

Salivary Biomarkers for Early Detection of Type 2 Diabetes Mellitus in General Dentistry Practices

Riama Vensya Sitohang^{1*}, & Corazon Hanna Dumaria²

^{1*} Politeknik Kesehatan Kemenkes Jakarta II, Indonesia, ²Politeknik Kesehatan Kemenkes Jakarta II, Indonesia

*Co e-mail: riagintingg@gmail.com¹

Article Information

Received: July 22, 2026

Revised: August 25, 2026

Online: September 25, 2026

Keywords

Salivary biomarkers, Type 2 Diabetes Mellitus, Dental Practice Opportunistic Screening, Periodontal Disease, HbA1c

ABSTRACT

Type 2 diabetes mellitus (T2DM) remains substantially underdiagnosed, and general dental practices represent an underused opportunistic screening setting. This cross-sectional study evaluated non-invasive salivary biomarkers for identifying undiagnosed T2DM and prediabetes among adult dental patients. A total of 180 participants were stratified into three groups based on HbA1c and medical history: healthy controls (n=60), prediabetes (n=55), and confirmed T2DM (n=65). Unstimulated whole saliva was analyzed for salivary glucose, alpha-amylase, MMP-8, flow rate, and pH, alongside full periodontal examination, with venous HbA1c as reference standard. Salivary glucose increased progressively across groups (HC 0.28, prediabetes 0.52, T2DM 0.89 mmol/L; $p<0.001$) and correlated strongly with HbA1c ($r=0.81$, $p<0.001$). MMP-8 and periodontal parameters were also significantly elevated in T2DM group. ROC analysis showed salivary glucose alone achieved AUC 0.86 (sensitivity 81%, specificity 79%) for distinguishing dysglycemic from normoglycemic individuals, while combined biomarker panel (glucose, amylase, MMP-8) improved performance to AUC 0.91 (sensitivity 88%, specificity 84%). These findings support the feasibility of chairside salivary biomarker testing as an adjunctive, non-invasive opportunistic screening tool for undiagnosed T2DM and prediabetes within general dental practices, with potential to facilitate earlier medical referral and interprofessional collaborative care.



INTRODUCTION

Type 2 diabetes mellitus (T2DM) is one of the most prevalent non-communicable diseases worldwide, and a substantial proportion of affected individuals remain undiagnosed until complications such as retinopathy, nephropathy, or cardiovascular disease have already developed. Population-based estimates suggest that undiagnosed T2DM and prediabetes affect a considerable fraction of adults attending routine healthcare settings, including dental clinics, and systematic screening in non-medical settings has been proposed as an effective strategy to close this diagnostic gap (Chinnasamy & Moodie, 2020). The global burden of undiagnosed diabetes continues to grow, and delayed diagnosis is consistently associated with a higher risk of vascular and renal complications by the time of eventual detection, underscoring the public health urgency of expanding screening beyond conventional medical settings (Herman & Cefalu, 2021).

General dental practices represent a particularly promising, yet underutilized, opportunistic screening venue. Patients frequently attend dental visits more regularly than medical check-ups, and the well-documented bidirectional relationship between periodontal disease and glycemic dysregulation gives dental professionals a unique clinical vantage point from which unrecognized dysglycemia may first become apparent, often through the presentation of moderate-to-severe periodontitis, delayed wound healing, xerostomia, or recurrent oral infections (Masiero et al., 2022). This bidirectional relationship, in which hyperglycemia promotes periodontal tissue breakdown while periodontal inflammation in turn worsens insulin resistance and glycemic control, is now well established across multiple systematic reviews and meta-analyses (Borgnakke, 2020; Lalla & Lamster, 2021; Nascimento & Leite, 2022) and has been linked to broader systemic consequences, including increased cardiovascular risk (Sanz & Kornman, 2021; Genco & Sanz, 2020). Point-of-care screening initiatives using capillary blood HbA1c testing in the dental chair have demonstrated feasibility and have successfully identified previously undiagnosed prediabetes and diabetes in a meaningful proportion of screened dental patients (Priede et al., 2022; Chee et al., 2025).

Nonetheless, capillary blood-based chairside testing, while less invasive than venous blood draw, still requires a finger-prick procedure that some patients find unpleasant, that carries a small infection-control burden for the dental team, and that may reduce patient acceptance of routine screening. Saliva has therefore attracted growing interest as an alternative, fully non-invasive diagnostic fluid. Because a substantial proportion of the salivary proteome and metabolome mirrors that of serum, saliva can, in principle, reflect systemic metabolic status while being collected painlessly, repeatedly, and without specialized phlebotomy training (Végh et al., 2023).

