Investigation

Self-reported oral health is associated with systemic health outcomes and all-cause mortality

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ABSTRACT

Background. Self-reported oral health questions (OHQs) are used commonly for epidemiologic surveillance of periodontal disease (PD). The authors' objective was to investigate how OHQs are associated with well-established systemic comorbidities of PD and their impact on all-cause mortality. The authors hypothesized that OHQs exhibit associations with systemic comorbidities similar to PD.

Methods. Two independent data sets were used to achieve these objectives: the Women's Health Study, a prospective cohort of women 45 years or older with self-reported information on PD, OHQs, cardiovascular disease, diabetes, and osteoporosis in various timeframes (continuous from 1992) and the National Health and Nutrition Examination Survey (NHANES), with data on OHQs and linked mortality (1999-2018). The authors applied multivariate logistic regression models and Cox proportional hazard regression survival analyses to test their hypotheses.

Results. The Women's Health Study participants who reported having PD until 2006 were more likely to later report deteriorating oral health, bone loss around their teeth, or periodontal treatment in 2018. Self-rated fair or poor oral health was independently associated with increased risk of cardiovascular disease (odds ratio, 1.39; 95% CI, 1.14 to 1.69; $P < .001$), diabetes (odds ratio, 1.21; 95% CI, 1.02 to 1.43; $P = .028$), and osteoporosis (odds ratio, 1.60; 95% CI, 1.38 to 1.84; $P < .001$). National Health and Nutrition Examination Survey participants who self-rated fair or poor oral health had higher risks of all-cause mortality (hazard ratio, 1.18; 95% CI, 1.02 to 1.37; $P = .027$).

Conclusions. Self-reported oral health had a similar magnitude of associations with systemic comorbidities as established with PD previously. Moreover, self-rated fair or poor oral health, suboptimal dental visits, or infrequent flossing were associated with increased all-cause mortality.

Practical Implications. These results support the use of OHQs in assessing systemic connections, especially when clinical dental access is limited. This clinical trial was registered at ClinicalTrials.gov. The registration number is NCT00000479.

Key Words. Oral health; surveys and questionnaires; periodontal disease; cardiovascular disease; diabetes mellitus; osteoporosis; mortality.

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Periodontal disease (PD) affects approximately 42% of US adults; 7.8% have its severe form.[1,2] PD is a microbially induced chronic inflammatory disease; factors such as cigarette smoking and genetics influence severity.[3] Researchers have established associations between PD and systemic conditions, including cardiovascular disease (CVD),[4,5] type 2 diabetes,[6-8] and osteoporosis.[9] Furthermore, reports from large epidemiologic cohorts have used self-reported PD diagnosis to explore associations with cardiovascular outcomes.[4,10-13]

Centers for Disease Control and Prevention and the American Academy of Periodontology developed plain-language oral health questions (OHQs) for assessing periodontal status.[14,15] These OHQs have been validated and used in the National Health and Nutrition Examination Survey (NHANES)[15] and were also adopted in the UK Biobank[16] and the Million Veterans Program.[17]

Self-reported OHQs provide new opportunities for exploring associations between oral health and systemic health in the absence of comprehensive clinical examinations. Survey approaches using OHQs may facilitate accessing oral health among disadvantaged populations who lack oral health care.[18] However, unlike earlier reports based on self-reported PD diagnosis, there has been limited research on the association between OHQs and systemic health outcomes. In our study, we aimed to investigate how OHQs are related to well-established systemic comorbidities of PD and their impact on all-cause mortality. We hypothesized that OHQs have associations with systemic comorbidities that are comparable with PD, providing valuable insights in situations in which clinical assessment is unavailable.

The Women's Health Study (WHS) was a prospective cohort study in the United States; researchers investigated initially healthy women 45 years or older with multiple systemic health outcomes.[19-21] Uniquely, WHS participants self-reported their PD diagnosis from 1992 through 2006, and, in 2018, validated OHQs were administered to the WHS participants. Previously, researchers found that there was a greater likelihood of developing PD among WHS participants with a family history of myocardial infarction.[22] Therefore, we first aimed to compare the 2018 self-reported OHQs with earlier self-reported PD data (1992-2006) among the WHS participants. Secondly, analyses were conducted to assess connections between 2018 OHQs and established systemic comorbidities of PD, namely CVD,[4,5] diabetes,[6-8] and osteoporosis.[9] Lastly, we re-examined such associations between OHQs and systemic health outcomes in the NHANES study by means of linking longitudinal mortality data. Researchers previously reported that the number of remaining natural teeth in NHANES data indicated risks of all-cause and disease-specific mortality.[23] Because NHANES data included dental visit history, self-rated teeth and gingival health, and dental flossing data linked to mortality through December 31, 2019, our investigation independently examined whether self-reported oral health correlated with all-cause mortality, which complements the WHS study.

METHODS

Study design and population

Figure 1 displays the chronological data collections in the WHS and NHANES data sets. Two independent studies were analyzed in this study. First, the WHS was a prospective cohort study that originally began as a clinical trial from 1992 through 1994 to test the benefits and risks of low-dose aspirin and vitamin E in the primary prevention of CVD and cancer. Annual follow-up questionnaires included self-reported PD status from the study inception through December 31, 2005. In 2018, oral health questions were administered to gather additional information on oral health conditions. Systemic outcomes, such as cardiovascular events and incidence of diabetes, were assessed annually throughout the study period (through December 31, 2018). In addition, osteoporosis was evaluated in 2009 using bone density reports. The WHS previously reported that women with baseline or incident PD had a higher risk of cardiovascular events. The second study used in this report was the NHANES. As of December 31, 2019, there were 59,062 participants eligible for mortality data linkage. We analyzed NHANES participants who had complete information on the number of teeth, demographic characteristics, education, income, cigarette smoking, body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared), existing health conditions (ie, CVDs, diabetes, hypertension, and stroke), and physical activities. Among them, 29,510 NHANES participants provided information on their last dental visit (collected from 1999-2004 and from 2011-2018), 21,488 responded to the question regarding "self-rated oral health (teeth and gums)," and 18,392 answered the question regarding the frequency of dental flossing. Both self-rated oral health (teeth and gingivae) and frequency of dental flossing were collected from 2009 through 2018. Detailed characteristics of NHANES participants can be found in eTables 1 through 4 (available online at the end of the article).

