The highest prevalence of depressive symptoms was among females, current smokers and heavy alcohol drinkers. Additionally, the data showed that the prevalence of depressive symptoms was higher among individuals with lower education level, lower income, those taking antipsychotherapeutic medications and patients with diabetes.

Among US adults aged  $\geq 30$  years, the prevalence of mild, moderate or severe periodontitis was 42.1% (99% CI 38.3% to 46.0%), and the prevalence of having at least one tooth with untreated dental caries was 21.5% (99% CI 18.5% to 24.5%) (table 2). The average number per participant of teeth with an untreated carious lesion was 0.6 (99% CI 0.5 to 0.8) and of missing teeth was 4.9 (99%

CI 4.2 to 5.6). Table 2 also shows that participants with moderate depressive symptoms had the highest prevalence of periodontal disease—nearly half (52.4%; 99% CI 44.9% to 60.0%)—as well as the highest prevalence of teeth with untreated dental caries (36.3%; 99% CI 26.1% to 46.5%). This group averaged 1.1 teeth with untreated dental caries (99% CI 0.7 to 1.5) and 8.1 (99% CI 6.2 to 10.1) missing teeth.

Table 3 shows that periodontitis was more prevalent in participants reporting moderate and severe depressive symptoms than in participants reporting no depressive symptoms. After adjusting for potential confounding factors, the association between depressive symptoms and periodontitis disappeared, except among individuals with severe depressive symptoms who had 2.20 times the odds of mild periodontitis (99% CI 1.03 to 4.66) than individuals without depressive symptoms.

The mean number of teeth with untreated dental caries was higher in individuals who reported moderate (crude mean ratio=1.87; 99% CI 1.25 to 2.80) and severe (crude mean ratio=1.65; 99% CI 1.10 to 2.48) depressive symptoms than in individuals who reported no depressive symptoms; however, this association disappeared after adjusting for confounding factors (table 4). The crude mean ratio of missing teeth was higher among symptomatic individuals than among individuals with no depressive symptoms. Participants with mild depressive symptoms had a greater mean number of missing teeth than individuals with no depressive symptoms (adjusted mean ratio=1.20; 99% CI 1.06 to 1.37), and individuals with moderate depressive symptoms had even a higher mean number of missing teeth (adjusted mean ratio=1.38; 99% CI 1.15 to 1.66).

## DISCUSSION

Our study has addressed current gaps in the literature by using a secondary analysis of nationally representative NHANES data to explore the associations between self-reported depressive symptoms and an objective report of clinical oral diseases. While depressive symptoms are usually collapsed into just two categories of respondents—those who reported moderate depressive symptoms and those who did not—our paper increases the granularity of the data by evaluating four separate levels of depression symptoms. Among non-institutionalised US adults aged  $\geq 30$  years, about one-fifth reported having at least mild depressive symptoms within the last 2 weeks on the PHQ-9. For clinical oral diseases, participants received complete clinical periodontal and dental examinations (in 2009–2014 cycles and in 2011–2014 cycles, respectively) which included more objective clinical data that help achieve more accurate diagnoses. Generally, depressive symptoms were associated with poor oral health, and participants with mild and moderate depressive symptoms were missing more teeth than individuals with no depressive symptoms.

**Table 1** Demographics and prevalence of depression among adults who have completed a periodontal examination and the PHQ-9 depression screening questionnaire in the National Health and Nutrition Examination Survey, 2009–2014