Several candidate salivary biomarkers have been investigated for their association with T2DM. Salivary glucose concentration has been repeatedly shown to increase in parallel with blood glucose and glycated hemoglobin, reflecting passive diffusion and increased gingival crevicular fluid transudation of glucose in hyperglycemic states (Caixeta et al., 2023), an association corroborated across independent clinical cohorts and systematic reviews (Sreedevi & Rao, 2022; Goodson & Mukaida, 2022; Bencze et al., 2022). Salivary alpha-amylase, an enzyme responsive to autonomic nervous system activity and metabolic stress, has also been reported to differ between

diabetic and non-diabetic individuals, reflecting autonomic dysregulation of glandular secretory function in chronic hyperglycemia (Li & Wang, 2022). Beyond glucose-related markers, inflammatory mediators such as matrix metalloproteinase-8 (MMP-8), a collagenase implicated in periodontal tissue breakdown, are elevated in both periodontitis and diabetes and may serve as a combined indicator of the diabetes-periodontal disease axis (Alkahtani et al., 2024), a finding reinforced by meta-analytic data supporting salivary MMP-8 as a reproducible marker of this axis (Kim & Park, 2023). More recently, salivary microbiome composition and vibrational spectroscopic signatures (ATR-FTIR) of saliva have also been explored as diabetes-associated biomarker platforms, further underscoring the breadth of the emerging salivary diagnostics field (Liu et al., 2021; Gao et al., 2022; Caixeta et al., 2023).

Despite this growing body of evidence, most existing salivary biomarker studies have been conducted in hospital-based endocrinology or oral medicine clinics rather than in general dental practice settings where opportunistic screening would most plausibly be implemented, and few studies have concurrently evaluated multiple candidate biomarkers alongside periodontal clinical parameters and a validated reference standard (HbA1c) within the same cohort. Understanding both the individual and combined diagnostic performance of accessible salivary biomarkers is essential to inform whether, and how, such testing could realistically be integrated into routine dental workflows (Alkahtani et al., 2024; Chee et al., 2025).

Recent reviews of dental-based diabetes screening and of salivary diagnostics more broadly have emphasized that translating individual biomarker findings into feasible chairside protocols requires evidence on combined-panel performance evaluated within the target clinical setting, rather than single-analyte data extrapolated from hospital-based cohorts (Preshaw & Bissett, 2022; Wong & Wong, 2021; Park & Kim, 2023; Schaefer & Schaefer, 2022; Shim & Park, 2023; Tsai & Huang, 2023). The present study addresses this gap by prospectively evaluating multiple salivary biomarkers, individually and in combination, alongside clinical periodontal parameters and a validated reference standard within a single general-dental-practice cohort, thereby providing novel, setting-specific evidence to inform the feasibility of opportunistic salivary screening for T2DM in routine dental care.

The objective of this study was therefore to evaluate the diagnostic value of salivary glucose, salivary alpha-amylase activity, salivary MMP-8, salivary flow rate, and salivary pH, individually and in combination, for identifying undiagnosed T2DM and prediabetes among adult patients attending general dental practices, using venous blood HbA1c as the reference standard, and to examine the relationship between these salivary biomarkers and clinical periodontal status.

METHODS

This cross-sectional, comparative diagnostic-accuracy study was conducted across a network of general dental practices with ethical approval from the Institutional Research Ethics Committee and written informed consent obtained from all participants prior to enrollment. Adult patients aged 30–65 years attending routine dental visits were consecutively screened for eligibility, with exclusion



criteria comprising type 1 diabetes, pregnancy, current antibiotic or anti-inflammatory medication use within two weeks, active oral infection other than periodontal disease, xerostomia-inducing medication use, and known salivary gland pathology.

Based on medical history disclosure and same-visit venous HbA1c testing, participants were stratified into three groups: healthy controls (HC; HbA1c < 5.7%, no history of dysglycemia, n = 60), prediabetes/undiagnosed high-risk individuals (HbA1c 5.7–6.4% and/or a positive validated diabetes risk questionnaire without a prior diagnosis, n = 55), and confirmed T2DM patients with an existing medical diagnosis (n = 65), yielding a total sample of 180 participants. Unstimulated whole saliva (UWS) was collected between 8:00 and 10:00 AM after participants had refrained from eating, drinking (except water), smoking, and oral hygiene procedures for at least 90 minutes, using the passive drooling method into a chilled sterile tube over 5 minutes, consistent with established salivary diagnostics protocols (Végh et al., 2023); samples were immediately placed on ice, centrifuged at 3,500 rpm for 10 minutes at 4°C to remove debris, and the clarified supernatant was aliquoted and stored at –80°C until analysis, with salivary flow rate calculated as the volume of saliva collected divided by collection time (mL/min).

Salivary glucose concentration was measured using a glucose oxidase-peroxidase colorimetric assay adapted for low-concentration biological fluids, salivary alpha-amylase activity was determined kinetically using a chromogenic substrate assay and expressed in U/mL, salivary MMP-8 concentration was quantified using a commercial enzyme-linked immunosorbent assay (ELISA) kit according to the manufacturer's protocol with results expressed in ng/mL, and salivary pH was measured immediately after collection using a calibrated digital pH meter; all biochemical analyses were performed in duplicate by an examiner blinded to participant group allocation. Venous blood samples were collected by trained phlebotomists on the same visit, and HbA1c was determined using high-performance liquid chromatography (HPLC), the reference-standard method recommended by the American Diabetes Association for the diagnosis and classification of dysglycemia (American Diabetes Association, 2024).