WHS

The WHS was initially designed as a 10-year randomized clinical trial among 39,876 initially healthy female health care professionals 45 years or older at baseline (1992-1994) evaluating low-dose aspirin and vitamin E use for cancer and CVD prevention.[19,20] After the trial ended in 2005, observational follow-up continued (mean, 27 years). Health and lifestyle data were collected at

ABBREVIATION KEY

BMI: Body mass index.
CVD: Cardiovascular disease.
NHANES: National Health and Nutrition Examination Survey.
OHQ: Oral health question.
PD: Periodontal disease.
WHS: Women's Health Study.

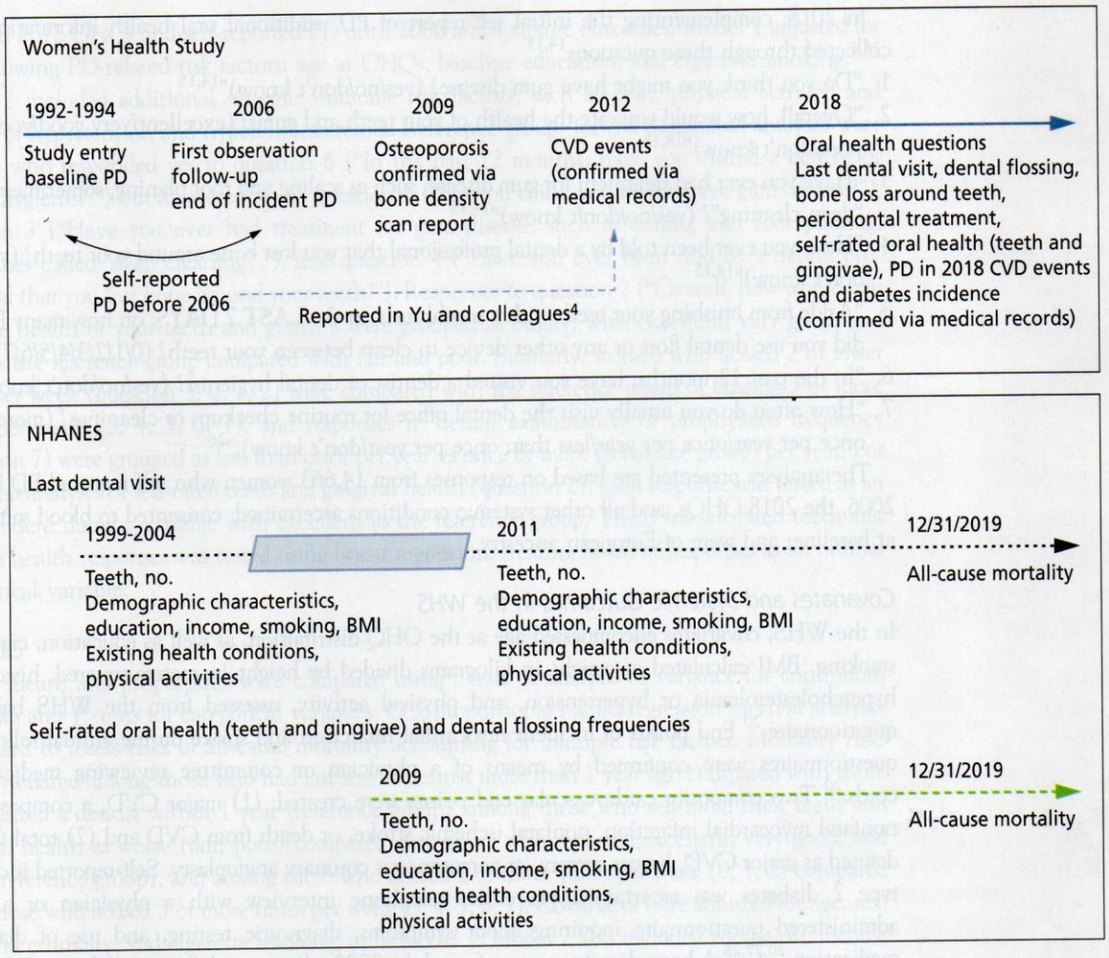

Figure 1. Flowchart of study timeline. BMI: Body mass index. CVD: Cardiovascular disease. PD: Periodontal disease.

baseline and annually via follow-up questionnaires. Written consent was obtained from all WHS participants, and the Brigham and Women's Hospital institutional review board approved the WHS study. Our report conforms to The Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[24]

NHANES

NHANES uses a stratified, multistage, cluster sampling design to gather representative health and nutrition data in the US population. Data were collected via home interviews and health or dental examinations conducted in mobile centers.[25] Data from 1999 onward are publicly available and are released biennially with survey and examination manuals. The National Center for Health Statistics Research Ethics Review Board approved NHANES, which conforms to The Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[24] Among the 59,062 participants with mortality data (1999-2018), 29,554 had complete information on traditional risk factors, dental examination, and time since their last dental visits. For our investigation, 21,490 participants self-rated their teeth and gingival health, and 18,393 reported their dental flossing frequency. Detailed participant characteristics are available in eTables 1 through 4 (available online at the end of the article).

