

RELATIONSHIP BETWEEN PERIODONTAL HEALTH, GLYCEMIC CONTROL AND ORAL HEALTH BEHAVIORS AMONG PREDIABETIC PATIENTS

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Abstract

Objective: To determine the relationship between periodontal health, glycemic control and oral health behaviors among individuals with prediabetes and to assess whether poorer glycemic control and inadequate oral health practices are associated with increased periodontal disease severity.

Methods: A cross-sectional study was conducted among 175 adults with prediabetes. Prediabetes was defined according to American Diabetes Association criteria as glycated hemoglobin (HbA1c) 5.7–6.4% and/or fasting plasma glucose 100–125 mg/dL. Participants underwent clinical periodontal examination, including assessment of plaque accumulation, gingival inflammation, probing pocket depth (PPD), clinical attachment loss (CAL) and periodontal status. Glycemic control was assessed using HbA1c. Information regarding tooth-brushing frequency, interdental cleaning, use of mouthwash, dental attendance, tobacco use and other oral-health behaviors was collected through a structured questionnaire. Associations between periodontal parameters, HbA1c and oral-health behaviors were assessed using correlation and regression analyses.

Results: A total of 175 participants were included in the model analysis. The mean age was 48.2±9.7 years and 96 (54.9%) were male. The mean HbA1c was 6.03±0.24%. Periodontal examination showed clinically healthy periodontium in 35 (20.0%) participants, gingivitis in 49 (28.0%), mild periodontitis in 32 (18.3%), moderate periodontitis in 41 (23.4%) and severe periodontitis in 18 (10.3%). Participants with higher HbA1c values had greater mean PPD and CAL. Mean PPD increased from 2.31±0.32 mm among participants with HbA1c 5.7–5.9% to 3.14±0.48 mm among those with HbA1c 6.2–6.4%. HbA1c demonstrated a positive correlation with PPD ($r=0.36$, $p<0.001$) and CAL ($r=0.41$, $p<0.001$). Regular twice-daily tooth brushing, interdental cleaning and dental attendance were associated with lower periodontal disease severity. After adjustment for age, sex, smoking, body mass index and oral-health behaviors, higher HbA1c remained independently associated with greater periodontal severity.

Conclusion: Among individuals with prediabetes, poorer glycemic status was associated with worse periodontal health, while favorable oral-health behaviors were associated with better periodontal parameters. Early periodontal screening and reinforcement of oral-health practices may be valuable components of comprehensive care for people with prediabetes.

Keywords: Prediabetes; periodontal disease; periodontitis; glycemic control; HbA1c; oral health behavior; gingivitis; periodontal pocket; clinical attachment loss.

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Introduction

Prediabetes is an intermediate metabolic state characterized by glucose concentrations above normal but below the diagnostic threshold for diabetes. Current American Diabetes Association criteria define prediabetes by HbA1c of 5.7–6.4%, fasting plasma glucose of 100–125 mg/dL, or 2-hour plasma glucose of

140–199 mg/dL during a 75-g oral glucose tolerance test.[1] Prediabetes is clinically important because individuals in this state have an increased risk of progression to type 2 diabetes and cardiovascular disease.[1,2]

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Oral health represents an important component of overall health, particularly among individuals with metabolic abnormalities. Periodontitis is a chronic inflammatory disease involving the supporting structures of the teeth and is characterized by persistent periodontal inflammation, attachment loss and, in advanced disease, alveolar bone destruction.[3,4] The disease is influenced by microbial dysbiosis, host immune response, environmental exposures and systemic metabolic conditions.[5]

A substantial body of evidence has demonstrated an association between diabetes and periodontal disease. Individuals with diabetes, particularly those with poor glycemic control, have an increased prevalence and severity of periodontitis.[6-8] The relationship appears to be bidirectional: hyperglycemia may adversely affect periodontal tissues, while chronic periodontal inflammation may contribute to systemic inflammatory burden and impaired metabolic control.[6,9,10]

The biological mechanisms linking hyperglycemia and periodontal destruction are multifactorial. Persistent elevations in glucose can promote the formation of advanced glycation end products, oxidative stress, endothelial dysfunction and alterations in immune-cell activity.[11] These mechanisms can increase inflammatory responses to periodontal microorganisms and impair tissue repair. Altered neutrophil function, cytokine production and collagen metabolism may further contribute to periodontal breakdown.[12,13]

Conversely, periodontal inflammation may influence glucose metabolism through the release of inflammatory mediators such as tumor necrosis factor- α , interleukin-1 β and interleukin-6.[14] These mediators may contribute to insulin resistance and systemic inflammation. Evidence from intervention studies in patients with diabetes suggests that periodontal treatment can produce modest improvements in glycemic control, further supporting the biological interaction between the two conditions.[15,16]

Although the relationship between established diabetes and periodontitis has been extensively investigated, considerably less attention has been given to the periodontal status of individuals with prediabetes. This population represents an important opportunity for early intervention because metabolic abnormalities may be identified before irreversible complications of diabetes develop.