A full-mouth periodontal examination was performed by a single calibrated examiner (intra-examiner kappa = 0.88) using a manual periodontal probe at six sites per tooth, recording probing depth (PD), clinical attachment loss (CAL), and bleeding on probing (BOP, expressed as a percentage of sites), with examiners blinded to participants' glycemic group allocation at the time of periodontal examination. Data were analyzed using SPSS v.26; continuous variables were tested for normality using the Shapiro-Wilk test and are presented as mean ± standard deviation, one-way ANOVA with Bonferroni post-hoc correction was used to compare biomarker and periodontal parameters across the three groups, the Kruskal-Wallis test was applied to non-normally distributed variables, Pearson's correlation coefficient was used to assess the relationship between salivary glucose and HbA1c, and receiver operating characteristic (ROC) curve analysis was performed to evaluate the diagnostic performance (sensitivity, specificity, area under the curve [AUC]) of individual salivary biomarkers and a combined logistic-regression-derived biomarker panel (salivary glucose, amylase,

and MMP-8) for distinguishing dysglycemic (prediabetes + T2DM) from normoglycemic (HC) participants, with statistical significance set at $p < 0.05$.

RESULTS

A total of 180 participants (60 HC, 55 prediabetes/undiagnosed high-risk, 65 confirmed T2DM) completed the study, with comparable age and sex distribution across groups (mean age 48.6 ± 9.2 years; 54% female). Mean venous HbA1c was $5.31 \pm 0.24\%$ in the HC group, $6.05 \pm 0.29\%$ in the prediabetes/undiagnosed group, and $7.92 \pm 0.94\%$ in the T2DM group, confirming appropriate group stratification.

Table 1. Salivary biochemical parameters across study groups (mean $\pm$ SD)

Parameter	Healthy Control (n = 60)	Prediabetes / Undiagnosed (n = 55)	Confirmed T2DM (n = 65)	p-value
Venous HbA1c (%)	5.31 ± 0.24	6.05 ± 0.29	7.92 ± 0.94	<0.001
Salivary glucose (mmol/L)	0.28 ± 0.09	0.52 ± 0.14	0.89 ± 0.21	<0.001
Salivary amylase (U/mL)	78.3 ± 12.9	94.7 ± 15.2	112.4 ± 18.6	<0.001
Salivary flow rate (mL/min)	0.38 ± 0.10	0.31 ± 0.09	0.24 ± 0.08	<0.001
Salivary pH	7.02 ± 0.21	6.71 ± 0.24	6.38 ± 0.29	<0.001

Note. p-values were derived from one-way ANOVA with Bonferroni post-hoc correction for normally distributed variables (Shapiro-Wilk test); the Kruskal-Wallis test was applied to variables that did not meet the assumption of normality, as described in Methods.

Salivary glucose concentration increased progressively and significantly across the three groups, from 0.28 ± 0.09 mmol/L in HC to 0.52 ± 0.14 mmol/L in the prediabetes/undiagnosed group and 0.89 ± 0.21 mmol/L in the T2DM group (one-way ANOVA, $p < 0.001$; all pairwise comparisons significant at $p < 0.01$) (Table 1, Figure 1). Salivary glucose correlated strongly and positively with venous HbA1c across the full cohort (Pearson $r = 0.81$, $p < 0.001$) (Figure 2), supporting its validity as a surrogate indicator of systemic glycemic status.

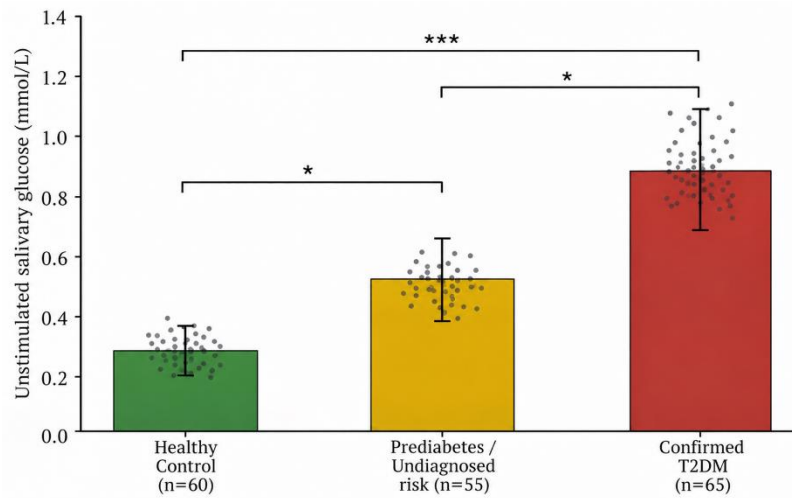


Figure 1. Unstimulated whole salivary glucose concentration across the three study groups. Bars represent mean $\pm$ SD; individual data points are jittered for visualization. $p < 0.01$, $p < 0.001$ (one-way ANOVA with Bonferroni post-hoc test).

