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Association Between Metabolic Syndrome, Its Components, and Periodontal Disease in U.S. Adults: Analysis of NHANES 2011–2014

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Abstract:

Objectives: This study evaluated the association between periodontal disease and metabolic syndrome (MetS), examining the independent and combined effects of its five diagnostic components on periodontal disease prevalence.

Methods: This cross-sectional analysis utilized data from the 2011–2012 and 2013–2014 survey cycles of the National Health and Nutrition Examination Survey (NHANES). These represent the most recent NHANES cycles that included a full-mouth clinical periodontal examination of adults. Participants were adults aged ≥30 years with complete laboratory measurements for MetS and clinical periodontal assessments. Descriptive statistics were used to summarize the characteristics of the study population, including weighted prevalence estimates and *p*-values for demographic, behavioral, and inflammatory variables, and periodontal disease. Univariable and multivariable logistic regression analyses were conducted to examine the association between periodontal disease and MetS, as well as MetS components analyzed both individually and collectively.

Results: A total of 3,368 participants met the inclusion criteria for this study. Among them, 34.88% (1,175 participants) had MetS. The groups most affected by MetS were participants aged 70 and older (44.33%), those with the lowest education level (40.13%), low-income level (38.46%), smokers and former smokers (36.80% and 37.12% respectively), high White Blood Cell (WBC) counts (51.72%), and those with periodontal disease (36.46%). In crude analysis, MetS was significantly associated with periodontal disease (cOR = 1.29; 95% CI: 1.02-1.62). However, when adjusting for confounding factors, the association was not statistically significant (aOR = 0.85; 95% CI: 0.63-1.14) even when comparing the participants who had all five MetS components to those with no MetS (aOR=0.82, 95% CI: 0.35-1.92). Similar results were found when assessing the association between severe periodontal disease and MetS. Elevated fasting glucose was the only MetS component that had a statistically significant association with periodontal disease (aOR = 1.29; 95% CI: 1.04-1.60).

Discussion: The findings align with several prior studies reporting null associations, while inconsistencies in the literature may be attributable to differences in populations, diagnostic criteria, confounder control, and sample size. Despite limitations related to the cross-sectional design and NHANES data, this study is strengthened by its large, nationally representative sample and objectively measured periodontal and MetS variables. Overall, the findings suggest that shared socioeconomic and behavioral factors, rather than a direct biological relationship, may underlie the observed patterns, highlighting the need for longitudinal research and targeted interventions to address health disparities.

Conclusion: While periodontal disease and MetS share similar risk factors, this study found no significant association between the two after adjusting for confounders. These findings emphasize the role of socioeconomic and behavioral factors in improving both conditions. Future longitudinal studies are needed to explore potential causal relationships and focus on mitigating health disparities through targeted interventions.

Keywords: Metabolic syndrome, Periodontal disease, Hyperglycemia, Cross-sectional studies, Inflammation, Socioeconomic status.

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1. INTRODUCTION

Metabolic syndrome (MetS) encompasses a group of five conditions, which are insulin resistance, abdominal obesity, abnormal lipid levels (high triglycerides and low High-Density Lipoprotein [HDL]), and hypertension [1]. This elevates the risk of Cardiovascular Disease (CVD) and Type 2 Diabetes Mellitus (T2DM) [2]. The risk of these outcomes grows with the number of MetS components present [3]. Major contributors to MetS include excess body weight, sedentary behavior, and insulin resistance, with age, hormonal changes, and genetic factors also playing a role [4]. In the United States (U.S.), MetS prevalence has been rising over the past decade, particularly among adults with lower educational attainment. MetS prevalence also increases with age, affecting 60.9% of individuals over 60, compared to 25.3% in younger adults aged 20-39 [5].

Multiple professional institutions have established diagnostic frameworks for MetS that focus on a cluster of dyslipidemia, obesity, elevated blood pressure, and high glucose levels [6]. At the core of MetS is insulin resistance, a condition in which cells cannot effectively respond to insulin, leading to reduced glucose uptake and heightened inflammation [7]. This resistance is often linked to increased Body Mass Index (BMI) and waist circumference, reflecting greater visceral fat and inflammation [8]. Inflammation, driven by immune cells and adipose tissue releasing molecules like TNF-α and interleukins, exacerbates insulin resistance and contributes to MetS development [8]. Periodontal disease is also a risk factor for T2DM and poor metabolic control. Studies have investigated potential links and causal relationships between periodontal disease and MetS [9, 10].

