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Original Article

Association of dietary zinc consumption with periodontitis in diabetes mellitus patients: A cross-sectional study of national health and nutrition examination surveys database (2009–2014)

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KEYWORDS
Dietary Zn intake;
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Abstract *Background/purpose:* Periodontitis is an independent risk factor for diabetes mellitus (DM), and DM patients had an increased risk in susceptibility to periodontitis. And serum zinc (Zn) levels were low in patients with periodontitis combined with DM. Herein, this study aimed to explore the association between dietary Zn intake and the risk of periodontitis in DM patients, in order to provide some scientific references for the prevention and treatment for periodontitis clinically.

Materials and methods: Demographic and clinical data of DM patients were extracted from the National Health and Nutrition Examination Surveys (NHANES) database in 2009–2014 in this cross-sectional study. Weighted univariate logistic regression and backward regression analyses were used for covariates screening. Weighted univariate and multivariate logistic regression analyses were used to explore the association between Zn and periodontitis with odds ratios (ORs) and 95% confidence intervals (CIs). Subgroup analyses of age and gender were also performed.

Results: Of the eligible participants, 1281 had moderate or severe periodontitis. After adjusting for the covariates, we found that comparing to DM patients who had not reach the recommended Zn intake level, those who reached had low odds for periodontitis [OR = 0.76, 95% CI: (0.58–0.99)]. In patients who aged ≥65 years old [OR = 0.59, 95% CI: (0.36–0.97)] and were female [OR = 0.71, 95% CI: (0.51–0.99)], reaching the recommended level of Zn intake was related to low odds of periodontitis.

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Conclusion: Sufficient dietary Zn intake antagonized the risk of periodontitis, which may provide some references for diet management in DM patients to reduce the risk of periodontitis.

Introduction

Periodontitis is the sixth most prevalent chronic disease characterized by the inflammation of the deep tissue leading to periodontal ligament disruption, and alveolar bone loss, often resulting in tooth loss.[1] Periodontitis increases the risk of masticatory dysfunction and negatively affects the quality of life in patients.[2] Periodontitis is an independent risk factor for diabetes mellitus (DM), and studies have reported that DM patients had an approximately threefold increase in susceptibility to periodontitis.[3,4] Elevated levels of oxidative stress and inflammation due to hyperglycemia and consequent damage to periodontal tissue may be a potential mechanism for the increased risk of periodontitis in DM patients.[4] Therefore, it is necessary to explore the influencing factors for the development of periodontitis in DM patients, in order to find potential avenues of prevention and control of periodontitis.

Antioxidant or anti-inflammatory dietary minerals may have a potential impact on the development of periodontitis.[5] A limited number of studies have found that inadequate dietary zinc (Zn) intake may be associated with an increased risk of periodontitis.[6] Zn deficiency may alter oral mucosal thickness and keratinization to increase the risk of infection, as well as affect immune cell function and antioxidant enzyme levels to influence periodontitis.[7] In addition, Zn can improve oxidative stress and chronic inflammatory state in DM.[8] Also, Thomas et al.[9] found that serum Zn levels were lower in patients with periodontitis combined with DM compared with the healthy population or patients with periodontitis only. However, studies analyzing the relationship between nutritional status of Zn and the risk of periodontitis in DM patients have been scarce.

Herein, this study aimed to explore the association between dietary Zn intake and the risk of periodontitis in DM patients, in order to provide some scientific references for the prevention and treatment for periodontitis clinically.

Materials and methods

Study design and participants

Demographic and clinical data of DM patients were extracted from the National Health and Nutrition Examination Surveys (NHANES) database in 2009–2014 in this cross-sectional study. NHANES aims to assess the nutritional and health status of the noninstitutionalized population in the U.S., which is conducted by the Centers for Disease Control and Prevention (CDC) and the National Center for Health Statistics (NCHS). NHANES uses a complex, multistage stratified probability sampling method based on selected counties, blocks, households, and persons within households. Interviews in participants' homes conducted by the NCHS trained professionals, and extensive physical examinations including blood and urine collection were conducted at mobile exam centers (MECs). Details of study implementation are available for online access: https://www.cdc.gov/nchs/nhanes/index.htm.