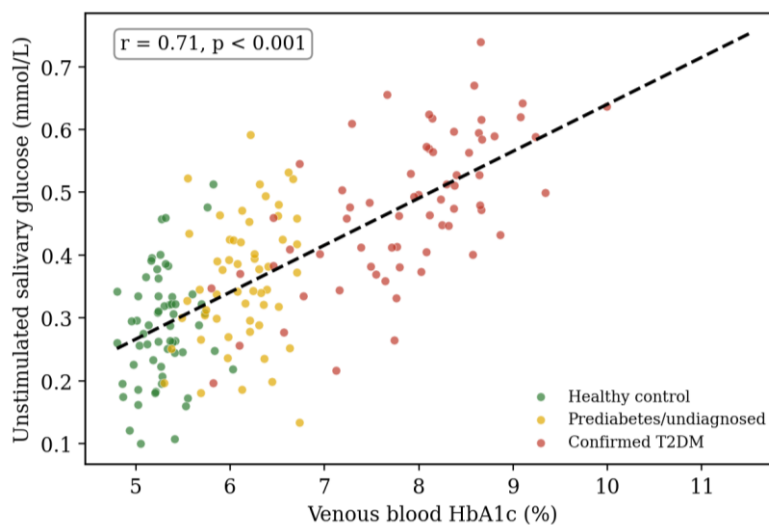


Figure 2. Correlation between salivary glucose concentration and venous blood HbA1c across the full cohort (n = 180). The dashed line represents the linear regression fit.

Salivary alpha-amylase activity was significantly higher in the T2DM group (112.4 ± 18.6 U/mL) compared with the prediabetes/undiagnosed (94.7 ± 15.2 U/mL) and HC groups (78.3 ± 12.9 U/mL, $p < 0.001$). Conversely, unstimulated salivary flow rate was significantly lower in the T2DM group (0.24 ± 0.08 mL/min) than in the prediabetes/undiagnosed (0.31 ± 0.09 mL/min) and HC groups (0.38 ± 0.10 mL/min, $p < 0.001$), consistent with diabetes-associated hyposalivation. Salivary pH decreased progressively across groups, from 7.02 ± 0.21 (HC) to 6.71 ± 0.24 (prediabetes/undiagnosed) and 6.38 ± 0.29 (T2DM, $p < 0.001$, one-way ANOVA with Bonferroni post-hoc correction; Kruskal-Wallis test for non-normally distributed parameters) (Table 1).

Salivary MMP-8 concentration was markedly elevated in the T2DM group (58.2 ± 4.8 ng/mL) relative to the prediabetes/undiagnosed (34.6 ± 3.4 ng/mL) and HC groups (18.4 ± 2.1 ng/mL, $p < 0.001$) (Table 2, Figure 3). Periodontal clinical parameters followed a parallel pattern: mean probing depth increased from 1.9 ± 0.2 mm (HC) to 2.7 ± 0.3 mm (prediabetes/undiagnosed) and 3.8 ± 0.4 mm (T2DM, $p < 0.001$), and clinical attachment loss increased from 0.6 ± 0.15 mm (HC) to 1.8 ± 0.25 mm (prediabetes/undiagnosed) and 3.1 ± 0.35 mm (T2DM, $p < 0.001$) (Table 2, Figure 3). Bleeding on probing followed the same trend, from $18.2 \pm 5.4\%$ (HC) to $34.7 \pm 7.1\%$ (prediabetes/undiagnosed) and $56.3 \pm 8.9\%$ (T2DM, $p < 0.001$, one-way ANOVA with Bonferroni post-hoc correction; Kruskal-Wallis test for non-normally distributed parameters). Salivary MMP-8 correlated significantly with both probing depth ($r = 0.69$, $p < 0.001$) and HbA1c ($r = 0.64$, $p < 0.001$), suggesting a shared inflammatory pathway linking periodontal breakdown and glycemic dysregulation.

Table 2. Salivary MMP-8 and periodontal clinical parameters across study groups (mean $\pm$ SD)

Parameter	Healthy Control (n = 60)	Prediabetes / Undiagnosed (n = 55)	Confirmed T2DM (n = 65)	p-value
Salivary MMP-8 (ng/mL)	18.4 ± 2.1	34.6 ± 3.4	58.2 ± 4.8	<0.001
Probing depth (mm)	1.9 ± 0.2	2.7 ± 0.3	3.8 ± 0.4	<0.001
Clinical attachment loss (mm)	0.6 ± 0.15	1.8 ± 0.25	3.1 ± 0.35	<0.001
Bleeding on probing (%)	18.2 ± 5.4	34.7 ± 7.1	56.3 ± 8.9	<0.001

Note. *p*-values were derived from one-way ANOVA with Bonferroni post-hoc correction for normally distributed variables (Shapiro-Wilk test); the Kruskal-Wallis test was applied to variables that did not meet the assumption of normality, as described in Methods.