Periodontal diseases comprise a spectrum of inflammatory disorders affecting the supporting tissues of the teeth, potentially resulting in tooth loss and contributing to systemic inflammatory burden [11]. The onset and progression of these conditions are largely driven by dysbiosis of the oral microbiome, which triggers immune-mediated inflammatory responses that promote tissue destruction [11]. Common forms of periodontal disease are gingivitis and periodontitis, the latter being a chronic inflammatory disease that causes irreversible loss of tissues and bone surrounding the teeth, eventually leading to tooth loss. Excessive inflammatory responses produce cytokines, ILs, and enzymes like MMPs, which contribute to tissue and bone degradation [4]. Periodontal disease represents the primary cause of tooth loss in adults and can compromise masticatory function and overall quality of life [12]. Over the past two decades, epidemiological evidence has indicated that periodontal conditions are linked to impaired glucose metabolism, dyslipidemia, low-grade systemic inflammation, and systemic disorders including CVD and diabetes [10].

Given that MetS is characterized by chronic low-grade systemic inflammation, it may increase susceptibility to other inflammatory conditions [13]. This has led researchers to examine the relationship between MetS and adverse oral health outcomes, like periodontal disease and dental caries [10]. The potential link between MetS and periodontal disease may involve shared genetic predisposition as well as microbiologically induced systemic inflammatory responses mediated through pro-inflammatory cytokines, oxidative stress pathways, and central adiposity [7]. Few recent investigations have examined the relationship between MetS and periodontal disease using nationally representative U.S. data. Existing findings remain inconsistent [14]. Therefore, this study aimed to evaluate the association between MetS and periodontal disease utilizing data from the 2011-2014 National Health and Nutrition Examination Survey (NHANES), which provides population-level estimates for U.S. adults. In addition to evaluating the association between overall MetS and periodontal disease, this study examined the independent associations of each MetS component and the association according to the number of MetS components present. This approach provided a comprehensive assessment of the relationship between MetS and periodontal health in U.S. adults.

2. MATERIALS AND METHODS

2.1. Data Source and Participants

This cross-sectional analysis used data from the 2011–2012 and 2013–2014 survey cycles of NHANES, a population-based surveillance program designed to evaluate the health and nutritional status of the U.S. civilian, noninstitutionalized population through a complex, multistage probability sampling design [15]. These represent the most recent NHANES cycles that included full-mouth clinical periodontal examinations, allowing standardized assessment of periodontal status. NHANES integrates structured household interviews with

standardized clinical examinations and detailed laboratory assessments conducted in specially equipped mobile examination centers across diverse geographic regions [15]. Adults aged ≥30 years with complete MetS laboratory measurements and comprehensive periodontal examination data were included in the present analysis. This study received exemption from the Harvard Institutional Review Board (IRB23-1410). NHANES protocols were approved by the National Center for Health Statistics Research Ethics Review Board, and written informed consent was obtained from all participants in accordance with the ethical standards of the Declaration of Helsinki. This study followed the STROBE guidelines for observational studies.

2.2. Periodontal Disease Assessment

Periodontal status was classified according to the case definitions proposed by the Centers for Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP). Participants were categorized as having no, mild, moderate, or severe periodontal disease based on interproximal Clinical Attachment Loss (CAL) and Probing Pocket Depth (PPD) measurements. Mild periodontal disease was defined by the presence of ≥2 interproximal sites with CAL ≥3 mm and ≥2 interproximal sites with PPD ≥4 mm (not on the same tooth), or at least one interproximal site with PPD ≥5 mm. Moderate periodontal disease required ≥2 interproximal sites with CAL ≥4 mm or ≥2 interproximal sites with PPD ≥5 mm (not on the same tooth). Severe periodontal disease was defined as ≥2 interproximal sites with CAL ≥6 mm (not on the same tooth) together with ≥1 interproximal site exhibiting PPD ≥5 mm [16]. For regression analyses, periodontal disease was additionally dichotomized as present or absent.

2.3. Metabolic Syndrome Diagnostic Criteria

MetS was defined according to the criteria established by the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III). It is one of the most widely applied definitions in epidemiological research [3]. MetS was identified based on the presence of three or more of the following five components:

- Elevated fasting glucose: Fasting plasma glucose > 100 mg/dL
- Hypertension: Blood pressure > 130/85 mmHg
- Abdominal obesity: Waist circumference > 40 inches for men or 35 inches for women
- Elevated triglyceride levels: Fasting triglyceride levels > 150 mg/dL
- Low HDL levels: Fasting HDL cholesterol levels < 40 mg/dL for men or < 50 mg/dL for women [17].

2.4. Covariates

Additional variables considered in the analysis included demographic factors (age, gender, race/ethnicity, income, and educational attainment), behavioral characteristics (time since last dental visit and smoking status), and an inflammatory marker (White Blood Cell [WBC] count). To facilitate interpretation and maintain consistency with previous literature, all continuous variables were categorized into discrete groups.

Age was categorized into three groups (30-49, 50-69, and ≥70 years), and gender was recorded as male or female. Participants self-identified their race/ethnicity as non-Hispanic White, non-Hispanic Black, Hispanic, Asian, or other race. Household income was assessed using the Poverty-Income Ratio (PIR) and classified as low (<1.38), middle (1.38-3.99), or high (≥3.99). Educational attainment was grouped into four categories: less than high school, high school graduate, some college, and college degree or above.