A total of 2032 DM patients received the oral health exam were initially included. Those who missing information of dietary Zn intake were excluded. Finally, 1914 of them were eligible. NHANES was approved by the institutional review board (IRB) of NCHS. The data were deidentified and all the participants provided informed consent. No ethical approval of our agency's IRB was required since this survey was publicly available.

Diagnosis of diabetes mellitus

DM was defined according to a self-reported diagnosis, the use of oral hypoglycemic agents or insulin, glycosylated hemoglobin (HbAlc) $\geq$6.5%, a plasma glucose level $\geq$200 mg/dL at 2-h after the oral glucose tolerance test (OGTT), or a fasting glucose level $\geq$126 mg/dL.[10]

Assessment of dietary zinc consumption

Dietary intake of Zn and its supplements from NHANES was based on the two 24-h dietary recall surveys. The first 24-h recall interview was conducted in person in the MEC by trained interviewers, and the second interview was performed by telephone or mail three to ten days later. We used the records of first 24-h recall in this study to minimize the recall bias.

Zn intake levels were divided into two levels according to the dietary reference intakes (DRIs), including reach the recommended level and not reach the recommended level. The recommended dietary Zn intake for males is $\geq$11 mg and that for female is $\geq$8 mg, the details can be found on the website: https://www.ncbi.nlm.nih.gov/books/NBK545442/table/appJ_tab3/?report=objectonly.

Examination of periodontitis

Participants had a full-mouth periodontal examination, and all the dental examiners were trained and calibrated by the NHANES survey's reference examiner.[11] The measurement of gingival recession and pocket depth for 6 sites/tooth (including wisdom teeth) used a color-coded periodontal probe with graduated in 2-mm increments (HU-Friedy, Chicago, IL, USA). All 4 quadrants were examined, and all

measurements were rounded to the lowest whole millimeter. Then the clinical attachment loss (CAL), namely the difference between pocket depth and gingival recession, at each site was calculated by an algorithm in the data entry program.[12] The proportion of sites with CAL ≥3 mm (i.e., CAL extent) was used to estimate periodontitis, which has been recommended for epidemiological studies as an extent measure.[13] In addition, mean CAL and mean pocket probing depth (PPD) per mouth in millimeters were calculated for description of measuring other aspects of periodontitis.

Non-periodontitis is defined as no evidence of mild, moderate, or severe periodontitis. Mild periodontitis means ≥2 interproximal sites with CAL ≥3 mm, and ≥2 interproximal sites with PPD ≥4 mm (not on same tooth) or one site with PPD ≥5 mm. Moderate periodontitis represents there are ≥2 interproximal sites with CAL ≥4 mm (not on same tooth), and ≥2 interproximal sites with PPD ≥5 mm (not on same tooth). And severe periodontitis means ≥2 interproximal sites with CAL ≥6 mm (not on same tooth), and ≥1 interproximal sites with PPD ≥5 mm. In this study we divided the varying degrees of periodontitis into two levels,[6] that are non-periodontitis/mild periodontitis, and moderate/severe periodontitis.

Variables collection

We collected potential confounding factors including age, gender, race, education level, poverty income ratio (PIR), smoking, drinking, physical activity, body mass index (BMI), diabetic retinopathy, white blood cell (WBC), antibiotics drug, anti-diabetic drug, hypertension, cardiovascular disease (CVD), hepatitis, dyslipidemia, autoimmune disease, decayed teeth, dental implant, tooth loss, dental floss use, total energy intake, protein, fiber, calcium (Ca), iron, copper (Cu), and chronic kidney disease (CKD).