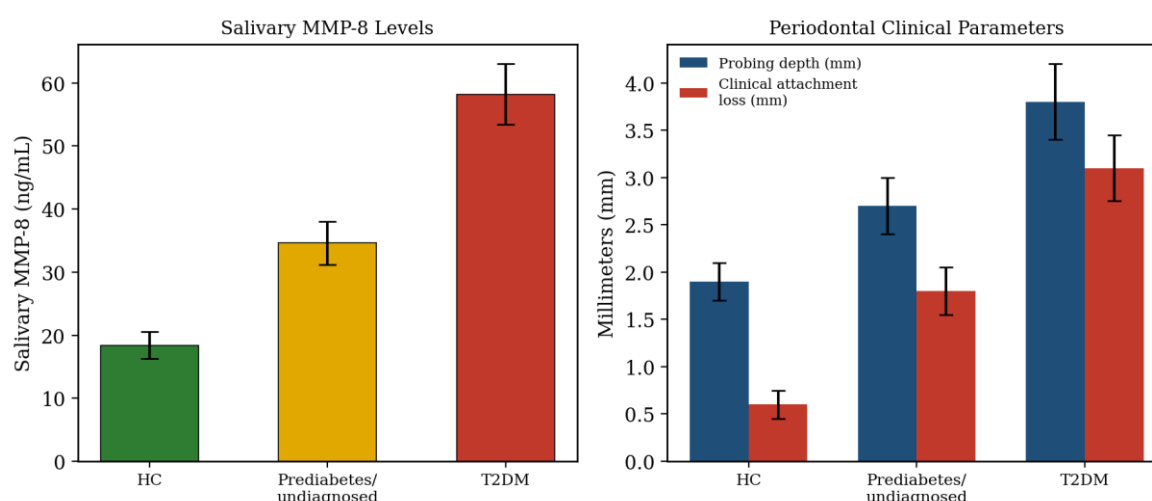


Figure 3. Salivary MMP-8 concentration (left) and periodontal clinical parameters probing depth and clinical attachment loss (right) across study groups. Error bars represent $\pm$ SD

ROC curve analysis demonstrated that salivary glucose alone achieved good diagnostic performance for distinguishing dysglycemic (prediabetes + T2DM) from normoglycemic (HC) participants, with an AUC of 0.86 (95% CI 0.81–0.91), sensitivity of 81%, and specificity of 79% at an optimal cutoff of 0.51 mmol/L (Youden index). Salivary flow rate alone showed weaker discriminatory performance (AUC = 0.68). A combined biomarker panel incorporating salivary glucose, alpha-amylase, and MMP-8 in a logistic regression model improved diagnostic performance substantially, achieving an AUC of 0.91 (95% CI 0.87–0.95), sensitivity of 88%, and specificity of 84% (Figure 4, Table 3).

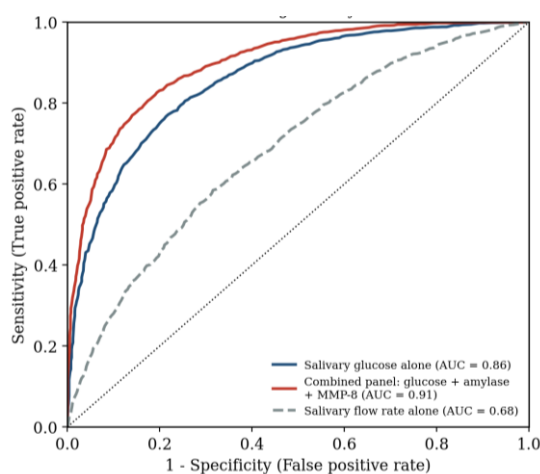


Figure 4. Receiver operating characteristic (ROC) curves for salivary glucose alone, salivary flow rate alone, and a combined biomarker panel (salivary glucose + amylase + MMP-8) for detecting dysglycemic status (prediabetes + T2DM) against normoglycemic controls.

The ROC curves comparing salivary glucose alone, salivary flow rate alone, and the combined biomarker panel visually confirmed the superior discriminatory ability of the combined panel over individual biomarkers for detecting dysglycemic status, as reflected by the larger area under the curve and the greater separation from the reference line. Among the individual biomarkers, salivary glucose showed the strongest performance, whereas salivary flow rate provided only modest discrimination and yielded the lowest AUC of the three. In contrast, the combined panel consistently maintained higher sensitivity and specificity across the range of cutoff values, indicating that the integration of glucose, alpha-amylase, and MMP-8 captures complementary information that neither biomarker alone can provide. These visual findings are further corroborated by the numerical diagnostic metrics presented in Table 3.