Self-reported PD and OHQs in the WHS

WHS participants were asked at study entry (1992-1994) whether they had ever received a diagnosis of any of several health outcomes, explicitly including PD.[4] Newly diagnosed PD was also inquired at 36, 48, 60, 72, 84, 96, 108, and 120 months during the trial and in 2006.[4] The question stems were "Since you started the trial (around 3 years ago)/In the past year, were you newly diagnosed with/have you had any of the following. . .."; PD was 1 possible response.[16]

In 2018, complementing the initial self-report of PD, additional oral health information was collected through these questions[14,15]

1. "Do you think you might have gum disease? (yes/no/don't know)"[14,15]
2. "Overall, how would you rate the health of your teeth and gums? (excellent/very good/good/fair/poor/don't know)"[14,15]
3. "Have you ever had treatment for gum disease, such as scaling and root planing, sometimes called "deep cleaning"? (yes/no/don't know)"[14,15]
4. "Have you ever been told by a dental professional that you lost bone around your teeth? (yes/no/don't know)"[14,15]
5. "Aside from brushing your teeth with a toothbrush, in the LAST 7 DAYS, on how many DAYS did you use dental floss or any other device to clean between your teeth? (0/1/2/3/4/5/6/7)"[14,15]
6. "In the past 12 months, have you visited a dentist or dental hygienist? (yes/no/don't know)"[26]
7. "How often do you usually visit the dental office for routine checkups or cleanings? (more than once per year/once per year/less than once per year/don't know)."[26]

The analyses presented are based on responses from 14,663 women who self-reported PD before 2006, the 2018 OHQs, and all other systemic conditions ascertained; consented to blood sampling at baseline; and were of European ancestry.

Covariates and Systemic Outcomes in the WHS

In the WHS, covariates encompassed age at the OHQ distribution, as well as education, cigarette smoking, BMI calculated as weight in kilograms divided by height in meters squared, history of hypercholesterolemia or hypertension, and physical activity, assessed from the WHS baseline questionnaire.[20] End points of incident myocardial infarction and stroke during annual follow-up questionnaires were confirmed by means of a physician or committee reviewing medical records.[20] Two composite cardiovascular end points were created: (1) major CVD, a composite of nonfatal myocardial infarction, nonfatal ischemic stroke, or death from CVD and (2) total CVD, defined as major CVD, bypass surgery, or percutaneous coronary angioplasty. Self-reported incident type 2 diabetes was ascertained via either telephone interview with a physician or a self-administered questionnaire inquiring about symptoms, diagnostic testing, and use of diabetes medication.[20,27,28] A bone density scan confirmed the 2009 self-reported diagnosis of osteoporosis.[21]

Covariates, Existing Systemic Conditions, Mortality, and Number of Remaining Teeth in the NHANES

Age, sex, race and ethnicity, education levels, income to poverty ratios, physical activities, and cigarette smoking status were obtained from the self-reported NHANES.[23,25,29] Physical activities were obtained from questionnaires during the home interview and categorized as sedentary ($\geq$ 5 hours of sedentary activities per day), insufficient, moderate ($\geq$ 150 minutes of moderate-intensity activities per week), or vigorous ($\geq$ 75 minutes of vigorous-intensity aerobic activities or a combination of moderate- and vigorous-intensity aerobic activities per week) as the Physical Activity Guidelines for Americans suggested.[29] BMI was determined from the NHANES body measures examination. Mortality was ascertained via the National Center for Health Statistics through record matching using the National Death Index death certificates and converted for public use.[23,30] Existing systemic comorbidities, such as total CVD (including congestive heart failure, coronary heart disease, angina, and heart attack) and stroke were summarized from the self-reported medical questionnaires.[25] Hypertension was defined via self-report, use of antihypertensive medications, or mean blood pressure greater than 140/90 millimeters of mercury. Diabetes mellitus was defined via self-report, presence of a fasting plasma glucose level greater than 140 mg/dL, plasma glucose level greater than 200 mg/dL, or the use of diabetic medications.[25] The NHANES tooth count was charted as primary, permanent, implant, and missing or residual roots, excluding third molars. We used the sum of permanent dentition (excluding residual roots) as the number of remaining natural teeth.[23]

Statistical analysis

WHS

Group means and proportions were compared using *t* tests for continuous variables and χ^2 tests for categorical variables. Multivariate logistic regression was performed to examine associations

between 2018 OHQs and self-reported PD until 2006 and systemic outcomes. Model 1 adjusted for the following PD-related risk factors: age at OHQs, baseline education, and cigarette smoking.[3,31] Model 2 included additional systemic outcome risk factors, such as BMI, physical activity, and history of hypertension and hypercholesteremia. Reference groups for the designated analyses were women who responded yes to question 6 ("In the past 12 months, have you visited a dentist or dental hygienist?") but answered no to question 1 ("Do you think you might have gum disease?"), question 3 ("Have you ever had treatment for gum disease, such as scaling and root planing, sometimes called 'deep cleaning?' "), and question 4 ("Have you ever been told by a dental professional that you lost bone around your teeth?"). Responses to question 2 ("Overall, how would you rate the health of your teeth and gums?") were grouped as binary, with excellent, very good, and good as the reference group compared with fair and poor. Similarly, women who flossed 2 or fewer times per week (question 5; 0, 1, 2) were compared with the reference group of flossing 3 or more times per week (3, 4, 5, 6, 7), and responses to dental examination or prophylaxis frequency (question 7) were grouped as less than once per year vs once or more (reference group) per year. For subgroup analyses of self-rated teeth and gingival health (question 2), each response was tested as an independent dummy variable with excellent as the reference group. Trend for self-rated teeth and gingiva health responses was tested using linear regression, treating levels of responses as an ordinal categorical variable.

