Salivary Glucose as a Non-Invasive Alternative in Monitoring Diabetics Attending General Hospital Minna, Niger State, Nigeria

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ABSTRACT

Introduction: Monitoring glucose levels is crucial for effective management of diabetes mellitus, a chronic metabolic disorder that remains a global health concern, implicating over 500 million people worldwide. The diagnosis of diabetes through blood is difficult in children, older adults, debilitated and chronically ill patients, so diagnosis by analysis of saliva can be potentially valuable as collection of saliva is noninvasive, easier and technically insensitive, unlike blood. The aim of the study was to correlate blood glucose level (BGL) and salivary glucose level (SGL) among individuals with normal fasting glucose (NFG), impaired fasting glucose (IFG) and provisional diabetes mellitus (PDM).

Methodology: A cross-sectional study was conducted in 423 patients aged between 18 and 65 years, categorised as 141 impaired diabetics, 142 provisional diabetics and 140 healthy individuals constituting the controls. The blood and unstimulated saliva samples were collected from the patients for fasting glucose levels. These samples were then subjected for analysis of glucose in blood and saliva via the enzymatic Glucose Oxidase Peroxidase (GOD-POD) end-point method, using RT-9200 Semi-auto Chemistry Analyser.

Results: The mean SGLs and BGLs were higher in provisional diabetics and impaired diabetics groups than in non-diabetic group (3.15:225.40 vs. 2.19:112.43 vs. 0.85:77.76 mg/dL; p-val=1.498852e-153), indicating a significant positive correlation between fasting saliva glucose and fasting blood glucose in all the groups.

Conclusion: In conclusion, tests measuring salivary glucose levels provide a promising alternative to conventional blood glucose tests in the realm of diabetes management, making it a reliable indicator. While addressing technical and clinical challenges requires additional research, the appealing non-invasive nature and the potential for frequent monitoring make salivary glucose level tests an attractive option for enhancing diabetes care. Future advancements in salivary glucose sensing technologies may revolutionise glucose monitoring, improving the quality of life for individuals with diabetes.

Keywords: global health, diabetes mellitus, salivary glucose, non-invasive, correlation.

INTRODUCTION

Background of the study

Diabetes remains to be a global health concern with over 400 million people affected worldwide (World Health Organisation [WHO], 2016), with an increasing prevalence and estimated increase to 552 million by 2030 (Knip, 2010). About 4.2 million adults died from diabetes mellitus and its complications, which is equivalent to 1 death every 8 seconds (International Diabetes Federation [IDF], 2019); with the advancement of living standards and environmental changes, the incidence of diabetes mellitus is increasing daily, which has steadily developed into one of the major threats to the health and well-being of modern people, imposing a significant financial burden on society (Sun et al., 2021).

Diabetes mellitus is a group of metabolic disorders of carbohydrate metabolism in which glucose is underutilized, producing hyperglycaemia with metabolic disturbance of carbohydrate, fat and protein because of either defects in insulin secretion, insulin action, or both (Nermeen et al., 2021). It is a floodgate to metabolic dysfunction of array of organ, especially the eyes, kidneys, nerves, heart, and blood (American Diabetes Association [ADA], 2014).

Saliva research is rapidly advancing because of the use of novel approaches such as metabolomics, genomics, proteomics and bioinformatics (Ahmadi et al., 2010). Saliva is an exocrine secretion of the salivary glands that contains mostly water (99 %), electrolytes, proteins, and enzyme. It is often referred to as the "mirror of the body" as it is the indicator of health not just in the oral cavity but also throughout the body. Saliva plays an important role in maintaining the equilibrium of the oral ecosystem by providing the sensory perception of food, aids in chewing, swallowing, and food digestion (Thayumanavan et al., 2015). Whole saliva contains locally produced as well as serum-derived biomarkers that have been found to be useful in the diagnosis of a variety of systemic disorders such as Grave's diseases, Rheumatoid arthritis, hypertension, Myasthenia gravis. Understanding the role of each salivary component in the oral cavity homeostasis is crucial to perceive how its changes or absence may be linked with pathological conditions (Lasisi and Fasanmade, 2012).

Several epidemiological studies have suggested that diabetes is a risk factor for the development of oral diseases in human (Chavez et al., 2010). Diabetes besides damaging various systems of the body may also impair salivary gland functions, which leads to a reduction in the salivary flow and changes in saliva's composition and Periodontitis (Agoro et al., 2017; Lasisi and Fasanmade, 2012). Screening for diabetes in general practice by measuring fasting blood glucose levels is feasible, stressful, invasive and time consuming. Different strategies have been suggested to improve diabetes detection and there has been increased interest towards non-invasive method to diagnose this disease, including the use of the saliva sample (Tiongco et al., 2018). Salivary gland hypofunction has a//lso been reported to be frequent in people with diabetes majorly due to overall diminished flow of saliva which is a consequence of dehydration which might contribute to their susceptibility to oral infections like candidiasis, dental caries, xerostomia, etc. (Kumar et al., 2017).

Aim and Objectives

Aim

The study is aimed at assessing salivary glucose as a non-invasive alternative in screening, diagnosis and monitoring diabetics attending General Hospital Minna, Niger State, Nigeria.