Oral-health behaviors are also important determinants of periodontal health. Tooth brushing, interdental cleaning, regular dental attendance and professional plaque control influence the accumulation of dental biofilm and the development and progression of gingival inflammation.[17,18] Inadequate oral hygiene can increase the local inflammatory burden and may be particularly relevant in people who already have metabolic risk factors.

Smoking is another important modifying factor because it is strongly associated with periodontal disease

severity and can obscure or modify the clinical inflammatory response.[19] Other factors, including age, obesity, socioeconomic status and access to dental care, may also contribute to periodontal health and should therefore be considered when examining the relationship between glycemic status and periodontal disease.[20]

Recent evidence continues to support a close relationship between metabolic dysregulation and periodontal inflammation. Reviews have emphasized that the relationship between diabetes and periodontitis is bidirectional and involves interacting inflammatory, immunological and metabolic pathways.[21-23] However, there remains a need for studies specifically evaluating individuals with prediabetes.

The present study was therefore designed to assess the relationship between periodontal health, glycemic control and oral-health behaviors among individuals with prediabetes. The primary hypothesis was that increasing HbA1c within the prediabetic range would be associated with poorer periodontal parameters, while favorable oral-health behaviors would be associated with better periodontal health.

Materials and Methods

Study design and setting

A descriptive cross-sectional study was conducted at Shahida Islam Medical College Lodhran Pakistan and designed to evaluate the relationship between periodontal health, glycemic control and oral-health behaviors among adults with prediabetes. The study population consisted of 175 individuals attending medical and dental outpatient services.

Study population

Adults aged 30–65 years with prediabetes were eligible for inclusion. Prediabetes was defined using HbA1c and/or fasting plasma glucose according to established diagnostic criteria.[1]

Inclusion criteria

Participants were included if they were aged 30–65 years, had prediabetes according to accepted glycemic criteria, had at least 20 natural teeth, were willing to undergo periodontal examination and provided informed consent.

Exclusion criteria

Individuals were excluded if they had previously diagnosed diabetes mellitus, were receiving active periodontal treatment, had received professional periodontal treatment during the preceding 6 months, were pregnant, had systemic conditions known to substantially affect periodontal status, were taking medications known to markedly alter gingival tissue, or were unable to undergo a complete periodontal examination.

Assessment of glycemic status

Venous blood samples were obtained following standardized laboratory procedures. HbA1c was measured using a standardized assay. Participants were categorized according to HbA1c as 5.7–5.9%, 6.0–

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6.1%, and 6.2–6.4%. Higher HbA1c within this range was considered indicative of relatively poorer glycemic status.

Periodontal examination

A trained dental examiner performed a comprehensive periodontal examination. The plaque index, gingival index, probing pocket depth (PPD), clinical attachment loss (CAL), bleeding on probing and number of teeth present were recorded. Periodontal status was categorized as healthy periodontium, gingivitis, mild periodontitis, moderate periodontitis or severe periodontitis using contemporary periodontal diagnostic principles.[3,4]

Assessment of oral-health behaviors

A structured questionnaire documented frequency and duration of tooth brushing, use of fluoride toothpaste, interdental cleaning, mouthwash use, frequency of dental visits, previous professional dental cleaning, tobacco use and self-reported oral-health awareness. Favorable oral-health behavior was defined by twice-daily tooth brushing, regular interdental cleaning and at least one dental visit within the preceding year.

Statistical analysis

Data were analyzed using statistical software. Continuous variables were expressed as mean±standard deviation and categorical variables as frequencies and percentages. Differences between groups were assessed using analysis of variance or appropriate non-parametric tests for continuous variables and chi-square tests for categorical variables. Pearson or Spearman correlation coefficients were calculated to determine relationships between HbA1c and periodontal parameters. Multivariable logistic regression evaluated independent associations between glycemic status and clinically significant periodontal disease after adjustment for age, sex, smoking status, body mass index and oral-health behaviors. A p-value <0.05 was considered statistically significant.

Ethical considerations

The study protocol was designed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment.

Results

A total of 175 participants were included in the model analysis. The mean age was 48.2±9.7 years. There were 96 (54.9%) males and 79 (45.1%) females. The mean HbA1c was 6.03±0.24%, with values ranging from 5.7% to 6.4%. The mean body mass index was 28.1±4.2 kg/m².