NHANES

Group means and proportions were compared using *t* tests or analysis of variance for continuous variables and χ^2 tests for categorical variables. Cox proportional hazard regression survival analyses were used to assess risks of all-cause mortality accounting for multiple risk factors. Mortality risks were evaluated among those who had last seen a dentist more than 1 year ago compared with those who visited a dentist within 1 year (reference group), among those who self-rated their teeth and gingival health as worse (fair, poor) compared with those who reported excellent, very good, and good (reference group), and among those who flossed 2 or fewer times per week (0, 1, 2) compared with those who flossed 3 or more times per week (3, 4, 5, 6, 7). Covariates were adjusted for age, sex, race and ethnicity, and cigarette smoking, as in model 1. Model 2 also included education, income to poverty ratio, BMI, physical activities, and preexisting medical conditions (eg, hypertension, CVDs, diabetes, and stroke). Model 3 adjusted for all covariates in model 2 plus the number of remaining teeth. Additional details of subgroup survival analyses as specified are provided in eTables 5 through 7 (available online at the end of this article) and Figure 2.

All analyses were conducted using R statistical software (R Development Core Team) and statistical significance was set at $P < .05$.

RESULTS

Characteristics of WHS participants based on their self-reported PD until 2006

A total of 14,663 participants from the WHS were analyzed on the basis of their self-reported PD until 2006, their 2018 OHQs, and their systemic health outcomes (Table 1). Compared with those without PD, women with a PD diagnosis by 2006 were slightly older (mean age 77.87 vs 76.79 years; $P < .001$), more likely to be current cigarette smokers (14.8% vs 6.8%; $P < .001$), had an increased prevalence of hypercholesterolemia (28.5% vs 25.7%; $P = .002$), and lower levels of physical activity at baseline (rarely and never, 35.5% vs 33.9%; $P = .045$).

Regarding dental behaviors, no significant differences emerged in dental visit frequency, weekly flossing, or yearly dental prophylaxis between those with or without 2006 self-reported PD. A greater percentage of women reporting PD until 2006 rated their 2018 teeth and gingival health as fair or poor (19.9% vs 8.6%; $P < .001$). Similarly, women with 2006 self-reported PD were more likely to report bone loss around their teeth (47.4% vs 12.8%; $P < .001$), receiving a PD diagnosis (20.1% vs 3.8%; $P < .001$), and having undergone periodontal treatment (62.9% vs 12.3%; $P < .001$) in 2018. In terms of systemic health outcomes, women with 2006 self-reported PD exhibited a significantly higher likelihood of later reporting CVD events and osteoporosis (20.9% vs 17.4%; $P < .001$). However, there was no significant difference in the prevalence of diabetes between women with and without 2006 self-reported PD.