Hypertension was defined by the laboratory inspection, self-reported hypertension or currently use of hypotensive drugs, or a measured systolic blood pressure (SBP) ≥140 mm Hg or diastolic blood pressure (DBP) ≥90 mm Hg.[14] Patients with TC ≥200 mg/dL (5.2 mmol/L) or triglycerides (TG) ≥150 mg/dL (1.7 mmol/L) or low-density lipoprotein cholesterol (LDL-C) ≥130 mg/dL (3.4 mmol/L) or high-density lipoprotein cholesterol (HDL-C) ≤40 mg/dL (1.0 mmol/L) or self-reported hypercholesteremia or receiving lipid-lowering therapy were identified as dyslipidemia.[15] CVD was determined by multiple choice question (MCQ) in NHANES: "Have you ever been told you had (congestive) heart failure, coronary heart disease, angina/angina pectoris, heart attack, stroke." Participants smoked at least 100 cigarettes in their life according to smoking motivation questionnaire (SMQ)-D are considered as a smoker, otherwise are considered as a non-smoker. If they have quit smoking for more than one year (current non-smoker) defined as a former smoker. The pattern of alcohol consumption was captured by questionnaires, and the participants were divided into non-drinker, current non-drinker (have quit drinking in the past year), and drinker.[16] Physical activity was converted to metabolic equivalent (MET), which was calculated according to the physical activity questionnaire (PAQ) in NHANES. Energy expenditure (MET·min) = recommended MET × exercise time of corresponding activity (min). Dietary intakes including total energy, protein, fiber, Ca, iron, and Cu were calculated by "Total nutrient intakes" and "Total dietary supplements" from 24-h dietary recalls of NHANES. CKD was defined as estimate glomerular filtration rate (eGFR) <60 ml/min per 1.73 m^2 or urine albumin-to-creatinine ratio (UACR) ≥30 mg/g.[17] Autoimmune disease was diagnosed if participants have one of the following diseases: rheumatoid arthritis, inflammatory bowel disease, ankylosing spondylitis, and thyroiditis through the questionnaires.

Statistical analysis

Measurement data were described using mean ± standard error (mean ± SE) and independent-samples t test for group comparison. Enumeration data were expressed as number with constituent ratio [N (%)] and chi-square test for the comparison. Ranked data examination was used the rank sum test. We used a set of weights "WTDRD1" because we used the day 1 dietary recall data for analyses. Day 1 weights were constructed by taking the 2-year MEC sample weights (WTMEC2YR) and further adjusting for (a) the additional non-response and (b) the differential allocation by day of the week for the dietary intake data collection (https://wwwn.cdc.gov/Nchs/Nhanes/2007-2008/DR1IFF_D.htm#WTDRD1).

Weighted univariate logistic regression analysis as well as backward regression were used to screen the covariates that related to periodontitis. Weighted univariate and multivariate logistic regression analyses were used to explore the association between dietary Zn intake and the risk of periodontitis. Model 1 was the crude model. Model 2 adjusted for age, gender, race, PIR, smoking, and dental implants.

The evaluation index was odds ratios (ORs) with 95% confidence intervals (CIs). Two-sided *P*-values < 0.05 was considered significant. Statistical analysis was performed using SAS 9.4 (SAS Institute, Cary, NC, USA). Missing variables were PIR, WBC, dental floss use, BMI and smoking. We used multiple imputation for the interpolation of missing variables, and the sensitivity analysis of patients' characteristics before and after the multiple imputation were showed in Table S1.

Results

Characteristics of study population

A total of 2032 DM patients receiving oral health exam were initially included. Those who missing the information of Zn intake (n = 118) were excluded. Finally, 1914 of them were eligible (Fig. 1).

Of all the eligible DM patients, 633 had non-periodontitis/mild periodontitis, and 1281 had moderate/severe periodontitis. The characteristics of participants were showed in Table 1. The average age of the patients was 58.34 years old. Male share 52.68% while female share 47.32%. There were respectively 421 (70.17%) and 745 (61.47%) DM patients who not achieve the recommended dietary Zn intake between non-periodontitis/mild periodontitis group and moderate/severe periodontitis group.