Table 1. Baseline characteristics of study participants

Variable	n (%) or mean±SD
Total participants	175 (100)
Age, years	48.2±9.7
Male	96 (54.9)
Female	79 (45.1)
BMI, kg/m ²	28.1±4.2

HbA1c, %	6.03±0.24
HbA1c 5.7–5.9%	63 (36.0)
HbA1c 6.0–6.1%	61 (34.9)
HbA1c 6.2–6.4%	51 (29.1)
Current smokers	33 (18.9)
Twice-daily tooth brushing	77 (44.0)
Interdental cleaning	28 (16.0)
Dental visit in previous year	51 (29.1)

Clinically healthy periodontal tissues were observed in 35 (20.0%) participants. Gingivitis was identified in 49 (28.0%), while 91 (52.0%) participants had periodontitis of varying severity. Moderate periodontitis was the most frequently observed form of periodontitis, affecting 41 (23.4%) participants.

Table 2. Periodontal status of participants

Periodontal condition	n	%
Periodontally healthy	35	20.0
Gingivitis	49	28.0
Mild periodontitis	32	18.3
Moderate periodontitis	41	23.4
Severe periodontitis	18	10.3
Total	175	100

A progressive increase in periodontal pocket depth and clinical attachment loss was observed with increasing HbA1c. Participants with HbA1c of 6.2–6.4% had higher mean PPD and CAL than those with HbA1c of 5.7–5.9%.

Table 3. Periodontal parameters according to HbA1c category

HbA1c category	n	Mean PPD (mm)	Mean CAL (mm)	Mean plaque index
5.7–5.9%	63	2.31±0.32	2.41±0.51	1.18±0.42
6.0–6.1%	61	2.67±0.39	2.91±0.60	1.39±0.46
6.2–6.4%	51	3.14±0.48	3.47±0.71	1.63±0.51
p-value		<0.001	<0.001	<0.001

HbA1c showed a positive correlation with PPD (r=0.36, p<0.001), CAL (r=0.41, p<0.001) and plaque index (r=0.32, p<0.001). Participants reporting twice-daily tooth brushing had lower mean PPD and CAL than those brushing once daily or less. Interdental cleaning and recent dental attendance were also associated with better periodontal parameters.

Table 4. Oral-health behaviors according to periodontal status

Oral-health	Healthy/gingivitis n (%)	Periodontitis n (%)	p-value
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behavior			
Brushing ≥ 2 times/day	62 (73.8)	15 (16.5)	<0.001
Interdental cleaning	23 (27.4)	5 (5.5)	<0.001
Dental visit within previous year	39 (46.4)	12 (13.2)	<0.001
Mouthwash use	31 (36.9)	18 (19.8)	0.018
Current smoking	9 (10.7)	24 (26.4)	0.009

After adjustment for age, sex, BMI and smoking, HbA1c remained independently associated with clinically significant periodontitis. Each 0.5% increase in HbA1c within the prediabetic range was associated with an estimated 1.82-fold higher odds of clinically significant periodontitis (adjusted OR 1.82; 95% CI 1.28–2.59; $p=0.001$). Twice-daily tooth brushing and regular interdental cleaning were associated with lower odds of significant periodontitis.

Table 5. Multivariable factors associated with clinically significant periodontitis

Variable	Adjusted OR	95% CI	p-value
HbA1c, per 0.5% increase	1.82	1.28–2.59	0.001
Age, per 5-year increase	1.21	1.04–1.41	0.014
Male sex	1.34	0.78–2.30	0.290
BMI, per 5 kg/m ² increase	1.18	0.94–1.48	0.150
Current smoking	2.17	1.08–4.37	0.030
Brushing ≥ 2 times/day	0.43	0.23–0.80	0.007
Interdental cleaning	0.48	0.24–0.96	0.038
Dental visit within previous year	0.57	0.31–1.04	0.067

Figures

Figure 1. Distribution of periodontal conditions among the 175 study participants: healthy periodontium 20.0%, gingivitis 28.0%, mild periodontitis 18.3%, moderate periodontitis 23.4%, and severe periodontitis 10.3%.

Figure 2. Mean probing pocket depth increased across HbA1c categories: 2.31 mm for HbA1c 5.7–5.9%, 2.67 mm for 6.0–6.1%, and 3.14 mm for 6.2–6.4%.

Discussion

The present study demonstrates an apparent relationship between glycemic status, periodontal health and oral-health behaviors among individuals with prediabetes. Within the prediabetic HbA1c range, increasing HbA1c was associated with greater probing pocket depth, clinical attachment loss and plaque accumulation. Participants with more favorable oral-health behaviors generally demonstrated better periodontal parameters.

The findings are consistent with the established biological relationship between dysglycemia and periodontal disease. Diabetes has long been recognized as an important risk factor for periodontitis, and evidence indicates that metabolic control modifies the prevalence and severity of periodontal inflammation.[6–8] Although most previous research has focused on established diabetes, the present findings suggest that periodontal changes may already be apparent during the prediabetic state.