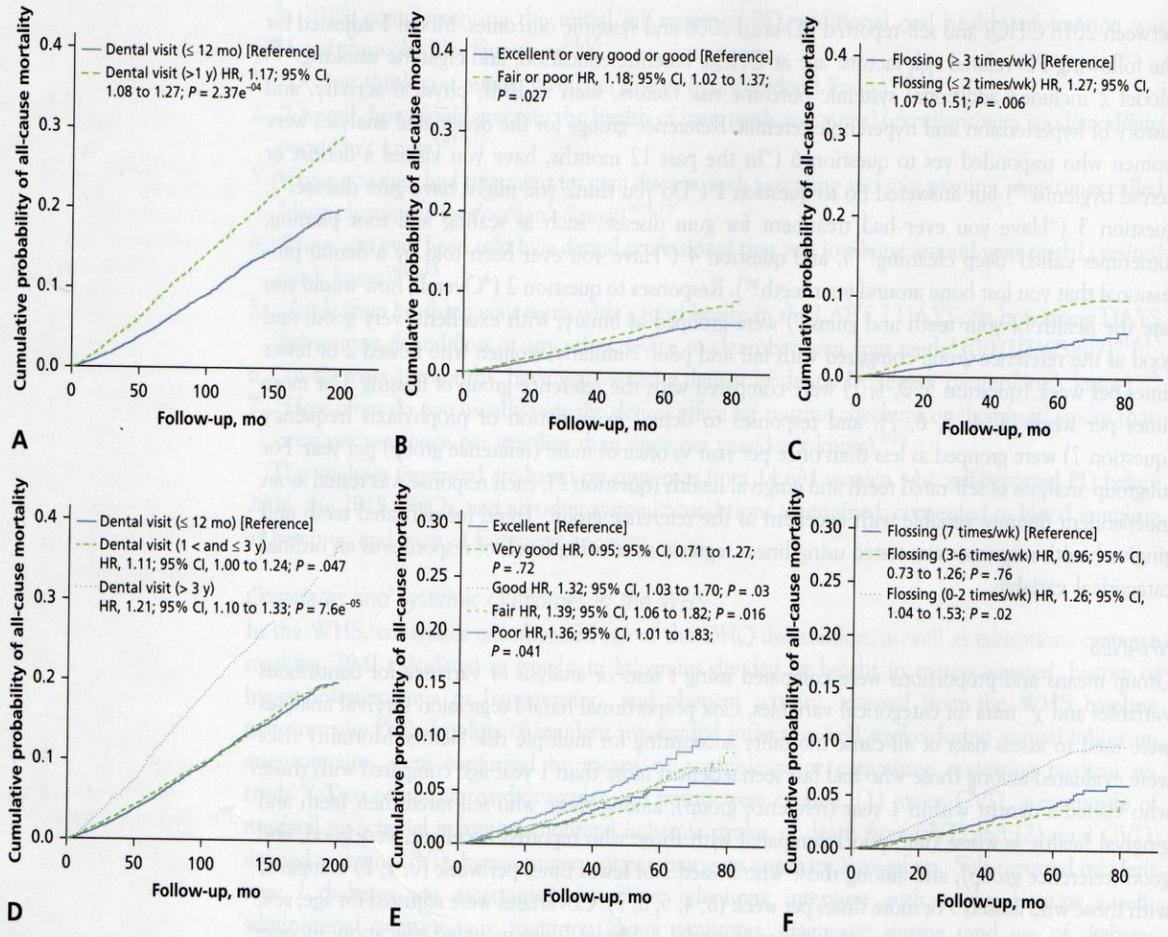

Figure 2. Kaplan-Meier survival curves according to last dental visit (**A**), self-rated oral health (teeth and gingivae) (**B**), and dental flossing frequency (**C**). Different survival curves were plotted for all-cause mortality on the basis of binary or multiple groups of responses for National Health and Nutrition Examination Survey participants' last dental visit (**D**), self-rated oral health (teeth and gingivae) (**E**), and dental flossing frequencies (**F**). Hazard ratio (HR) estimates and *P* values derived from the Cox proportional hazard regression survival analyses are provided in the upper left of each panel.

2018 OHQs and systemic health outcomes in the WHS

Associations between the 2018 OHQs and systemic conditions are outlined in Table 2. In model 1, adjustment accounted for the following established PD risk factors: age, education, and cigarette smoking.[3,31] In model 2, we adjusted for additional recognized systemic outcome risk factors (that is, BMI, physical activity, and history of hypertension and hypercholesteremia). Results in both models revealed significant associations with multiple systemic health outcomes, particularly among women who flossed 2 or fewer times per week or who rated their teeth and gingival health as fair or poor. Specifically, women with fair or poor self-rated teeth and gingival health were more likely to report a history of total CVD (odds ratio [OR], 1.39; 95% CI, 1.14 to 1.69; $P < .001$), major CVD (OR, 1.36; 95% CI, 1.05 to 1.74; $P = .018$), stroke (OR, 1.48; 95% CI, 1.06 to 2.01; $P = .017$), incident diabetes (OR, 1.21; 95% CI, 1.02 to 1.43; $P = .028$), and osteoporosis (OR, 1.60; 95% CI, 1.38 to 1.84; $P < .001$). All OHQ responses, except periodontal treatment, were significantly associated with osteoporosis. Lastly, women with infrequent oral health care behaviors (eg, flossing 2 or fewer times per week, no dental visit or prophylaxis within the past year) or those with fair or poor self-rated teeth and gingival health had higher odds of incident diabetes. It is also worth noting that, comparable with self-reported PD until 2006, participants who self-rated their teeth and gingival health as fair or poor in 2018 exhibited similar effect sizes for associations with total and major CVD, slightly higher for stroke, diabetes, and osteoporosis.

Detailed total CVD output (model 2) is provide in eTable 8 (available online at the end of the article).

Table 1. Characteristics of Women's Health Study participants who responded to the 2018 oral health questions, according to their self-reported periodontal disease status until 2006.

CHARACTERISTIC	Total	SELF-REPORTED EVER HAVING PERIODONTAL DISEASE UNTIL 2006		
		No	Yes	*P* Value*
Participants, No. (%)	14,663	11,260 (77)	3,403 (23)	Not applicable
Age at Oral Health Questions, Y, Mean (SD)	77.0 (5.6)	76.79 (5.5)	77.87 (5.8)	< .001
Baseline Information at the Beginning of the Clinical Trial				
Education, no. (%)				
< Bachelor's degree	7,609 (51.9)	5,890 (52.3)	1,719 (50.5)	.072
≥ Bachelor's degree	7,054 (48.1)	5,370 (47.7)	1,684 (49.5)	
Cigarette smoking, no. (%)				
Current	1,269 (9)	764 (6.8)	505 (14.8)	< .001
Past	5,510 (38)	4,049 (36.0)	1,461 (43.0)	
Never	7,976 (54)	6,441 (57.2)	1,435 (42.2)	
Body mass index,† mean (SD)	25.6 (4.7)	25.55 (4.7)	25.74 (4.7)	.049
Hypertension, no. (%)	2,873 (20)	2,173 (19.3)	700 (20.6)	.11
Hypercholesterolemia, no. (%)	3,859 (26)	2,891 (25.7)	968 (28.5)	.002
Physical activity, no. (%)				
Rarely or never	5,019 (34)	3,813 (33.9)	1,206 (35.5)	.045
< 1 time/wk	2,930 (20)	2,224 (19.8)	706 (20.8)	
1-3 times/wk	4,930 (34)	3,820 (33.9)	1,110 (32.6)	
≥ 4 times/wk	1,779 (12)	1,400 (12.4)	379 (11.1)	
Responses to Oral Health Questions in 2018, No. (%)				
Last dental visit > 1 y ago	1,501 (10)	1,143 (10.2)	358 (10.6)	.53
Self-rated oral health (fair, poor)	1,615 (11)	954 (8.6)	661 (19.9)	< .001
Floss ≤ 2 times/wk	2,671 (18)	2,065 (18.5)	606 (18.0)	.5
Bone loss around teeth	2,884 (20)	1,382 (12.8)	1,502 (47.4)	< .001
Prophylaxis < 1/y	1,314 (9)	987 (8.9)	327 (9.8)	.13
Had periodontal treatment	3,426 (23)	1,361 (12.3)	2,065 (62.9)	< .001
Periodontal disease in 2018	1,072 (7.3)	418 (3.8)	654 (20.1)	< .001
Systemic Health Outcomes Across the Observational Study Period, No. (%)				
Total cardiovascular disease (2018)	845 (6)	593 (5.3)	252 (7.4)	< .001
Major cardiovascular disease (2018)	474 (3)	325 (2.9)	149 (4.4)	< .001
Myocardial infarction (2018)	235 (2)	156 (1.4)	79 (2.3)	< .001
Stroke (2018)	286 (2)	206 (1.8)	80 (2.4)	.06
Diabetes (2017)	1,392 (9)	1,054 (9.4)	338 (9.9)	.34
Osteoporosis (2009)	2,266 (15)	1,665 (17.4)	601 (20.9)	< .001

* *P* values are from χ^2 test for categorical variables or *t* test for continuous variables comparing groups. † Calculated as weight in kilograms divided by height in meters squared.