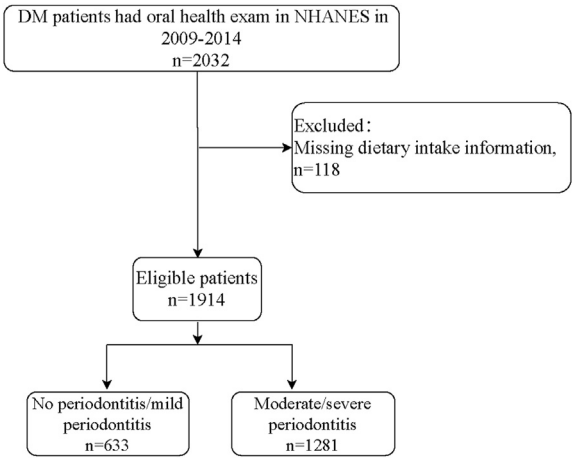

Figure 1 Flowchart of participants screening in the current study.

Additionally, significant differences were also found between non-periodontitis/mild periodontitis group and moderate/severe periodontitis group in race, education level, PIR, smoking, BMI, hypertension, CVD, hepatitis, decayed teeth, dental implant, tooth loss, and dental floss use (all *P*-values < 0.05).

Association between dietary Zn intake and periodontitis

We first screened for the covariates linked to periodontitis (Table 2), and found that age, gender, race, education level, PIR, smoking, BMI, hypertension, CVD, hepatitis, decayed teeth, dental implant, tooth loss, and dental floss use were significantly associated with periodontitis (all *P*-values < 0.05). Then, we used the backward regression and selected the final covariates for further analysis including age, gender, race, PIR, smoking, and dental implants.

After adjusting for the covariates, the results showed that comparing to DM patients who had not reach the recommended Zn intake level, those reached the recommended level had low odds for periodontitis [OR = 0.76, 95% CI: (0.58–0.99)] (Table 3).

Role of Zn intake in periodontitis in subgroups of age and gender

The relationship of dietary Zn intake and periodontitis was further explored in DM patients with different age and gender (Table 4). Patients who aged <65 years old seemed to have low odds of periodontitis when their Zn intake achieved the recommended levels [OR = 0.70, 95% CI: (0.50–0.99)], and however, after adjusting for covariates, this association disappeared (*P*-value = 0.268). In those who aged ≥65 years old [OR = 0.59, 95% CI: (0.36–0.97)] and were female [OR = 0.71, 95% CI: (0.51–0.99)], reaching the recommended level of Zn intake was related to the decreased risk of periodontitis.

Discussion

In this cross-sectional study, we explored the relationship between dietary Zn intake and periodontitis in DM patients. The results indicated that dietary Zn consumption reached the recommended level was linked to low odds of periodontitis comparing to those not reach. Besides, in DM patients who aged ≥65 years old or were female, high intake levels of Zn seemed to be associated with a decreased risk of periodontitis.

To our knowledge, no study have explored the role of dietary Zn intake in periodontitis in DM patients so far. Thomas et al.[9] compared the Zn status in the serum of DM patients and healthy individuals with periodontitis, and found a decreased level of Zn in diabetic patients with periodontitis. In reality, DM is an independent risk factor for periodontitis,[3] and nutrition status is also a key modifiable factor for periodontitis.[18] Zn is present in oral environment, daily diet, oral health products, and dental restorative materials.[19] Liu et al.[19] summarized the regulatory effect of Zn during periodontitis process, indicating that Zn supplementation may enhance immune defense or accelerate local cells proliferation and differentiation, and further promote periodontal regeneration. Aziz et al.[20] found that a disrupted Zn homeostasis was expected to exert a negative effect on periodontal health and related to periodontitis' development and progression. A study of NHANES database explored the relationship of serum Zn and periodontitis in non-DM smoking and non-smoking adults, which showed that serum Zn levels were linked to the risk of periodontitis in non-DM smokers but not non-smokers.[21] In the current study, we additionally discovered high dietary intake level of Zn (i.e., reaching WHO recommended level) was associated with low odds of periodontitis.