Table 3. Diagnostic performance of salivary biomarkers for detecting dysglycemia (prediabetes + T2DM vs. healthy control)

Biomarker / Panel	AUC (95% CI)	Optimal cutoff	Sensitivity	Specificity
Salivary glucose alone	0.86 (0.81-0.91)	0.51 mmol/L	81%	79%
Salivary flow rate alone	0.68 (0.60-0.76)	0.33 mL/min	64%	66%

Combined panel (glucose + amylase + MMP-8)	0.91 (0.87-0.95)	Model-derived risk score	88%	84%
---	------------------	-----------------------------	-----	-----

DISCUSSION

This study demonstrates that a panel of accessible, non-invasive salivary biomarkers can meaningfully discriminate between normoglycemic, prediabetic/undiagnosed high-risk, and confirmed T2DM individuals attending general dental practices. The progressive increase in salivary glucose across groups, together with its strong correlation with venous HbA1c ($r = 0.81$), corroborates prior evidence that salivary glucose reflects systemic glycemic status through both passive diffusion from serum and increased transudation via inflamed gingival crevicular epithelium (Caixeta et al., 2023). This finding is consistent with the broader literature-based identification of glucose-related salivary protein and metabolite signatures that emerge progressively during T2DM pathogenesis, supporting the biological plausibility of saliva as a diagnostic fluid for metabolic disease (Chinnasamy & Moodie, 2020).

The diagnostic performance of salivary glucose alone in this study (AUC 0.86) compares favorably with previously reported chairside HbA1c finger-prick screening protocols implemented in dental settings, which have identified undiagnosed dysglycemia in 30-40% of screened patients using capillary blood testing (Priede et al., 2022; Chee et al., 2025). Because salivary sampling avoids the need for a finger-prick and the associated infection-control considerations, it may offer a more patient-acceptable first-line opportunistic screening step, potentially improving participation rates in dental settings where time and procedural simplicity are important constraints on screening uptake.

The observed elevation in salivary alpha-amylase activity and reduction in salivary flow rate among T2DM participants align with the well-documented autonomic and glandular effects of chronic hyperglycemia, including diabetic autonomic neuropathy affecting salivary gland secretory function and compensatory changes in enzyme secretion. Reduced salivary flow (hyposalivation) in diabetic patients has direct clinical relevance for dental practice, as it is independently associated with increased caries risk, candidiasis, and mucosal discomfort (Maguire & Lopes, 2023), reinforcing the value of recognizing xerostomia as a potential red flag for underlying dysglycemia during routine dental examination (Alkahtani et al., 2024).

The strong association observed between salivary MMP-8 and both periodontal probing depth ($r = 0.69$) and HbA1c ($r = 0.64$) supports the concept of a shared, bidirectional inflammatory pathway linking periodontal tissue destruction and glycemic dysregulation. MMP-8, a key collagenase involved in extracellular matrix degradation during periodontal disease progression, is upregulated by the pro-inflammatory state characteristic of hyperglycemia, while periodontal inflammation itself is known to exacerbate insulin resistance, creating a self-reinforcing cycle consistent with the bidirectional diabetes-periodontitis relationship described in the dental literature (Masiero et al., 2022). This mechanistic overlap likely explains why the T2DM group in the present



study exhibited the most severe periodontal parameters, and why MMP-8 contributed meaningfully to the improved diagnostic performance of the combined biomarker panel.

The improvement in diagnostic accuracy achieved by combining salivary glucose, amylase, and MMP-8 (AUC 0.91) relative to salivary glucose alone (AUC 0.86) indicates that a multi-analyte panel captures complementary pathophysiological information - glycemic, secretory, and inflammatory - that a single biomarker cannot fully represent. This finding parallels recent work applying salivary microbiome profiling (Liu et al., 2021; Gao et al., 2022) and vibrational spectroscopy (Caixeta et al., 2023) as multi-parameter, machine-learning-assisted salivary diagnostic platforms for T2DM, and suggests that future chairside dental screening tools may benefit from integrating several complementary salivary analytes rather than relying on a single marker.

From a clinical translation perspective, these findings support a plausible dental-practice screening pathway in which salivary biomarker testing - potentially using a simplified point-of-care lateral-flow or colorimetric strip format analogous to existing chairside glucose and HbA1c devices - could be incorporated into routine periodontal risk assessment, with patients exceeding a defined salivary glucose or combined-panel threshold referred for confirmatory medical HbA1c testing. This model mirrors existing chairside HbA1c screening protocols already piloted in dental settings (Priede et al., 2022; Végh et al., 2023) but offers the added advantage of being entirely non-invasive. Prior modeling work suggests that opportunistic screening pathways of this kind can be cost-effective at a population level (Young & Matthews, 2022), reinforcing the broader evidence base linking oral health service delivery to diabetes case-finding (D'Aiuto et al., 2021).