Ordinal self-rated oral health responses and systemic health outcomes

Associations between different self-rated teeth and gingival health levels and systemic health outcomes are detailed in Table 3. Deteriorating oral health ratings (from excellent to poor) corresponded to elevated odds of experiencing various systemic comorbidities. For instance, odds of total CVD events increased from excellent (reference group) to very good (OR, 1.04; 95% CI, 0.83 to 1.31; $P = .72$), good (OR, 1.27; 95% CI, 1.02 to 1.59; $P = .037$) fair (OR, 1.51; 95% CI, 1.15 to 1.98; $P = .003$, and poor (OR, 1.92; 95% CI, 1.22 to 2.94; $P = .003$). The increasing trends of ORs

Table 2. Associations of Women's Health Study 2018 oral health questions with systemic health outcomes.

VARIABLE	PERIODONTAL DISEASE IN 2006	FLOSS ≤2 TIMES/WK	LAST DENTAL VISIT >1 Y AGO	PROPHYLAXIS <1 TIME/Y	BONE LOSS AROUND TEETH	SELF-RATED ORAL HEALTH* (BINARY)	PERIODONTAL TREATMENT	PERIODONTAL DISEASE IN 2018
Model 1,† OR (95% CI)								
Total CVD‡	1.26 (1.08 to 1.47)§	1.35 (1.14 to 1.59)¶	1.28 (1.04 to 1.56)#	1.33 (1.07 to 1.64)§	0.98 (0.82 to 1.17)	1.54 (1.27 to 1.86)¶	1.03 (0.87 to 1.22)	1.02 (0.77 to 1.33)
Major CVD	1.34 (1.09 to 1.64)§	1.32 (1.06 to 1.63)#	1.06 (0.8 to 1.39)	1.23 (0.92 to 1.62)	0.88 (0.69 to 1.12)	1.47 (1.14 to 1.87)§	1.03 (0.82 to 1.28)	1.08 (0.75 to 1.51)
Myocardial infarction	1.42 (1.07 to 1.87)#	1 (0.71 to 1.37)	1.58 (1.1 to 2.21)§	1.67 (1.15 to 2.36)§	1.06 (0.76 to 1.45)	1.31 (0.9 to 1.84)	1.13 (0.83 to 1.52)	1.17 (0.71 to 1.82)
Stroke	1.16 (0.89 to 1.51)	1.53 (1.16 to 1.99)§	0.71 (0.46 to 1.05)	0.8 (0.51 to 1.19)	0.75 (0.53 to 1.04)	1.55 (1.13 to 2.1)§	0.93 (0.69 to 1.24)	1.07 (0.66 to 1.64)
Incident diabetes	1.06 (0.93 to 1.2)	1.82 (1.6 to 2.07)¶	1.76 (1.5 to 2.05)¶	1.77 (1.5 to 2.09)¶	0.92 (0.8 to 1.06)	1.64 (1.4 to 1.91)¶	0.89 (0.78 to 1.02)	1.12 (0.9 to 1.37)
Osteoporosis (2009)	1.17 (1.05 to 1.3)§	1.12 (0.99 to 1.26)	1.22 (1.05 to 1.42)#	1.14 (0.97 to 1.34)	1.36 (1.21 to 1.52)¶	1.46 (1.27 to 1.68)¶	1.04 (0.93 to 1.16)	1.36 (1.15 to 1.61)¶
Model 2,‡ OR (95% CI)								
Total CVD	1.27 (1.08 to 1.49)§	1.23 (1.03 to 1.46)#	1.1 (0.89 to 1.35)	1.18 (0.94 to 1.47)	1.02 (0.84 to 1.22)	1.39 (1.14 to 1.69)¶	1.04 (0.88 to 1.24)	1 (0.75 to 1.31)
Major CVD	1.31 (1.07 to 1.61)§	1.21 (0.96 to 1.5)	0.96 (0.71 to 1.26)	1.14 (0.85 to 1.51)	0.91 (0.71 to 1.16)	1.36 (1.05 to 1.74)#	1.03 (0.82 to 1.28)	1.06 (0.73 to 1.49)
Myocardial infarction	1.42 (1.07 to 1.88)#	0.87 (0.62 to 1.21)	1.41 (0.97 to 1.99)	1.54 (1.05 to 2.2)#	1.09 (0.78 to 1.5)	1.17 (0.8 to 1.67)	1.11 (0.81 to 1.5)	1.18 (0.72 to 1.85)
Stroke	1.12 (0.85 to 1.46)	1.45 (1.1 to 1.91)§	0.61 (0.38 to 0.92)#	0.69 (0.43 to 1.05)	0.76 (0.54 to 1.05)	1.48 (1.06 to 2.01)#	0.96 (0.71 to 1.28)	1.04 (0.63 to 1.61)
Incident diabetes	1 (0.86 to 1.15)	1.46 (1.27 to 1.68)¶	1.23 (1.03 to 1.46)#	1.33 (1.11 to 1.6)§	0.96 (0.82 to 1.12)	1.21 (1.02 to 1.43)#	0.85 (0.73 to 0.99)#	1.04 (0.82 to 1.29)
Osteoporosis (2009)	1.2 (1.07 to 1.33)§	1.2 (1.06 to 1.35)§	1.34 (1.14 to 1.57)¶	1.24 (1.05 to 1.47)#	1.32 (1.17 to 1.47)¶	1.6 (1.38 to 1.84)¶	1.03 (0.92 to 1.15)	1.38 (1.16 to 1.63)¶