Zn is a high abundant trace mineral necessary for human body, which primary source includes spinach, protein-rich foods, nuts, and fortified cereals.[5,22,23] Zn has antioxidative properties, neutralizes bacterial toxins, and is also a cofactor in enzyme-controlled processes.[22,24] The pathogenesis of periodontitis is complex due to it involves diverse microbial floras and its products combining with the chronic inflammatory process.[9] Deficiency of Zn may increase the susceptibility to infection through increasing the permeability of gingival epithelium for bacteria, as well as impair neutrophils and macrophages functions and stimulate them to interleukin-1 (IL-1) production.[25] The mechanisms of DM increasing phlogistic process for periodontal tissues are different. In patients with DM, advanced glycation end-products (AGEs) and their receptors (RAGEs) are interacted and deposited in the periodontal tissues activating the local inflammation. This interaction increased the release of pro-inflammatory cytokines by monocytes/macrophages and endothelial cells, such as IL-1β, IL-6, and tumor necrosis factor (TNF)-α.[26,27] This exacerbated inflammation may further increase the periodontal inflammation and attachment, and bone loss.[28,29] We hypothesized that in DM patients, adequate dietary Zn intake may neutralize bacterial toxins and alleviate local inflammation, thereby reducing the risk of periodontitis.

Table 1 Characteristics of the DM patients in the current study.

Variables	Total (n = 1914)	Non-periodontitis/ mild periodontitis (n = 633)	Moderate/severe periodontitis (n = 1281)	*P*
Age, years, Mean (S.E)	58.34 (0.38)	55.04 (0.56)	60.48 (0.46)	<0.001
Gender, n (%)				<0.001
Male	996 (52.68)	253 (43.44)	743 (58.65)	
Female	918 (47.32)	380 (56.56)	538 (41.36)	
Race, n (%)				<0.001
Mexican American	339 (10.54)	73 (6.79)	266 (12.96)	
Other Hispanic	219 (6.90)	71 (6.86)	148 (6.92)	
Non-Hispanic White	654 (57.89)	264 (64.95)	390 (53.33)	
Non-Hispanic Black	506 (15.46)	158 (13.58)	348 (16.68)	
Other Race	196 (9.21)	67 (7.82)	129 (10.12)	
Education level, n (%)				<0.001
Less than 9th grade	294 (9.51)	47 (4.30)	247 (12.88)	
9—11th grade	297 (13.10)	77 (10.67)	220 (14.67)	
High school graduate	424 (23.67)	126 (23.64)	298 (23.69)	
AA degree	536 (31.81)	217 (33.52)	319 (30.71)	
College graduate	359 (21.85)	165 (27.85)	194 (17.96)	
Unknown	4 (0.07)	1 (0.03)	3 (0.10)	
PIR, Mean (S.E)	2.72 (0.06)	3.09 (0.08)	2.49 (0.08)	<0.001
Smoking, n (%)				<0.001
Never smoked	1029 (51.96)	394 (59.99)	635 (46.76)	
Quitting	605 (33.93)	182 (31.54)	423 (35.48)	
Current smoker	280 (14.11)	57 (8.47)	223 (17.76)	
Drinking, n (%)				0.056
No	1402 (69.42)	452 (65.56)	950 (71.92)	
Yes	512 (30.58)	181 (34.44)	331 (28.08)	
Physical activity, MET·min, Mean (S.E)	536.47 (29.29)	525.02 (48.48)	543.87 (40.52)	0.779
BMI, kg/m^2, Mean (S.E)				0.031
<25	243 (11.76)	69 (8.71)	174 (13.74)	
25—29.9	549 (25.40)	159 (24.10)	390 (26.24)	
≥30	1122 (62.84)	405 (67.20)	717 (60.02)	
Diabetic retinopathy, n (%)				0.598
No	1048 (56.56)	340 (55.60)	708 (57.17)	
Yes	209 (9.12)	59 (8.28)	150 (9.66)	
Unknown	657 (34.33)	234 (36.12)	423 (33.16)	
WBC, 1000 cells/μL, Mean (S.E)	7.63 (0.08)	7.57 (0.16)	7.67 (0.08)	0.556
Antibiotics drug, n (%)				0.640
No	763 (39.80)	259 (40.71)	504 (39.21)	
Yes	1151 (60.20)	374 (59.29)	777 (60.79)	
Anti-diabetic drug, n (%)				0.635
No	1891 (98.54)	622 (98.30)	1269 (98.69)	
Yes	23 (1.46)	11 (1.70)	12 (1.31)	
Hypertension, n (%)				<0.001
No	329 (17.16)	132 (21.99)	197 (14.03)	
Yes	1585 (82.84)	501 (78.01)	1084 (85.97)	
CVD, n (%)				0.004
No	1558 (82.07)	540 (86.28)	1018 (79.34)	
Yes	339 (17.24)	91 (13.43)	248 (19.70)	
Unknown	17 (0.70)	2 (0.30)	15 (0.95)	
CKD, n (%)				0.348
No	1614 (85.42)	544 (87.23)	1070 (84.25)	
Yes	205 (10.23)	53 (8.70)	152 (11.22)	
Unknown	95 (4.35)	36 (4.07)	59 (4.53)	
Hepatitis, n (%)				0.003
No	1657 (90.12)	563 (93.24)	1094 (88.11)	
Yes	183 (6.57)	42 (3.70)	141 (8.43)	
Unknown	74 (3.31)	28 (3.06)	46 (3.47)	