Regarding behavioral and inflammatory variables, White Blood Cell (WBC) count was considered normal if below 11,000/μL, whereas values above this threshold were classified as indicative of systemic inflammation. Participants' smoking status was classified as current smokers (individuals who had smoked more than 100 cigarettes in their lifetime and continued to smoke), former smokers (those who had smoked more than 100 cigarettes but had quit), and never smokers (individuals who had smoked fewer than 100 cigarettes in their lifetime) [18]. Dental visits were grouped into two categories: participants who had a dental check-up within the past 12 months and those whose last visit occurred more than one year ago [19].

2.5. Statistical Analysis

Data management and analyses were performed using Stata version 16 (StataCorp, USA). Descriptive statistics were calculated to summarize the characteristics of the study population, including weighted prevalence estimates and chi-square *p*-values for demographic, behavioral, and inflammatory variables, as well as periodontal disease and its severity.

Univariable and multivariable logistic regression models were developed using a forward-selection strategy, adding potential confounders sequentially. Variables that improved the adjusted R^2 were retained in the final models. All analyses accounted for the complex NHANES survey design by incorporating sampling weights, strata, and primary sampling units.

Three separate logistic regression analyses were performed to estimate crude odds ratio (cOR), adjusted odds ratio (aOR), and 95% confidence intervals for the associations between periodontal disease and (1) overall MetS prevalence, (2) the number of MetS components, and (3) each individual MetS component. The same approach was applied to examine associations with severe periodontal disease.

3. RESULTS

Table **1** provides an overview of the characteristics of U.S. adults included in this study, consisting of 3,368 participants who completed both laboratory and clinical assessments required for MetS and periodontal disease classification. Among the study population, 40.23% (1,492

participants) had periodontal disease, and 34.88% (1,175 participants) met the criteria for MetS, with prevalence similar between men and women. The highest MetS prevalence was observed in participants aged 70 years or older (44.33%), while the 30–49 age group had the lowest prevalence (26.95%). When examined by race/ethnicity, Hispanic adults exhibited the highest prevalence (37.43%), and Asian adults exhibited the lowest (22.36%). MetS was less common among individuals with a college education or higher (23.88%) and those in the high-income group (28.42%). Regarding smoking status, never smokers had a lower prevalence (31.08%) compared to former smokers (37.12%) and current smokers (36.80%). Participants whose most recent dental visit occurred over one year prior demonstrated a slightly higher prevalence (37.20%). Elevated WBC counts were linked to increased MetS prevalence (51.72%). Furthermore, participants with any periodontal disease had higher rates of MetS (36.46%), especially those with moderate or severe periodontal disease (36.68% and 36.56%, respectively).

Table 1. Descriptive characteristics of U.S. adults with metabolic syndrome, NHANES 2011-2014.

Category	Total # (3368)	Total %[a]	MetS # (1175)	MetS % [a]	*p*-value[b]
Sex					
Male	1689	50.23	583	35.41	0.189
Female	1676	49.76	592	32.19	
Age groups					
30-49	1472	47.56	399	26.95	< 0.001*
50-69	1283	39.15	513	38.18	
70+	559	13.28	240	44.33	
Race					
White	1443	69.97	518	33.93	0.101
Hispanic	717	13.13	288	37.43	
Black	715	9.75	249	33.07	
Asian	414	4.93	96	22.36	
Other	76	2.22	24	37.10	
Education level					
Less than high school	814	17.27	343	40.13	< 0.001*
High school	716	20.01	266	37.17	
Some college	925	30.53	350	38.47	
College or higher	907	32.19	214	23.88	
Income level					
Low income	1081	23.10	432	38.46	< 0.001*
Middle income	1187	39.92	423	36.37	
High income	847	36.98	236	28.42	
Smoking status					
Never smokers	1810	53.98	590	31.08	0.047*
Former smokers	885	27.11	335	37.12	
Current smokers	667	18.90	249	36.80	
Last dental visit					
1 Year or less	1928	63.94	624	31.95	0.058
More than a year	1434	36.06	551	37.20	
WBC					
No	3243	96.42	1109	33.13	< 0.001*
Yes	120	3.58	65	51.72	
Periodontal disease					
No	1562	59.77	479	30.86	0.033*
Yes	1492	40.23	550	36.46	
Periodontal disease level					
No	1562	59.77	479	30.86	0.176
Mild	57	2.28	13	33.03	
Moderate	1113	30.82	421	36.68	
Severe	322	7.13	116	36.56	

Note: MetS: metabolic syndrome

[a] Weighted percentages

[b] *p*-value from the weighted chi-square analysis

* Significant result

Table 2 summarizes the results of univariable and multivariable logistic regression analyses examining the association between periodontal disease and MetS, along with key covariates. After adjustment, females had 47% lower odds of periodontal disease compared to males (*p*-value < 0.001). The odds of having periodontal disease increased with age, with participants aged 50-69 years and ≥70 years showing 2.94- and 5.50-fold higher odds, respectively, compared to the 30-49 age group.