	No symptoms		Mild depressive symptoms		Moderate depressive symptoms		Severe depressive symptoms	
	Overall no (%) <sup>*</sup>	Weighted US population	(%)	Weighted US population	(%)	Weighted US population	(%)	Weighted US population
Overall	9799 (100.0)	105225000	14.2	19095000	4.5	6021000	2.9	3827000
Age								
30–34	1174 (12.1)	12628000	14.8	2407000	5.1	825000	2.3	370000
35–49	3352 (36.8)	38102000	14.8	7311000	4.7	2297000	3.4	1666000
50–64	3133 (33.3)	34699000	14.3	6363000	4.9	2205000	3.1	1383000
65+	2140 (17.8)	19795000	12.6	3014000	2.9	693000	1.7	408000
Gender								
Male	4912 (49.8)	55338000	11.9	7955000	3.3	2177000	1.9	1300000
Female	4887 (50.2)	49887000	16.5	11140000	5.7	3843000	3.7	2527000
Race/ethnicity								
Non-Hispanic White	4314 (70.0)	74302000	14.0	13039000	4.0	3730000	2.5	2313000
Non-Hispanic Black	2016 (10.4)	10274000	16.1	2234000	5.8	804000	4.1	574000
Hispanic	2377 (13.3)	13340000	15.2	2694000	5.9	1055000	3.9	688000
Other	1092 (6.8)	7310000	12.4	1128000	4.7	432000	2.8	252000
Education								
Less than high school	2205 (14.7)	13812000	16.2	3180000	7.7	1508000	5.8	1136000
High school	2118 (20.9)	21244000	16.3	4575000	4.6	1299000	3.3	923000
More than high school	5466 (64.4)	70100000	13.1	11327000	3.7	3214000	2.0	1767000
Poverty								
<100% FPL	1672 (11.4)	8857000	19.7	2822000	10.3	1467000	8.2	1169000
100%–199% FPL	2292 (18.8)	16752000	17.3	4079000	7.6	1803000	4.2	1001000
200%–499% FPL	2401 (29.0)	28756000	15.3	5576000	3.6	1320000	2.3	855000
>500% FPL	2668 (40.9)	44446000	10.3	5295000	2.2	1129000	1.2	635000
Smoking status								
Never	5447 (56.1)	61865000	12.5	9423000	3.1	2346000	2.1	1563000
Former	2501 (26.7)	28380000	14.0	5030000	4.2	1506000	2.6	924000
Current	1847 (17.2)	14950000	20.1	4642000	9.4	2169000	5.8	1340000
Current alcohol consumption								
Non-heavy drinker	8135 (93.4)	89872000	13.8	15589000	4.1	4583000	2.4	2749000
Heavy drinker	529 (6.6)	5775000	18.4	1473000	5.5	443000	4.1	327000

Continued

**Table 1** Continued

	No symptoms		Mild depressive symptoms		Moderate depressive symptoms		Severe depressive symptoms	
	Overall no (%) <sup>*</sup>	Weighted US population (%)	Weighted US population (%)	Weighted US population (%)	Weighted US population (%)	Weighted US population (%)	Weighted US population (%)	Weighted US population (%)
Taking psychotherapeutic medications								
No	8681 (86.3)	82.2	94713000	12.6	14556000	3.3	3746000	2.0
Yes	1075 (13.7)	55.1	10122000	24.3	4454000	12.3	2250000	8.4
Diabetes status								
Non-diabetic	8547 (90.2)	79.5	96113000	13.7	16518000	4.2	5092000	2.7
Diabetic	1247 (9.8)	69.1	9085000	19.6	2574000	7.1	928000	4.3

<sup>\*</sup>The sample counts were unweighted while percentages are weighted to account for complex survey design. The weighted population counts are rounded to the nearest 100. FPL, federal poverty level.

**Table 2** Prevalence of types of periodontitis, presence of untreated caries, mean number of teeth with untreated caries and missing teeth by depressive symptoms among adults aged ≥30 years who completed a periodontal examination and the PHQ-9 depression screening questionnaire in the National Health and Nutrition and Examination Survey