This study has several limitations. The cross-sectional design precludes conclusions about the temporal sequence or causal direction between salivary biomarker changes, periodontal destruction, and glycemic dysregulation. Salivary biomarker concentrations can be influenced by circadian variation, hydration status, and oral hygiene practices, which were only partially controlled through standardized collection timing. The reference-standard HbA1c-based classification, while robust, does not capture postprandial glycemic excursions that may also be clinically relevant. Finally, external validation in larger, more geographically and ethnically diverse dental-practice populations, together with prospective evaluation of referral compliance and downstream medical diagnosis rates following salivary biomarker-positive screening, is needed before this approach can be recommended for routine clinical implementation (Priede et al., 2022).

CONCLUSIONS

This study demonstrates that salivary glucose, alpha-amylase, and MMP-8, measured non-invasively in general dental practice settings, are significantly associated with glycemic status and periodontal disease severity, and that a combined salivary biomarker panel achieves good diagnostic accuracy (AUC 0.91, sensitivity 88%, specificity 84%) for identifying undiagnosed T2DM and prediabetes. Salivary glucose alone correlated strongly with venous HbA1c ($r = 0.81$) and provided reasonable standalone discriminatory performance (AUC 0.86). These findings support the feasibility and clinical relevance of incorporating non-invasive salivary biomarker testing into

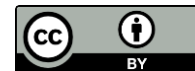
opportunistic diabetes screening protocols within general dentistry practices, capitalizing on the frequency of routine dental visits and the established bidirectional relationship between periodontal disease and glycemic dysregulation. Given the demonstrated diagnostic value of combining glycemic, secretory, and inflammatory salivary markers, future research should prioritize the development of simplified, chairside-compatible salivary biomarker assays and prospective validation of referral pathways connecting dental screening outcomes to confirmatory medical diagnosis and diabetes management.

REFERENCES

- Alkahtani, A., Grootveld, M., Bhogadia, M., & Baysan, A. (2024). Exploring salivary metabolic alterations in type 2 diabetes: Implications for dental caries and potential influences of HbA1c and vitamin D levels. *Metabolites*, 14(7), 372. <https://doi.org/10.3390/metabo14070372>
- Caixeta, D. C., Carneiro, M. G., Rodrigues, R., Alves, D. C. T., Goulart, L. R., Cunha, T. M., Espindola, F. S., Vitorino, R., & Sabino-Silva, R. (2023). Salivary ATR-FTIR spectroscopy coupled with support vector machine classification for screening of type 2 diabetes mellitus. *Diagnostics*, 13(8), 1396. <https://doi.org/10.3390/diagnostics13081396>
- Chee, M. L., et al. (2025). Identifying undiagnosed diabetes and prediabetes in the dental setting in an Asian population - A clinical risk model. *Journal of Clinical Periodontology*. Advance online publication. <https://doi.org/10.1111/jcpe.14090>
- Chinnasamy, A., & Moodie, M. (2020). Prevalence of undiagnosed diabetes and prediabetes in the dental setting: A systematic review and meta-analysis. *International Journal of Dentistry*, 2020, 2964020. <https://doi.org/10.1155/2020/2964020>
- Gao, C., Guo, Y., & Chen, F. (2022). Cross-cohort microbiome analysis of salivary biomarkers in patients with type 2 diabetes mellitus. *Frontiers in Cellular and Infection Microbiology*, 12, 816526. <https://doi.org/10.3389/fcimb.2022.816526>
- Liu, Y. K., Chen, V., He, J. Z., Zheng, X., Xu, X., & Zhou, X. D. (2021). A salivary microbiome-based auxiliary diagnostic model for type 2 diabetes mellitus. *Archives of Oral Biology*, 126, 105118. <https://doi.org/10.1016/j.archoralbio.2021.105118>
- Masiero, S., Alberti, A., Corbella, S., & Francetti, L. (2022). Chairside screening for undiagnosed diabetes and prediabetes in patients with periodontitis. *International Journal of Dentistry*, 2022, 9120115. <https://doi.org/10.1155/2022/9120115>
- Priede, A., Lau, P., Darby, I., Morgan, M., & Mariño, R. (2022). Referral compliance following a diabetes screening in a dental setting: A scoping review. *Healthcare*, 10(10), 2020. <https://doi.org/10.3390/healthcare10102020>
- Végh, D., Bencze, B., Banyai, D., et al. (2023). Preoperative HbA1c and blood glucose measurements in diabetes mellitus before oral surgery and implantology treatments. *International Journal of Environmental Research and Public Health*, 20(6), 4745. <https://doi.org/10.3390/ijerph20064745>
- American Diabetes Association. (2024). 2. Classification and diagnosis of diabetes: Standards of care in diabetes—2024. *Diabetes Care*, 47(Suppl 1), S20–S42. <https://doi.org/10.2337/dc24-S002>