Table 1 (*continued*)

Variables	Total (n = 1914)	Non-periodontitis/ mild periodontitis (n = 633)	Moderate/severe periodontitis (n = 1281)	*P*
Dyslipidemia, n (%)				0.451
No	267 (11.30)	99 (11.58)	168 (11.11)	
Yes	1609 (87.44)	523 (87.59)	1086 (87.35)	
Unknown	38 (1.26)	11 (0.83)	27 (1.54)	
Autoimmune disease, n (%)				0.448
No	1713 (90.78)	564 (89.98)	1149 (91.30)	
Yes	201 (9.22)	69 (10.02)	132 (8.70)	
Decayed teeth, n (%)				<0.001
Yes	677 (30.67)	157 (21.03)	520 (36.91)	
No	10 (0.48)	1 (0.18)	9 (0.67)	
Unknown	1227 (68.85)	475 (78.79)	752 (62.42)	
Dental implant, n (%)				0.002
Yes	43 (2.33)	24 (3.92)	19 (1.30)	
No	1871 (97.67)	609 (96.09)	1262 (98.70)	
Tooth loss, n (%)				<0.001
1	311 (20.92)	192 (35.40)	119 (11.55)	
1–5	758 (42.67)	248 (41.33)	510 (43.54)	
≥6	845 (36.41)	193 (23.27)	652 (44.91)	
Dental floss use, times per week, Mean (S.E)	3.23 (0.09)	3.53 (0.12)	3.04 (0.15)	0.030
Total energy intake, kcal, Mean (S.E)	2014.56 (25.09)	2009.87 (45.26)	2017.60 (36.38)	0.904
Protein, gm, Mean (S.E)	81.25 (1.13)	80.25 (2.10)	81.90 (1.37)	0.529
Fiber, gm, Mean (S.E)	17.37 (0.35)	17.05 (0.59)	17.58 (0.39)	0.427
Ca, mg, Mean (S.E)	1118.11 (25.42)	1147.15 (33.55)	1099.34 (32.47)	0.274
Iron, gm, Mean (S.E)	19.26 (0.62)	19.82 (1.12)	18.91 (0.62)	0.450
Cu, mg, Mean (S.E)	1.59 (0.04)	1.59 (0.06)	1.60 (0.04)	0.866
Zn, mg, n (%)				0.003
≥11 (male) or ≥8 (female)	748 (35.11)	212 (29.83)	536 (38.53)	
<11 (male) or <8 (female)	1166 (64.89)	421 (70.17%)	745 (61.47)	

DM: diabetes mellitus, SE: standard error, PIR: poverty income ratio, MET: metabolic equivalent, BMI: body mass index, WBC: white blood cell, CVD: cardiovascular disease, CKD: chronic kidney diseases, Ca: calcium, Cu: copper, Zn: zinc.