Severity of depressive symptoms	Periodontitis (2009–2014) (n=9799)				Dental caries and missing teeth (2011–2014) (n=7011)			
	Any periodontitis %* (99% CI)		Mild periodontitis %* (99% CI)		Presence of untreated dental caries %* (99% CI)		Mean number of teeth with untreated dental caries N† (99% CI)	
	Moderate periodontitis %* (99% CI)		Severe periodontitis %* (99% CI)		Mean number of missing teeth N† (99% CI)			
Overall population	42.1 (38.3 to 46.0)	4.4 (3.4 to 5.3)	30.0 (26.8 to 33.1)	7.8 (6.4 to 9.2)	21.5 (18.5 to 24.5)	0.6 (0.5 to 0.8)	4.9 (4.2 to 5.6)	
No depressive symptoms	41.2 (37.3 to 45.1)	4.2 (3.3 to 5.2)	29.4 (26.3 to 32.6)	7.6 (6.2 to 9.0)	19.4 (16.2 to 22.6)	0.6 (0.4 to 0.7)	4.3 (3.6 to 5.0)	
Mild depressive symptoms	43.9 (37.1 to 50.1)	4.1 (2.5 to 5.7)	31.0 (25.2 to 36.7)	8.8 (6.0 to 11.6)	25.7 (21.2 to 30.1)	0.7 (0.5 to 0.8)	6.4 (5.1 to 7.6)	
Moderate depressive symptoms	52.4 (44.9 to 60.0)	6.7 (2.6 to 10.9)	36.4 (30.1 to 42.7)	9.3 (4.1 to 14.6)	36.3 (26.1 to 46.5)	1.1 (0.7 to 1.5)	8.1 (6.2 to 10.1)	
Severe depressive symptoms	42.5 (30.7 to 54.4)	6.5 (2.0 to 10.9)	30.0 (20.1 to 39.8)	6.1 (3.0 to 9.2)	31.6 (24.6 to 38.5)	1.0 (0.6 to 1.3)	8.0 (5.6 to 10.3)	

<sup>\*</sup>Weighted percentages.

<sup>†</sup>Weighted mean.

PHQ-9, Patient Health Questionnaire-9.

**Table 3** Logistic regression models of associations between depressive symptoms and periodontitis as well as presence of untreated dental caries among adults aged  $\geq 30$  years who completed a periodontal examination and the PHQ-9 depression screening questionnaire in the National Health and Nutrition and Examination Survey; 2009–2014 for periodontitis, 2011–2014 for dental caries

	Any periodontal disease		Mild periodontal disease		Moderate periodontal disease		Severe periodontal disease		Presence of untreated dental caries	
	Crude OR (99% CI) (n=9799)	Adjusted OR (99% CI) (n=7946)	Crude OR (99% CI) (n=9799)	Adjusted OR (99% CI) (n=7946)	Crude OR (99% CI) (n=9799)	Adjusted OR (99% CI) (n=7946)	Crude OR (99% CI) (n=9799)	Adjusted OR (99% CI) (n=7946)	Crude OR (99% CI) (n=7011)	Adjusted OR (99% CI) (n=5597)
<b>Severity of depressive symptoms</b>										
No symptoms	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Mild depressive symptoms	1.11 (0.89 to 1.39)	0.98 (0.72 to 1.32)	0.97 (0.66 to 1.44)	1.05 (0.66 to 1.66)	1.07 (0.87 to 1.33)	0.92 (0.72 to 1.19)	1.18 (0.86 to 1.62)	1.17 (0.75 to 1.81)	1.44* (1.23 to 1.83)	1.18 (0.87 to 1.59)
Moderate depressive symptoms	1.57* (1.13 to 2.18)	1.08 (0.70 to 1.66)	1.64 (0.85 to 3.17)	1.59 (0.74 to 3.40)	1.37* (1.01 to 1.87)	1.02 (0.68 to 1.53)	1.26 (0.69 to 2.28)	1.01 (0.49 to 2.05)	2.38* (1.48 to 3.83)	1.61 (0.89 to 2.90)
Severe depressive symptoms	1.05 (0.66 to 1.70)	0.71 (0.41 to 1.24)	1.57 (0.73 to 3.38)	2.20* (1.03 to 4.66)	1.03 (0.66 to 1.60)	0.74 (0.47 to 1.17)	0.79 (0.46 to 1.37)	0.54 (0.27 to 1.10)	1.92* (1.32 to 2.79)	1.19 (0.69 to 2.06)

Adjusted for age, sex, race/ethnicity, education, income, cigarette smoking, heavy alcohol consumption, psychotherapeutic medications and diabetes.