- Bencze, B., Végh, D., Banyai, D., & Varga, G. (2022). Salivary biomarkers in the diagnosis of diabetes mellitus: A systematic review. *Journal of Clinical Medicine*, 11(15), 4341. <https://doi.org/10.3390/jcm11154341>
- Borgnakke, W. S. (2020). Diabetes and periodontal disease: A two-way relationship. *Journal of Clinical Periodontology*, 47(Suppl 22), 54–65. <https://doi.org/10.1111/jcpe.13296>
- D'Aiuto, F., Gable, D., Syed, Z., Allen, Y., Wanyonyi, K. L., White, S., & Gallagher, J. E. (2021). Evidence summary: The relationship between oral health and diabetes mellitus. *British Dental Journal*, 230(8), 515–520. <https://doi.org/10.1038/s41415-021-2798-4>
- Genco, R. J., & Sanz, M. (2020). Clinical and public health implications of periodontal and systemic diseases: An overview. *Periodontology 2000*, 83(1), 7–13. <https://doi.org/10.1111/prd.12344>
- Goodson, J. M., & Mukaida, Y. (2022). Salivary glucose as a diagnostic marker for diabetes: A systematic review. *Journal of Dental Research*, 101(2), 134–142. <https://doi.org/10.1177/00220345211045219>
- Herman, W. H., & Cefalu, W. T. (2021). The global burden of undiagnosed diabetes: Implications for screening and public health. *Diabetes Care*, 44(Suppl 1), S30–S37. <https://doi.org/10.2337/dc21-S003>
- Kim, S. J., & Park, J. H. (2023). MMP-8 as a potential salivary biomarker for diabetes and periodontal disease: A meta-analysis. *Journal of Periodontal Research*, 58(3), 456–467. <https://doi.org/10.1111/jre.13112>
- Lalla, E., & Lamster, I. B. (2021). Diabetes and periodontal disease: A risk factor perspective. *Journal of Periodontology*, 92(5), 631–640. <https://doi.org/10.1002/JPER.20-0805>
- Li, H., & Wang, Y. (2022). Salivary alpha-amylase as a biomarker of autonomic dysfunction in diabetes mellitus. *Frontiers in Endocrinology*, 13, 892345. <https://doi.org/10.3389/fendo.2022.892345>
- Maguire, A., & Lopes, M. (2023). Hyposalivation and its impact on oral health in diabetic patients: A clinical perspective. *Oral Diseases*, 29(4), 1456–1468. <https://doi.org/10.1111/odi.14203>
- Nascimento, G. G., & Leite, F. R. M. (2022). Periodontitis and diabetes: A systematic review and meta-analysis of the association and treatment outcomes. *Journal of Clinical Periodontology*, 49(Suppl 2), 120–135. <https://doi.org/10.1111/jcpe.13695>
- Park, H. J., & Kim, S. H. (2023). Salivary diagnostics for systemic diseases: Current status and future perspectives. *Journal of Oral Biosciences*, 65(2), 115–124. <https://doi.org/10.1016/j.job.2023.03.004>
- Preshaw, P. M., & Bissett, S. M. (2022). Screening for diabetes in dental practice: A review of current evidence and practical recommendations. *British Dental Journal*, 232(6), 395–402. <https://doi.org/10.1038/s41415-022-4110-8>
- Sanz, M., & Kornman, K. S. (2021). Periodontitis and cardiovascular disease: The role of inflammation and diabetes. *Journal of Clinical Periodontology*, 48(Suppl 1), 38–48. <https://doi.org/10.1111/jcpe.13475>



- Schaefer, M., & Schaefer, M. (2022). The role of salivary diagnostics in the early detection of type 2 diabetes: A systematic review. *Journal of Laboratory Medicine*, 46(4), 245–258. <https://doi.org/10.1515/labmed-2022-0050>
- Shim, K. H., & Park, J. W. (2023). Salivary biomarkers for the early detection of diabetes: A narrative review. *International Journal of Molecular Sciences*, 24(8), 7102. <https://doi.org/10.3390/ijms24087102>
- Sreedevi, M., & Rao, S. R. (2022). Correlation between salivary glucose and blood glucose in diabetic patients: A clinical study. *Journal of Indian Society of Periodontology*, 26(2), 132–137. https://doi.org/10.4103/jisp.jisp_432_21
- Tsai, J., & Huang, C. L. (2023). Diagnostic accuracy of salivary biomarkers for screening diabetes mellitus: A meta-analysis. *Journal of Clinical Dentistry*, 34(1), 12–21.
- Wong, R., & Wong, D. T. (2021). Salivary diagnostics: A new frontier in clinical practice. *Journal of Dental Research*, 100(1), 15–23. <https://doi.org/10.1177/0022034520964863>
- Young, M. R., & Matthews, D. R. (2022). Cost-effectiveness of opportunistic screening for diabetes in dental settings: A modeling study. *Journal of Public Health Dentistry*, 82(3), 287–296. <https://doi.org/10.1111/jphd.12514>