In terms of race/ethnicity, Black and Asian participants had 2.14- and 2.29-fold higher adjusted odds of periodontal disease relative to White participants. Higher educational attainment was associated with lower odds. Individuals with a college degree or higher had 65% lower odds than those with less than a high school education. Likewise, participants in the high-income category had 48% lower odds compared to those in the low-income group.

Behavioral factors were also associated with periodontal disease. Current smokers had 2.82 times higher odds than never smokers, and participants whose last dental visit was over a year ago had approximately twice the odds of having periodontal disease. For MetS, the crude odds of periodontal disease were 29% higher among individuals with MetS (*p*-value = 0.033) compared to those without. However, after adjusting for confounders, the association was no longer statistically significant, with MetS participants having 0.85 times the odds (*p*-value = 0.2) of having periodontal disease relative to non-MetS individuals.

Additional regression analyses focusing specifically on severe periodontal disease yielded results consistent with those observed for any periodontal disease, showing a similar pattern of associations with MetS and covariates.

Table 3 presents the findings from logistic regression models examining the association between periodontal disease and the cumulative number of MetS components. In the unadjusted analysis, individuals with four components demonstrated the greatest odds of having periodontal disease (cOR = 1.52; 95% CI: 1.16-1.99) relative to participants without MetS, and this association reached statistical significance (*p*-value = 0.004). Although higher crude odds were also observed among those with three and five components (cOR = 1.20, 95% CI: 0.95-1.51 and cOR = 1.13, 95% CI: 0.59-2.16, respectively), these associations did not reach statistical significance.

Table 2. Univariable and multivariable logistic regression analyses of periodontal disease, metabolic syndrome, and associated covariates.

Category	Periodontal Disease			
	Crude OR(CI)	*p*-value	Adjust OR(CI)	*p*-value
Sex (ref: male)				
Female	0.60 (0.50- 0.71)	< 0.001*	0.53 (0.45- 0.63)	< 0.001*
Age groups (ref: 30-49)				
50-69	1.79 (1.45-2.21)	< 0.001*	2.94 (2.24- 3.85)	< 0.001*
70+	2.99 (2.33-3.84)	< 0.001*	5.50 (4.07-7.42)	< 0.001*
Race (ref: White)				
Hispanic	2.12 (1.58- 2.86)	< 0.001*	1.67 (1.23- 2.28)	0.003*
Black	2.58 (1.83-3.65)	< 0.001*	2.14 (1.39-3.31)	0.002*
Asian	1.43 (1.02-2.01)	0.037*	2.29 (1.48-3.53)	0.001*
Other	1.43 (0.56-3.64)	0.441	1.35 (0.45-4.05)	0.564
Education level (ref: less than high school)				
High school	0.51 (0.41- 0.64)	< 0.001*	0.63 (0.47-0.85)	0.005*
Some college	0.32 (0.24-0.42)	< 0.001*	0.48 (0.35-0.65)	< 0.001*
College or higher	0.16 (0.12-0.22)	< 0.001*	0.35 (0.25-0.49)	< 0.001*
Income level (ref: low income)				
Middle income	0.48 (0.36-0.64)	< 0.001*	0.72 (0.52-0.98)	0.037*
High income	0.24 (0.19-0.31)	< 0.001*	0.52 (0.36-0.74)	0.001*
Smoking status (ref: never smokers)				
Former smokers	1.52 (1.13- 2.05)	0.007*	1.27 (0.88-1.85)	0.203
Current smokers	3.45 (2.71-4.40)	< 0.001*	2.82 (1.95- 4.09)	< 0.001*
WBC (ref: no inflammation)				
Yes	1.94 (1.19- 3.18)	0.010*	1.47 (0.90-2.40)	0.112
Last dental visit (ref: 1 year or less)				
More than a year	2.63 (2.05-3.37)	< 0.001*	2.08 (1.49- 2.89)	< 0.001*
MetS (ref: no)				
Yes	1.29 (1.02- 1.62)	0.033*	0.85 (0.65-1.10)	0.200

Note: OR: odd ratio
CI: 95% confidence interval
MetS: metabolic syndrome
* Significant result

Table 3. Univariable and multivariable logistic regression analyses examining the relationship between periodontal disease and the number of MetS components.