* Self-rated oral health (teeth and gingivae), with binary grouping of levels of responses as excellent, very good, and good [Reference] vs fair and poor. † Models: The associations of individual oral health questions with systemic health outcomes were assessed by means of multivariate logistic regression adjusting for (model 1) age at the time of oral health questions, baseline information on educational and smoking, and in model 2, variables in model 1 plus body mass index (calculated as weight in kilograms divided by height in meters squared), physical activities, and history of hypertension and hypercholesteremia. ‡ CVD: Cardiovascular disease. § $P < .01$. ¶ $P < .001$. # $P < .05$.

associated with total CVD, diabetes, and osteoporosis across self-reported oral health responses were significant in both models 1 and 2 ($P < .001$).

All-cause mortality risks among NHANES participants

Having identified significant associations between self-reported oral health and systemic health outcomes in the WHS, we conducted an independent analysis using the NHANES data to examine whether OHQs exhibit similar associations with mortality (Table 4). Detailed NHANES participant characteristics are provided in eTables 1 through 4. The risks of all-cause mortality were estimated on the basis of the NHANES participants' OHQ responses. Participants who reported no dental visit within the past year had higher all-cause mortality risks than those who visited a dentist within the past year (hazard ratio [HR], 1.17; 95% CI, 1.07 to 1.27; $P < .001$). Participants self-rating teeth and gingival health as fair or poor also had elevated risks of all-cause mortality compared with those rating it as excellent, very good, and good (HR, 1.18; 95% CI, 1.02 to 1.37; $P = .027$). Furthermore, participants flossing 2 or fewer times per week exhibited higher mortality risks than those flossing 3 or more times per week (HR, 1.27; 95% CI, 1.07 to 1.51; $P = .006$). Survival curves are displayed in Figure 2 and detailed estimates from these analyses are provided in eTables 5 through 7. The results of subgroup analyses, further dividing dental visit, flossing frequency, and self-rated oral health into 3 or more groups, consistently showed increasing mortality risks compared with the reference group.

Table 3. Associations with systemic health outcomes according to levels of responses to the Women's Health Study question: "Overall, how would you rate the health of your teeth and gums? (excellent/very good/good/fair/poor/don't know)."

VARIABLE	SELF-RATED ORAL HEALTH OF TEETH AND GINGIVAE					*P* VALUE FOR TREND
	Excellent	Very Good	Good	Fair	Poor	
Participants. No. (%)	2,651 (18)	5,683 (39)	4,512 (31)	1,376 (10)	239 (2)	Not applicable
Model 1,* Odds Ratio (95% CI)						
Total CVD†	[Reference]	1.04 (0.83 to 1.31)	1.38 (1.11 to 1.72)‡	1.71 (1.31 to 2.22)§	2.26 (1.44 to 3.44)§	<.001
Major CVD	[Reference]	0.97 (0.73 to 1.3)	1.37 (1.04 to 1.83)¶	1.63 (1.16 to 2.3)‡	1.84 (0.99 to 3.21)	<.001
Myocardial infarction	[Reference]	0.89 (0.6 to 1.33)	1.28 (0.88 to 1.91)	1.22 (0.74 to 2.0)	2.23 (1.03 to 4.42)¶	.006
Stroke	[Reference]	1.16 (0.8 to 1.71)	1.36 (0.94 to 2.0)	2.06 (1.34 to 3.19)‡	1.11 (0.38 to 2.62)	.008
Incident diabetes	[Reference]	1.14 (0.95 to 1.36)	1.79 (1.51 to 2.14)§	2.02 (1.63 to 2.51)§	3.1 (2.16 to 4.39)‡	<.001
Osteoporosis (2009)	[Reference]	0.98 (0.85 to 1.11)	1.17 (1.02 to 1.34)¶	1.49 (1.24 to 1.78)§	1.85 (1.30 to 2.61)§	<.001
Model 2,* Odds Ratio (95% CI)	[Reference]					
Total CVD	[Reference]	1.04 (0.83 to 1.31)	1.27 (1.02 to 1.59)¶	1.51 (1.15 to 1.98)‡	1.92 (1.22 to 2.94)‡	<.001
Major CVD	[Reference]	0.97 (0.73 to 1.3)	1.28 (0.96 to 1.71)	1.47 (1.04 to 2.09)¶	1.65 (0.89 to 2.89)	.001
Myocardial infarction	[Reference]	0.91 (0.61 to 1.37)	1.18 (0.8 to 1.77)	1.06 (0.63 to 1.75)	1.96 (0.9 to 3.92)	.05
Stroke	[Reference]	1.16 (0.8 to 1.71)	1.33 (0.92 to 1.96)	1.95 (1.26 to 3.04)‡	1.06 (0.36 to 2.51)	.02
Incident diabetes	[Reference]	1.11 (0.92 to 1.34)	1.48 (1.23 to 1.78)§	1.45 (1.15 to 1.83)‡	1.69 (1.13 to 2.5)‡	<.001
Osteoporosis (2009)	[Reference]	0.99 (0.87 to 1.13)	1.26 (1.1 to 1.45)§	1.66 (1.38 to 1.99)§	2.3 (1.6 to 3.28)§	<.001

* The associations of each response of self-reported oral health as an indicator variable and the trend for levels of responses as an ordinal categorical variable to systemic outcomes were assessed using multivariate logistic regression adjusting for (model 1) age at the time of self-rated oral health responses, baseline information about education and cigarette smoking (3 groups), and in model 2 with body mass index (calculated as weight in kilograms divided by height in meters squared), physical activities, and history of hypertension and hypercholesteremia. † CVD: Cardiovascular disease. ‡ $P < .01$. § $P < .001$. ¶ $P < .05$.