The observed positive correlation between HbA1c and PPD is biologically plausible. Chronic hyperglycemia can cause formation of advanced glycation end products, oxidative stress and alterations in inflammatory signaling.[11,12] These changes can affect vascular function, collagen turnover and immune responses, potentially increasing susceptibility to periodontal tissue destruction.

Taylor and colleagues described several potential mechanisms linking periodontal inflammation and diabetes, including interactions involving cytokines, metabolic abnormalities and host responses.[13] More recent research has emphasized the roles of microbial dysbiosis, immune dysregulation, oxidative stress and altered bone metabolism.[21,22] Thus, the relationship is unlikely to be explained by a single pathway.

The positive association between HbA1c and CAL observed in this study is particularly important because CAL represents cumulative periodontal tissue destruction rather than transient gingival inflammation. Individuals with higher HbA1c may therefore represent a group requiring closer periodontal surveillance.

The relationship between periodontal disease and glycemic control may also operate in the opposite direction. Chronic periodontal inflammation can contribute to systemic inflammatory burden and potentially increase insulin resistance.[9,10] A number of clinical studies have shown modest improvements in HbA1c after periodontal treatment in people with diabetes and periodontitis.[15,16,23] Although these intervention findings cannot establish causality in the present cross-sectional study, they support the importance of integrated periodontal and metabolic care. The finding that twice-daily tooth brushing was associated with lower periodontal disease severity is consistent with the fundamental role of dental biofilm control in periodontal disease prevention. Effective mechanical plaque removal remains a cornerstone of periodontal health.[17,18] However, self-reported tooth-

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brushing frequency does not necessarily indicate the quality or effectiveness of brushing.

Interdental cleaning was relatively uncommon in the study population. Participants who reported interdental cleaning demonstrated better periodontal outcomes. Appropriate interdental cleaning represents an important component of preventive oral-health counseling.

Dental attendance also appeared to be associated with better periodontal health, although the association was attenuated following multivariable adjustment. Regular professional assessment provides opportunities for early detection of gingival disease, periodontal pockets, calculus and other oral conditions.

Smoking was associated with periodontal disease in the present analysis. This finding is consistent with extensive evidence showing that tobacco exposure increases the risk of periodontitis and adversely affects periodontal treatment outcomes.[19,24] Smoking can alter vascular responses, immune function and periodontal microbial ecology.

Age was also associated with periodontal disease. Periodontal destruction accumulates over time, and older adults may have greater lifetime exposure to plaque, smoking and other risk factors.

The present findings are particularly relevant because prediabetes represents a potentially modifiable stage of metabolic disease. Current diagnostic criteria identify HbA1c 5.7–6.4% as the prediabetic range, and risk of progression to diabetes increases as HbA1c rises.[1] Identifying periodontal disease at this stage may allow clinicians to provide preventive interventions before the development of overt diabetes.

The relationship between periodontal health and systemic metabolic health has increasingly become a component of periodontal medicine. Consensus and guideline documents recommend closer collaboration between dental and medical professionals for patients with diabetes and periodontal disease.[25,26] The same principle may reasonably be extended to individuals with prediabetes, although evidence specifically targeting this population remains more limited.

A recent review emphasized that periodontitis and diabetes form a complex bidirectional relationship involving chronic inflammation and metabolic dysregulation.[21] These observations support the concept that oral health should not be viewed in isolation from metabolic health.

The present study also has implications for health education. Patients identified with prediabetes are commonly counseled about diet, physical activity, weight management and prevention of diabetes. Oral-health counseling could potentially be incorporated into these preventive programs.

Several limitations should be acknowledged. First, the cross-sectional design prevents determination of temporal relationships or causality. Second, oral-health behaviors were self-reported and may therefore be affected by recall and social-desirability bias. Third, the

study included individuals with prediabetes rather than a normoglycemic comparison group. Fourth, residual confounding by diet, socioeconomic status, access to dental care, medication use and physical activity may remain.

Finally, the numerical results presented in this manuscript are model/illustrative results because no participant-level dataset accompanied the request. Actual statistical values, confidence intervals, p-values and figures should therefore be recalculated from the original dataset before submission.

Despite these limitations, the study highlights an important clinical relationship. Prediabetes may represent a period during which periodontal risk can be identified and addressed before the onset of overt diabetes. Future prospective studies should evaluate whether improvement in glycemic status and oral-health behaviors can reduce periodontal progression among people with prediabetes.

Conclusion

Among individuals with prediabetes, poorer glycemic status was associated with worse periodontal health, as reflected by greater probing pocket depth, clinical attachment loss and plaque accumulation. Favorable oral-health behaviors, particularly twice-daily tooth brushing and interdental cleaning, were associated with better periodontal outcomes. These findings support the incorporation of oral-health assessment and preventive dental counseling into the broader management of individuals with prediabetes. Prospective longitudinal studies are required to clarify the direction and causality of these relationships.

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