In subgroup analyses, we found in DM patients who aged ≥65 years old or were female, sufficient dietary Zn consumption was also related to low odds of periodontitis. Periodontitis is highly prevalent among American adults ≥65 years of age,[30] and epidemiological studies and clinical observations have reported that the prevalence and severity of periodontitis increased with age.[31,32] Loss of inflammation control in aging would aggravate the severity of periodontitis and was accompanied by the loss of balance between microorganisms and antibody.[33] The mechanism by which high levels of Zn intake may reduce the risk of periodontitis in older DM patients has not yet been elucidated, our results indicated that as an antioxidant metal element, adequate intake of Zn may mitigate its physiological loss in the elderly patients to achieve more significant anti-inflammatory and antioxidant effects in periodontitis.[34] We found the negative association between Zn intake and periodontitis also in female DM patients. Zorina et al.[35] considered that female was subjected to have a higher risk of chronic periodontitis with the *Porphyromonas gingivalis* (*P. gingivalis*) as the prevalent causative agent. In this study, there were respectively 58.65% male and 41.36% female DM patients in moderate/severe periodontitis group, which indicating the gender distribution of the population is more balanced. There are also significant gender differences in DM. Biological risk factors for female include BMI, metabolic syndrome, sex hormones, and gestational diabetes mellitus (GDM).[36,37] For female with DM, a lower intake of added sugar[38] and a higher intake of dietary fiber[39] appear to be important for reducing BMI and inhibiting *P. gingivalis*, while Zn-rich foods[5] such as protein-rich foods and nuts can also lower cholesterol, and may play a role in reducing the risk of periodontitis.

This study explored the role of dietary Zn consumption in periodontitis, which may provide some references for lifestyle intervention for the prevention and control of periodontitis in DM patients. This large sample study was based on the NHANES database that used multi-stage complex sampling for better representation. In addition, periodontal testing was more comprehensive (covering 28 teeth, 6 positions per tooth). However, there are some limitations. This was a cross-sectional study that was unable to clarify the causal association between Zn intake and

Table 2 Confounding factors related to the periodontitis in the current study.

Variables	OR (95% CI)	*P*
Age	1.04 (1.03—1.05)	<0.001
Gender		
Male	Ref	
Female	0.54 (0.41—0.71)	<0.001
Race		
Mexican American	Ref	
Other Hispanic	0.53 (0.31—0.89)	0.017
Non-Hispanic White	0.43 (0.30—0.61)	<0.001
Non-Hispanic Black	0.64 (0.43—0.96)	0.030
Other Race	0.68 (0.39—1.19)	0.169
Education level		
Less than 9th grade	Ref	
9—11th grade	0.46 (0.29—0.72)	0.001
High school graduate	0.33 (0.22—0.51)	<0.001
AA degree	0.31 (0.20—0.47)	<0.001
College graduate	0.22 (0.14—0.34)	<0.001
Unknown	1.23 (0.10—14.38)	0.868
PIR	0.79 (0.72—0.86)	<0.001
Smoking		
Never smoked	Ref	
Quitting	1.44 (1.10—1.89)	0.008
Current smoker	2.69 (1.73—4.18)	<0.001
Drinking		
No	Ref	
Yes	0.74 (0.54—1.01)	0.061
Physical activity	1.00 (1.00—1.00)	0.785
BMI	0.98 (0.96—1.00)	0.054
<25		
25—29.9	0.69 (0.40—1.19)	0.178
≥30	0.57 (0.35—0.91)	0.020
Diabetic retinopathy		
No	Ref	
Yes	1.14 (0.72—1.78)	0.574
Unknown	0.89 (0.64—1.25)	0.501
WBC	1.02 (0.95—1.10)	0.563
Antibiotics drug		
No	Ref	
Yes	1.06 (0.81—1.39)	0.643
Anti-diabetic drug		
No	Ref	
Yes	0.77 (0.25—2.35)	0.638
Hypertension		
No	Ref	
Yes	1.73 (1.31—2.27)	<0.001
CVD		
No	Ref	
Yes	1.60 (1.19—2.13)	0.002
Unknown	3.49 (0.50—24.22)	0.201
CKD		
No	Ref	
Yes	1.33 (0.86—2.08)	0.195
Unknown	1.15 (0.66—2.02)	0.609
Hepatitis		
No	Ref	
Yes	2.41 (1.50—3.88)	<0.001
Unknown	1.20 (0.59—2.45)	0.610
Dyslipidemia		
No	Ref	
Yes	1.04 (0.74—1.46)	0.820
Unknown	1.93 (0.65—5.76)	0.231
Autoimmune		
No	Ref	
Yes	0.86 (0.57—1.30)	0.454
Decayed teeth		
Yes	Ref	
No	2.09 (0.24—18.01)	0.496
Unknown	0.45 (0.33—0.61)	<0.001
Dental implant		
No		
Yes	3.09 (1.42—6.68)	0.005
Tooth loss		
1	Ref	
1—5	3.23 (2.24—4.65)	<0.001
>6	5.92 (4.10—8.54)	<0.001
Dental floss use	0.95 (0.90—0.99)	0.033
Total energy intake	1.00 (1.00—1.00)	0.905
Protein	1.00 (1.00—1.00)	0.533
Fiber	1.01 (0.99—1.02)	0.435
Ca	1.00 (1.00—1.00)	0.279
Iron	1.00 (0.99—1.00)	0.439
Cu	1.01 (0.90—1.13)	0.867