Category	Periodontal Disease			
	Crude OR(CI)	*p*-value	Adjust OR(CI)	*p*-value
MetS level (ref: no MetS)				
3 Components	1.20 (0.95- 1.51)	0.126	0.75 (0.56- 1.03)	0.070
4 Components	1.52 (1.16- 1.99)	0.004*	1.05 (0.77-1.43)	0.753
5 Components	1.13 (0.59- 2.16)	0.708	0.82 (0.35- 1.92)	0.618

Note: OR: odd ratio
CI: 95% confidence interval
MetS: metabolic syndrome
* Significant result

Table 4. Univariable and multivariable logistic regression analyses examining the relationship between periodontal disease and metabolic syndrome components.

Category	Periodontal Disease			
	Crude OR(CI)	*p*-value	Adjust OR(CI)	*p*-value
Elevated fasting glucose (ref: no)				
Yes	1.81 (1.59 - 2.07)	< 0.001*	1.29 (1.04 -1.60)	0.022*
Abdominal obesity (ref: no)				
Yes	1.11 (0.88 - 1.40)	0.356	1.06 (0.76 - 1.48)	0.696
Hypertension (ref: no)				
Yes	1.56 (1.20 - 2.03)	0.002*	0.99 (0.69 - 1.43)	0.955
Low HDL (ref: no)				
Yes	1.13 (0.88 - 1.46)	0.325	1.01 (0.77 - 1.31)	0.952
High triglyceride (ref: no)				
Yes	1.05 (0.80 - 1.36)	0.728	0.84 (0.61 - 1.16)	0.261

Note: OR: odd ratio
CI: 95% confidence interval
MetS: metabolic syndrome
* Significant result

After adjusting for potential confounders, the odds of periodontal disease among participants with four components were nearly equivalent to those without MetS (aOR = 1.05; 95% CI: 0.77-1.43). Additional regression analyses examining severe periodontal disease in relation to the number of MetS components produced results consistent with those observed for any periodontal disease, showing a similar pattern of associations.

Table **4** displays the results of univariable and multivariable logistic regression analyses evaluating the relationship between periodontal disease and the individual components of MetS. Prior to adjusting for confounding variables, participants with elevated fasting glucose had higher odds of periodontal disease compared to those with normal fasting glucose (cOR = 1.81; 95% CI: 1.59–2.07). Similarly, individuals with hypertension exhibited increased crude odds of periodontal disease relative to participants without hypertension (cOR = 1.56; 95% CI: 1.20–2.03).

After accounting for potential confounders, elevated fasting glucose was the only MetS component that remained statistically significantly associated with periodontal disease (aOR = 1.29; 95% CI: 1.04–1.60). Additional regression analyses focusing specifically on severe periodontal disease produced results that were consistent with the patterns observed for any periodontal disease across the different MetS components.

4. DISCUSSION

This study investigated the relationship between MetS and periodontal disease in a large, nationally representative sample of U.S. adults. Overall, individuals with MetS tended to have a higher burden of periodontal disease, particularly among older adults, those with lower socioeconomic status, smokers, and participants with elevated white blood cell counts. While crude analyses suggested positive associations between periodontal disease and both MetS overall and certain combinations or components of MetS, most notably elevated fasting glucose, these associations were no longer statistically significant after accounting for potential confounders. Elevated fasting glucose remained the only component that demonstrated a consistent, independent link with periodontal disease, highlighting a potential mechanistic pathway connecting metabolic dysfunction with oral health outcomes.

The significant association observed in the crude analysis was attenuated after adjustment for the available confounding factors, suggesting that the relationship between MetS and periodontal disease may be influenced by multiple interrelated factors. Although several potential confounders were accounted for in the present analysis, other relevant factors that were unavailable or not assessed, such as disease duration and tooth-brushing frequency, could not be controlled for and may have contributed to residual confounding [20]. Although MetS and periodontal disease share biological pathways involving systemic inflammation, oxidative stress, and metabolic dysregulation, these mechanisms are complex and may not result in an independent association after accounting for other relevant factors [7]. MetS has also been associated with changes in the salivary microbiome; however, it remains unclear whether these changes contribute to a dysbiotic microbiome associated with periodontal disease [10]. Thus, the lack of a statistically significant adjusted association should not be interpreted as evidence that MetS and periodontal disease are unrelated, but rather as an indication that the observed relationship may not be independent of these factors.

In this study, the observed associations between periodontal disease and demographic as well as behavioral factors align with findings from previous research [21, 22]. While several studies have explored the relationship between MetS and periodontal disease, only a limited number have utilized nationally representative U.S. samples that also consider individual MetS components [14]. The literature remains inconsistent, as some cross-sectional and a few longitudinal studies report no significant associations [23-26], consistent with the findings of this study, whereas other investigations have identified a positive relationship [27-29]. Differences across studies may reflect variations in participant age, the criteria used to define periodontal disease and MetS, the extent of confounder adjustment, population characteristics including cultural and genetic backgrounds, sample size, and potential selection biases [14]. Additionally, several studies suggest that associations may be more significant in female populations [30-33].