Table 4. Risk of all-cause mortality in the National Health and Nutrition Examination Survey based on last dental visit, self-rated oral health (teeth and gingivae), or frequency of dental flossing.*

ALL-CAUSE MORTALITY	MODEL 1	MODEL 2	MODEL 3
Participants, No. (Events, No.)	29,510 (2,937)	29,510 (2,937)	29,510 (2,937)
Last Dental Visit, HR† (95% CI), [Reference, ≤1 y]			
>1 y	1.52 (1.41 to 1.64)‡	1.26 (1.16 to 1.36)‡	1.17 (1.08 to 1.27)‡
Participants, No. (Events, No.)	21,488 (791)	21,488 (791)	21,488 (791)
Self-Rated Oral Health,§ HR (95% CI), [Reference, Excellent or Good]			
Fair or poor	1.39 (1.20 to 1.61)‡	1.18 (1.02 to 1.38)¶	1.18 (1.02 to 1.37)¶
Participants, No. (Events, No.)	18,392 (775)	18,392 (775)	18,392 (775)
Flossing Frequency, HR (95% CI), [Reference, ≥3 times/wk]			
≤2 times/wk	1.74 (1.49 to 2.03)‡	1.46 (1.25 to 1.71)‡	1.27 (1.07 to 1.51)#

* Cox proportional hazard regression survival analyses were adjusted for the following covariates: model 1: age, sex, race and ethnicity (4 groups) and smoking (3 groups); model 2: covariates in model 1, education (3 groups), income to poverty ratio, body mass index (calculated as weight in kilograms divided by height in meters squared), physical activities (4 groups), and preexisting medical conditions of hypertension, total cardiovascular diseases, diabetes, and stroke; model 3: covariates in model 2 and the total number of remaining teeth. † HR: Hazard ratio. ‡ $P < .001$. § Self-rated oral health (teeth and gingivae). ¶ $P < .05$. # $P < .01$.

In summary, our investigations, spanning 2 independent large studies, underscored robust connections among self-reported oral health, systemic health outcomes, and heightened risks of all-cause mortality.

DISCUSSION

The link between poor oral health and PD and heightened mortality and frailty is well-documented.[32-34] In alignment with prior findings,[4-9] our analysis of self-reported OHQs from WHS participants reinforced robust associations with systemic health outcomes. Similarly, NHANES participants with infrequent dental visits, limited flossing, or self-rated fair or poor oral health faced elevated risks of all-cause mortality, independent of their remaining teeth count. Therefore, our results emphasized the importance of self-reported OHQs in delineating oral health's connection with systemic health outcomes across large-scale studies. In addition, to our knowledge, our findings of infrequent dental flossing among WHS participants significantly linking to higher odds of stroke, diabetes, and osteoporosis had not yet been reported.

Existing evidence indicates that oral health behaviors, such as frequency of toothbrushing, are linked to cardiovascular events,[35] as well as to changes in markers like C-reactive protein,[36,37] fibrinogen,[36] and vascular function.[37] Researchers using a composite score based on self-reported oral health identified heightened incident hypertension risks tied to poor oral health conditions.[38] Our results based on OHQ responses are consistent with those of previous researchers who established the epidemiologic associations of PD or tooth loss with CVD,[4,39] diabetes,[6-8] and osteoporosis.[9,40,41] Combining our results with prior evidence,[35-37] toothbrushing and dental flossing warrant further exploration as preventive interventions for systemic health outcomes.

Our data elucidated that WHS participants reporting PD until 2006 were more likely to self-assess their teeth and gingival health as fair or poor, report undergoing periodontal treatment or bone loss around their teeth, or consider themselves as still having PD in 2018. These findings reveal strong correlations between the responses across 2 distinct time points.

Our study has several limitations. There are no clinical data related to the WHS self-reported OHQs, except a limited subset of women with retrieved dental records. Among those 63 women, fewer teeth were noted among those with worse oral health conditions (previously reported).[42] In addition, the cross-sectional nature of the presented WHS analyses and different timing of PD and OHQ information limit causal interpretation, necessitating further research for additional exploration and validation.

To reinforce the associations between self-reported OHQs and systemic health outcomes, we independently conducted survival analyses for all-cause mortality in the NHANES. This was separate from the WHS observations but similarly relied on self-reported oral health and systemic disease data based on a representative population. Results indicated higher risks of all-cause mortality for participants without dental visits within the past year, those self-rating teeth and gingival health as fair or poor, or participants flossing 2 or fewer times per week. Hence, the WHS- and NHANES-derived results together underscore the oral-systemic connection and expand the rationale for using self-reported OHQs in population studies.

CONCLUSIONS

Our study elucidated the value of self-reported oral health indicators, especially time since last dental visit, self-assessed teeth and gingival health, and dental flossing frequency. These metrics are invaluable for assessing oral health in extensive studies or data-rich databases in which thorough clinical examinations or dental records might be lacking. Moreover, our investigations, spanning 2 independent large studies, underscored the significant relationship between self-reported oral health and systemic health outcomes and heightened risks of all-cause mortality. The significant oral–systemic correlations we have identified not only reinforced the well-established links between PD and systemic comorbidities,[4-9,43] as reported previously, but also highlight the need for future investigations. Furthermore, our finding of increased all-cause mortality among those having suboptimal dental visits emphasized the urgency of addressing barriers to accessing oral health care. ■

DISCLOSURE

None of the authors reported any disclosures.

SUPPLEMENTAL DATA

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