OR: odds ratio, CI: confidence interval, Ref: reference, PIR: poverty income ratio, BMI: body mass index, WBC: white blood cell, CVD: cardiovascular disease, CKD: chronic kidney diseases, Ca: calcium, Cu: copper.

periodontitis. The dietary intake of Zn was collected using the 24-h dietary recall that unable to avoid the influence of recall bias. And information related to plaque status and gingival treatment was not collected in the database, so the impact of these factors could not be assessed in this analysis.

Dietary Zn intake at the recommended level of intake may improve the onset and progression of periodontitis in patients with DM. Older patients as well as female patients

Table 3 Association between dietary Zn intake and periodontitis.

Variables	Crude model		Adjusted model	
	OR (95% CI)	P	OR (95% CI)	P
Zn intake				
Not reach the recommended level	Ref		Ref	
Reach the recommended level	0.68 (0.52—0.89)	0.006	0.76 (0.58—0.99)	0.044

Zn: zinc, OR: odds ratio, CI: confidence interval, Ref: reference. Adjusted model: adjusted for age, gender, race, PIR, smoking, and dental implants.

Table 4 Association between dietary Zn intake and periodontitis in age and gender subgroups.

Subgroups	Crude model		Adjusted model	
	OR (95% *CI*)	*P*	OR (95% CI)	*P*
Age <65 (n = 1216)				
Not reach the recommended level	Ref		Ref	
Reach the recommended level	0.70 (0.50–0.99)	0.046	0.82 (0.58–1.17)	0.268
Age ≥65 (n = 698)				
Not reach the recommended level	Ref		Ref	
Reach the recommended level	0.61 (0.39–0.96)	0.032	0.59 (0.36–0.97)	0.038
Male (n = 996)				
Not reach the recommended level	Ref		Ref	
Reach the recommended level	0.67 (0.41–1.07)	0.092	0.75 (0.46–1.23)	0.253
Female (n = 918)				
Not reach the recommended level	Ref		Ref	
Reach the recommended level	0.64 (0.44–0.92)	0.016	0.71 (0.51–0.99)	0.048

Zn: zinc, OR: odds ratio, CI: confidence interval, Ref: reference.
Age subgroups: adjusted for gender, race, PIR, smoking, and dental implants.
Gender subgroups: adjusted for age, race, PIR, smoking, and dental implants.

should especially take care of the monitoring of oral conditions to prevent periodontitis.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jds.2023.07.025.

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