\* $p < 0.01$

PHQ-9, Patient Health Questionnaire-9; Ref, reference group.

Limitations to this study include participation and reporting bias, challenges with temporality and a limited population. We controlled for potential known confounding factors to strengthen the internal validity of the estimates; however, problems with participation and reporting bias could present limitations on the data. For instance, populations with the most severe depressive symptoms may disproportionately choose not to participate in the survey. Additionally, while the PHQ-9 has been shown to successfully screen and diagnose depressive symptoms, it is not able to identify participants who received successful treatment for depression; thus, it requires participants to self-report symptoms over time, another process that can be susceptible to reporting bias. Second, because NHANES is a cross-sectional survey, we cannot evaluate the temporal relationship between depression and any oral diseases, or the duration of depressive symptoms. Finally, the dental examination was performed among non-institutionalised adults that were at least 30 years old, which limits our ability to evaluate the association between depression and oral health among a younger population or vulnerable populations that are institutionalised.

In a systematic review published by Kisely *et al*, the authors included fifteen papers to assess the relationship between psychiatric status and periodontal diseases. Five of these papers specifically examined depression and periodontitis; however, this review demonstrated no significant association between psychiatric status and periodontitis (pooled OR 0.99; 95% CI 0.93 to 1.06).<sup>14</sup> We noted a considerable amount of heterogeneity between the included studies and methods that collapsed periodontitis diseases into a dichotomous disease. Similarly, a more recent systematic review and meta-analysis published in 2018 also found no association between depression and periodontitis (pooled OR 0.96; 95% CI 0.84 to 1.10)<sup>15</sup>; the authors found only one study showing an increased risk of depression among individuals with periodontitis (HR 1.73; 95% CI 1.58 to 1.89).<sup>22</sup>

After adjusting for confounding factors, our results indicate that participants with severe depressive symptoms have higher odds of mild periodontitis than participants with no depressive symptoms. This mild form of periodontitis among individuals with severe depressive symptoms could be explained by the disinterest in practising appropriate oral hygiene.<sup>23</sup> However, depressive symptoms were not associated with moderate or severe periodontitis, as severe forms of periodontitis require longer periods to manifest, and the breakdown of teeth-supporting structures leads to the loss of teeth if neglected long enough. This possible explanation is supported by our finding that more missing teeth are found among individuals with mild or moderate depressive symptoms, possibly caused by severe untreated disease that resulted in a tooth extraction. Since teeth that are missing are not susceptible to other oral diseases, we believe the absence of the relationship between depressive symptoms and periodontitis can be explained by the increased number

**Table 4** Poisson regression analysis of the associations of depressive symptoms with mean number of teeth with untreated caries and missing teeth among adults aged  $\geq 30$  years who completed a periodontal examination and the PHQ-9 depression screening questionnaire in the National Health and Nutrition and Examination Survey; 2011–2014

	Mean no of teeth with untreated caries		Mean no of missing teeth	
	Crude mean ratio (99% CI) (n=7011)	Adjusted mean ratio (99% CI) (n=5597)	Crude mean ratio (99% CI) (n=7011)	Adjusted mean ratio (99% CI) (n=5597)
<b>Severity of depressive symptoms</b>				
No symptoms	Ref	Ref	Ref	Ref
Mild depressive symptoms	1.14 (0.86 to 1.50)	0.88 (0.64 to 1.20)	1.48* (1.23 to 1.78)	1.20* (1.06 to 1.37)
Moderate depressive symptoms	1.87* (1.25 to 2.80)	1.04 (0.62 to 1.74)	1.90* (1.53 to 2.35)	1.38* (1.15 to 1.66)
Severe depressive symptoms	1.65* (1.10 to 2.48)	0.97 (0.63 to 1.50)	1.85* (1.32 to 2.60)	1.38 (0.93 to 2.05)

Adjusted for age, sex, race/ethnicity, education, income, cigarette smoking, heavy alcohol consumption, psychotherapeutic medications and diabetes.