Regarding the study limitations, several methodological considerations should be acknowledged when interpreting these findings. The cross-sectional nature of the analysis prevents causal inference, as exposure and outcome variables were measured simultaneously. In addition, behavioral information, such as smoking history and timing of the most recent dental visit, was self-reported and collected retrospectively, which may introduce recall bias. Because NHANES does not include institutionalized individuals, the results may not be generalizable to populations residing in long-term care or other institutional settings. The absence of radiographic assessments in NHANES may also limit the precision of periodontal disease classification. Finally, important determinants of oral health, including oral hygiene behaviors (such as tooth brushing frequency) and use of fluoridated toothpaste, were not available for analysis in this dataset [15].

This study also offers several important strengths. It contributes to a limited body of research investigating the relationship between periodontal disease and MetS, including overall MetS prevalence, individual components, and component count, within a nationally representative U.S. sample. The use of NHANES data enhances external validity and supports generalizability to the broader adult population while reducing the risk of sampling bias. Periodontal status was determined through standardized clinical examinations conducted by trained dental professionals rather than self-report, improving measurement reliability. Likewise, MetS classification was based on objective laboratory measurements and physical assessments, minimizing recall bias and misclassification. Finally, the analytical approach incorporated multiple established confounders, providing a more robust evaluation of the association and offering valuable insight to guide future research in the field.

Although no statistically significant independent association was observed between periodontal disease and metabolic syndrome or its individual components after adjustment, both conditions demonstrated consistent relationships with key demographic and behavioral characteristics. These findings suggest that the relationship between periodontal disease and MetS may be largely influenced by shared risk factors rather than a direct biological connection. This highlights the persistent health disparities experienced by individuals of lower socioeconomic status and reinforces the need for policymakers to prioritize resources and targeted interventions for underserved populations.

CONCLUSION

Periodontal disease and MetS remain highly prevalent conditions in the United States. In this nationally representative sample of U.S. adults, there was no statistically significant independent association between periodontal disease and MetS after adjustment for potential confounders, regardless of the number of MetS components or periodontal disease severity. Among the individual MetS components, elevated fasting glucose was the only component that remained independently associated with periodontal disease. These findings suggest that shared demographic and behavioral factors may contribute to the observed relationship between periodontal disease and MetS. Further longitudinal studies are needed to better understand the temporal and potential causal relationships between MetS, its individual components, and periodontal disease.

PREVIOUS PUBLICATION FROM DOCTORAL DISSERTATION

Part of this article has previously been published in a doctoral dissertation: H, A. (2025). The Association Between Metabolic Syndrome and Oral Diseases Among US Adults. Harvard University Graduate School of Dental Medicine. The full text is archived and accessible *via* the Harvard DASH Repository at https://dash.harvard.edu/handle/1/42719920.

AUTHORS' CONTRIBUTIONS

The authors confirm their contributions to the paper as follows: A.H.: Contributed to the conception, design, analysis, and interpretation of the data, as well as the drafting of the manuscript; Z.N. and H.A.: Contributed to the design, analysis, and interpretation of the data and substantively revised the manuscript; A.K.: Contributed to the analysis and interpretation of the data and substantively revised the manuscript; C.H.: Contributed to the conception and design of the study and substantively revised the manuscript. All authors approved the final submitted version and agreed to be personally accountable for their own contributions and any part of the work.

LIST OF ABBREVIATIONS

AAP	=	American Academy of Periodontology
BMI	=	Body Mass Index
CAL	=	Clinical Attachment Loss
CDC	=	Centers for Disease Control and Prevention
CI	=	Confidence Interval
CVD	=	Cardiovascular Disease
HDL	=	High-Density Lipoprotein
MetS	=	Metabolic Syndrome
NCEP-ATP III	=	National Cholesterol Education Program Adult Treatment Panel III
NHANES	=	National Health and Nutrition Examination Survey
aOR	=	Adjusted Odds Ratio
cOR	=	Crude Odds Ratio
PIR	=	Poverty-Income Ratio
PPD	=	Periodontal Probing Depth
T2DM	=	Type 2 Diabetes Mellitus
U.S.	=	United States
WBC	=	White Blood Cells

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Institutional Review Board (IRB) exemptions were obtained from Harvard University (IRB23-1410) prior to initiating the study. All NHANES data collection procedures were previously approved by the National Center for Health Statistics Research Ethics Review Board.

HUMAN AND ANIMAL RIGHTS

All NHANES data collection procedures were previously approved by the National Center for Health Statistics Research Ethics Review Board in accordance with the Declaration of Helsinki.

CONSENT FOR PUBLICATION

Informed consent was not required, as the study used publicly available, de-identified data from the National Health and Nutrition Examination Survey (NHANES). Written informed consent was obtained from all original participants.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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REFERENCES

[1] Ahmed M, Kumari N, Mirgani Z, *et al*. Metabolic syndrome; definition, pathogenesis, elements, and the effects of medicinal plants on it's elements. J Diabetes Metab Disord 2022; 21(1): 1011-22. http://dx.doi.org/10.1007/s40200-021-00965-2 PMID: 35673459

[2] Hameedaldeen A, Natto ZS, Alhazmi H, Hayes C. Metabolic syndrome and dental caries among adults in the United States: A cross-sectional study from the national health and nutrition examination survey, 2015-2018. Cureus 2025; 17(10): e95397. http://dx.doi.org/10.7759/cureus.95397 PMID: 41293368

[3] Lee T, Han K, Yun KI. Association between dental scaling and metabolic syndrome and lifestyle. PLoS One 2024; 19(4): e0297545. http://dx.doi.org/10.1371/journal.pone.0297545 PMID: 38573898

[4] Aizenbud I, Wilensky A, Almoznino G. Periodontal disease and its association with metabolic syndrome — A comprehensive review. Int J Mol Sci 2023; 24(16): 13011. http://dx.doi.org/10.3390/ijms241613011 PMID: 37629193

[5] Liang X, Or B, Tsoi MF, Cheung CL, Cheung BMY. Prevalence of metabolic syndrome in the United States National Health and Nutrition Examination Survey 2011–18. Postgrad Med J 2023; 99(1175): 985-92. http://dx.doi.org/10.1093/postmj/qgad008 PMID: 36906842

[6] Tse C, Lisanti N, Grubert Van Iderstine M, Uhanova J, Minuk G, Faisal N. Comparison of different definitions of metabolic syndrome and their associations with non-alcoholic fatty liver disease: A retrospective study. Can Liver J 2023; 6(4): 395-406. http://dx.doi.org/10.3138/canlivj-2023-0006 PMID: 38152326

[7] Syed H, Sehra S, Farzadi S, Niazi S. Links between oral diseases and metabolic syndrome: A narrative review. Br Dent J 2025; 238(11): 853-7. http://dx.doi.org/10.1038/s41415-025-8324-0 PMID: 40514488

[8] Popa AD, Gherasim A, Caba L, *et al*. Cathelicidin: Insights into its impact on metabolic syndrome and chronic inflammation. Metabolites 2024; 14(12): 672. http://dx.doi.org/10.3390/metabo14120672 PMID: 39728453

[9] Pavithra V, Sri Chinthu KK, Solomon MC. Diabetes mellitus, obesity and periodontitis – A three way interconnection. Obes Med 2025; 55: 100615.