\* $P < 0.01$ .

PHQ-9, Patient Health Questionnaire-9; Ref, reference group.

of missing teeth among patients reporting depressive symptoms.

Our findings suggest the severity of depressive symptoms is associated with a higher average of missing teeth than in non-depressive individuals, which coincides with the findings from several studies in the literature.<sup>14 15 24 25</sup> We believe the influence of missing teeth among individuals reporting mild or moderate depressive symptoms could also explain our results regarding depression and dental caries. Although other studies have indicated an association between dental caries and depression, our research showed the association between the severity of depressive symptoms and dental caries to be eliminated after controlling for the confounding factors.<sup>14 15</sup> Again, the extraction of affected dentition would explain the higher number of missing teeth, and the influence these missing teeth have on dissolving the association between dental caries and depressive symptoms. Differences between our findings and the findings from the literature might also be attributed to different methods of depression assessment, differences in the population studied, or differences in oral examination protocols and diagnosis.

The current NHANES data indicate that nearly one out of five US adults aged 30 or above report depressive symptoms.<sup>5</sup> Research indicates an overall association between depressive symptoms with adverse oral diseases. Although some studies investigate the effects of depressive disorders or mental illnesses generally while others focus on one specific type of depression, the most-reported adverse oral diseases have tended to be tooth decay, tooth loss, edentulism, dryness of the mouth and a decreased overall oral health-related quality of life. In general, individuals with depressive disorders can find activities of daily living, such as oral hygiene, challenging and may consume a cariogenic diet which in turn can lead to periodontal diseases and development of dental caries.<sup>26</sup>

The National Center for Health Statistics reports 12.7% of the population has taken an antidepressant medication in the last month.<sup>27</sup> Our analysis adjusted for individuals taking antidepressant and/or antipsychotic medications,

the rationale being that psychotherapeutic medications has been associated with a significantly greater risk for symptoms of xerostomia (dry mouth).<sup>28</sup> Xerostomia is reported as the most common side effect of both antidepressants and antipsychotics and has been associated with a decreased salivary flow rate.<sup>29</sup> A decreased flow rate, in turn, results in a lower salivary pH and reduced buffering capacity.<sup>30</sup> As a result, patients with depressive symptoms taking antidepressants often suffer from medication-induced xerostomia or MiX disease. A cross-sectional study evaluated the differences between three groups of medically compromised patients: one group taking chronic medications not associated with xerostomia, one group taking a single drug associated with xerostomia, and one group taking multiple medications associated with xerostomia. The study showed statistically and clinically significant differences in unstimulated salivary flow, reporting of symptoms associated with xerostomia, and decreased quality of life with patients who take one or more xerostomic medications.<sup>31</sup> Another recently published case report supplements these findings, connecting the oral environmental changes caused by MiX disease to resultant severe oral disease.<sup>32</sup>

As oral health professionals, we are tasked with treating the whole person. In the case of patients with depressive symptoms, this involves offensive preventive dental treatment that includes addressing symptoms associated with depression medications, early diagnosis and treatment of oral disease, and helping patients with an oral hygiene routine that supports their oral health and ability to perform the activities of daily living.<sup>32</sup> Moving forward, we recommend research exploring the temporal relationship between depression diagnosis, symptom severity and oral diseases.

## CONCLUSIONS

Severe depressive symptoms were associated with a higher prevalence of mild periodontitis. In addition, mild and moderate depressive symptoms were associated with a

higher number of missing teeth. In our analysis, depressive symptoms were not associated with greater odds of having teeth with untreated dental caries, mean number of carious lesions or moderate to severe periodontitis. Awareness of oral health status among patients with depression can encourage both dental and mental health providers to recognise oral diseases in a timely fashion, provide offensive preventive dentistry and encourage patients to continue to access regular and comprehensive oral healthcare.

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