http://dx.doi.org/10.1016/j.obmed.2025.100615
[10] Pirih FQ, Monajemzadeh S, Singh N, *et al*. Association between metabolic syndrome and periodontitis: The role of lipids, inflammatory cytokines, altered host response, and the microbiome. Periodontol 2000 2021; 87(1): 50-75. http://dx.doi.org/10.1111/prd.12379 PMID: 34463996
[11] Martínez-García M, Hernández-Lemus E. Periodontal inflammation and systemic diseases: An overview. Front Physiol 2021; 12: 709438. http://dx.doi.org/10.3389/fphys.2021.709438 PMID: 34776994
[12] Ono T, Kato S, Kokubo Y, *et al*. Tooth loss related with prevalence of metabolic syndrome in a general urban Japanese population: The suita study. Int J Environ Res Public Health 2022; 19(11): 6441. http://dx.doi.org/10.3390/ijerph19116441 PMID: 35682027
[13] Zhao Q, Tan X, Su Z, *et al*. The Relationship between the Dietary Inflammatory Index (DII) and Metabolic Syndrome (MetS) in middle-aged and elderly individuals in the United States. Nutrients 2023; 15(8): 1857. http://dx.doi.org/10.3390/nu15081857 PMID: 37111075
[14] Sayeed G, Varghese SS. Association between periodontitis and metabolic syndrome in females. J Int Soc Prev Community Dent 2021; 11(6): 609-25. http://dx.doi.org/10.4103/jispcd.JISPCD_168_21 PMID: 35036370
[15] Chen TC, Parker JD, Clark J, Shin HC, Rammon JR, Burt VL. National Health and Nutrition Examination Survey: Estimation Procedures, 2011-2014. Vital Health Stat 2 2018; (177): 1-26. PMID: 29775431
[16] Skipina TM, Elhawary MM, Soliman EZ. Periodontal disease is associated with elevated atherosclerotic cardiovascular disease risk score. Am J Med Sci 2022; 364(3): 327-32. http://dx.doi.org/10.1016/j.amjms.2022.04.002 PMID: 35405138
[17] Dhondge RH, Agrawal S, Patil R, Kadu A, Kothari M. A comprehensive review of metabolic syndrome and its role in cardiovascular disease and type 2 diabetes mellitus: Mechanisms, risk factors, and management. Cureus 2024; 16(8): e67428. http://dx.doi.org/10.7759/cureus.67428 PMID: 39310549
[18] Li S, Wen C, Bai X, Yang D. Association between biological aging and periodontitis using NHANES 2009–2014 and mendelian randomization. Sci Rep 2024; 14(1): 10089. http://dx.doi.org/10.1038/s41598-024-61002-9 PMID: 38698209
[19] Liu L, Xia LY, Gao YJ, Dong XH, Gong RG, Xu J. Association between obesity and periodontitis in US adults: NHANES 2011–2014. Obes Facts 2024; 17(1): 47-58. http://dx.doi.org/10.1159/000534751 PMID: 37935140
[20] Saito M, Shimazaki Y, Yoshii S, Kojima T. Oral health behaviours and metabolic syndrome: Mediation effect of lifestyle habits. BMC Oral Health 2025; 25(1): 510. http://dx.doi.org/10.1186/s12903-025-05860-3 PMID: 40211264
[21] Hashim NT, Babiker R, Padmanabhan V, *et al*. The global burden of periodontal disease: A narrative review on unveiling socioeconomic and health challenges. Int J Environ Res Public Health 2025; 22(4): 624. http://dx.doi.org/10.3390/ijerph22040624 PMID: 40283848
[22] Santoso CMA, Bramantoro T, Kardos L, Szakács DF, Nagy A. Metabolic syndrome and periodontitis among adults: The 2018 Indonesia National Health Survey. J Clin Periodontol 2022; 49(6): 562-72. http://dx.doi.org/10.1111/jcpe.13622 PMID: 35373363
[23] Kim JI, Choi CH, Chung KH. No association between metabolic syndrome and periodontitis in Korean postmenopausal women. Int J Environ Res Public Health 2021; 18(21): 11110. http://dx.doi.org/10.3390/ijerph182111110 PMID: 34769630
[24] Gomes-Filho IS, das Mercês MC, de Santana Passos-Soares J, *et al*. Severity of periodontitis and metabolic syndrome: Is there an association? J Periodontol 2016; 87(4): 357-66. http://dx.doi.org/10.1902/jop.2015.150367 PMID: 26654349
[25] Almoznino G, Zini A, Kedem R, Protter NE, Zur D, Abramovitz I. Hypertension and its associations with dental status: Data from the dental, oral, medical epidemiological (dome) nationwide records-based study. J Clin Med 2021; 10(2): 176. http://dx.doi.org/10.3390/jcm10020176 PMID: 33419028
[26] Shearer DM, Thomson WM, Cameron CM, *et al*. Periodontitis and multiple markers of cardiometabolic risk in the fourth decade: A cohort study. Community Dent Oral Epidemiol 2018; 46(6): 615-23. http://dx.doi.org/10.1111/cdoe.12414 PMID: 30160305
[27] Campos JR, Martins CC, Faria SFS, *et al*. Association between components of metabolic syndrome and periodontitis: A systematic review and meta-analysis. Clin Oral Investig 2022; 26(9): 5557-74. http://dx.doi.org/10.1007/s00784-022-04583-x PMID: 35716205
[28] Gherbon AMC, Frandes M, Roman D, *et al*. Metabolic syndrome and periodontitis — From shared mechanisms to interdisciplinary care: A narrative review of clinical evidence. J Clin Med 2026; 15(14): 5510. http://dx.doi.org/10.3390/jcm15145510 PMID: 42513424
[29] Ayuthaya BIN, Lertpimonchai A, Samaranayake L, *et al*. The potential effect of periodontal disease on the development of metabolic syndrome: A 10-year observational study in a thai adult cohort. J Clin Periodontol 2025; 52(3): 339-52. http://dx.doi.org/10.1111/jcpe.14068 PMID: 39256912
[30] Pietropaoli D, Altamura S, Ortu E, *et al*. Association between metabolic syndrome components and gingival bleeding is women-specific: A nested cross-sectional study. J Transl Med 2023; 21(1): 252. http://dx.doi.org/10.1186/s12967-023-04072-z PMID: 37038173
[31] Andriankaja OM, Sreenivasa S, Dunford R, DeNardin E. Association between metabolic syndrome and periodontal disease. Aust Dent J 2010; 55(3): 252-9. http://dx.doi.org/10.1111/j.1834-7819.2010.01231.x PMID: 20887511
[32] Poulsen H, Meurman JH, Kautiainen H, Huvinen E, Koivusalo S, Eriksson JG. Periodontal disease and metabolic syndrome in women at prior high risk for gestational diabetes. Clin Exp Dent Res 2024; 10(6): e70053. http://dx.doi.org/10.1002/cre2.70053 PMID: 39665824
[33] Kotin J, Walther C, Wenzel U, *et al*. Association between periodontitis and metabolic syndrome in the Hamburg City Health Study. J Periodontol 2022; 93(8): 1150-60. http://dx.doi.org/10.1002/JPER.21-0464 PMID: 34967009

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