Objectives

- Determining the fasting salivary and blood glucose levels of diabetics attending General Hospital Minna, Niger State.
- Determining the fasting salivary and blood glucose levels among individuals with normal fasting glucose (NFG) attending General Hospital Minna, Niger State.
- Correlating the levels of salivary and blood glucose among individuals with normal fasting glucose (NFG), impaired fasting glucose (IFG) and provisional DM (PDM).

Justification of the research

Although the biomarkers in saliva reflect the health status of the human body, the use of salivary glucose as a diagnostic fluid for diabetes mellitus has been hindered, mainly because the correlation between salivary glucose and blood glucose has been greatly controversial (Zhao and Leung, 2020). Over the past few decades, the non-invasive monitoring of diabetes mellitus by fluid analysis (as well as other biological fluids such as saliva, sweat and urine) has attracted worldwide attention (Alizadeh et al., 2018; Ahmed and Haque, 2021; Zhang et al., 2021). Among the existing non-invasive methods, salivary glucose has a very positive significance, and has received much attention (Turner, 2013; Palomar et al., 2021). Saliva is considered an

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ultrafiltrate of blood and is a potential source of clinical information that accurately reflects the pathological state, according to the literature (Cui et al., 2021). Studies have shown that for diabetes mellitus patients, the salivary glucose level is positively correlated with the blood glucose level, so salivary glucose can be used as a marker for the detection of diabetes mellitus (Chakraborty et al., 2021; Goel et al., 2021).

Statement of research problem

Self-monitoring of blood glucose is critical for diabetes mellitus control and serves as the foundational tool for all management strategies (Janapala et al., 2019). Sim et al. (2021) also point out that the frequent monitoring of blood glucose is of great significance for patients in order to manage the condition and control the development of their complications. Unfortunately, traditional blood glucose monitoring methods usually require blood sampling operations. Blood extraction is painful, inconvenient and presents the risk of infection and mental pains to patients, especially for those patients who need to check their blood glucose levels several times a day (Shang et al., 2022).

Not only does an urgent need exist for a non-invasive glucose monitoring technology so as to make a major improvement in the lives of millions of people around the world living with diabetes mellitus, but also to ease preventive monitoring (Bamgboje et al., 2021). Furthermore, saliva has numerous advantages as a diagnostic fluid because it is non-invasive, simple to collect, preserve, and contains exceedingly high-quality DNA. Thus, saliva could serve an excellent substitute for blood (Cui et al., 2022).

Research hypothesis

The present study tests the following hypotheses based on the established physiological relationship between blood and glucose spillover into saliva and the need for non-invasive glycemic monitoring tools, particularly in resource-limited settings such as General Hospital Minna, Niger State, Nigeria.

Null Hypotheses (H_0)

1. There is no statistically significant positive correlation between fasting salivary glucose levels and fasting blood glucose levels among patients with type 2 diabetes mellitus attending General Hospital Minna.

2. Mean salivary glucose concentrations do not differ significantly between diabetic patients and age- and sex-matched non-diabetic controls attending the same facility.

3. Salivary glucose levels do not demonstrate acceptable diagnostic accuracy (sensitivity, specificity, and area under the ROC curve) as a non-invasive alternative for glycemic monitoring when compared with standard blood glucose methods.

Alternative Hypotheses (H_1)

1. There is a statistically significant positive correlation (expected Pearson's $r \geq 0.6$) between fasting salivary glucose levels and fasting blood glucose levels among diabetic patients.

2. Diabetic patients will exhibit significantly higher mean salivary glucose concentrations than non-diabetic controls.

3. Salivary glucose will show clinically useful diagnostic performance (sensitivity and specificity ≥ 80 %, AUC ≥ 0.85) for identifying poor glycemic control, supporting its feasibility as a practical, pain-free alternative in routine diabetes monitoring at General Hospital Minna.

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MATERIAL AND METHODS

Research design

The present study adopted a hospital-based comparative cross-sectional design allowing simultaneous collection of salivary glucose and blood glucose data at a single point in time from diabetic patients and non-diabetic controls at the Medical Laboratory Department of General Hospital Minna, Niger State, Nigeria. Four hundred and twenty three (423) human participants aged between 18 and 65 years were recruited for this study, and were equally divided into 3 groups (normal fasting glucose, impaired fasting glucose and provisional diabetes mellitus) based on their fasting blood glucose level.

Respondents with an FBG level of <100 mg/dL classified under Group A or those with a normal fasting glucose (NFG), those with an FBG between 100 and 125 mg/dL to be classified under Group B or those with an impaired fasting glucose (IFG), and those with an FBG of greater than or equal to 126 mg/dL classified under Group C or those who have provisional diabetes mellitus (PDM). According to the American Diabetes Association 2015 following criteria: (FBG ≥ 126mg/dl or 2-hour PG ≥ 200mg/dl or A1C ≥ 6.5% or random plasma glucose ≥ 200mg/dl with classic symptoms of hyperglycemia or hyperglycemic crises).

Study area

This present study was conducted at the Medical Laboratory Department of General Hospital Minna, Niger State, between the months of July 2024 and September 2025. Minna lies between Latitudes 9˚33' and 9˚40' North of the Equator and Longitudes 6˚29' and 6˚35' East of the Greenwich Meridian.The hospital serves as the major referral centre for diabetes care in the state, with documented attendance of diabetic patients.it provides routine outpatient services, laboratory facilities for glucose analysis, and access to diverse patient population from urban and rural areas of Niger State.

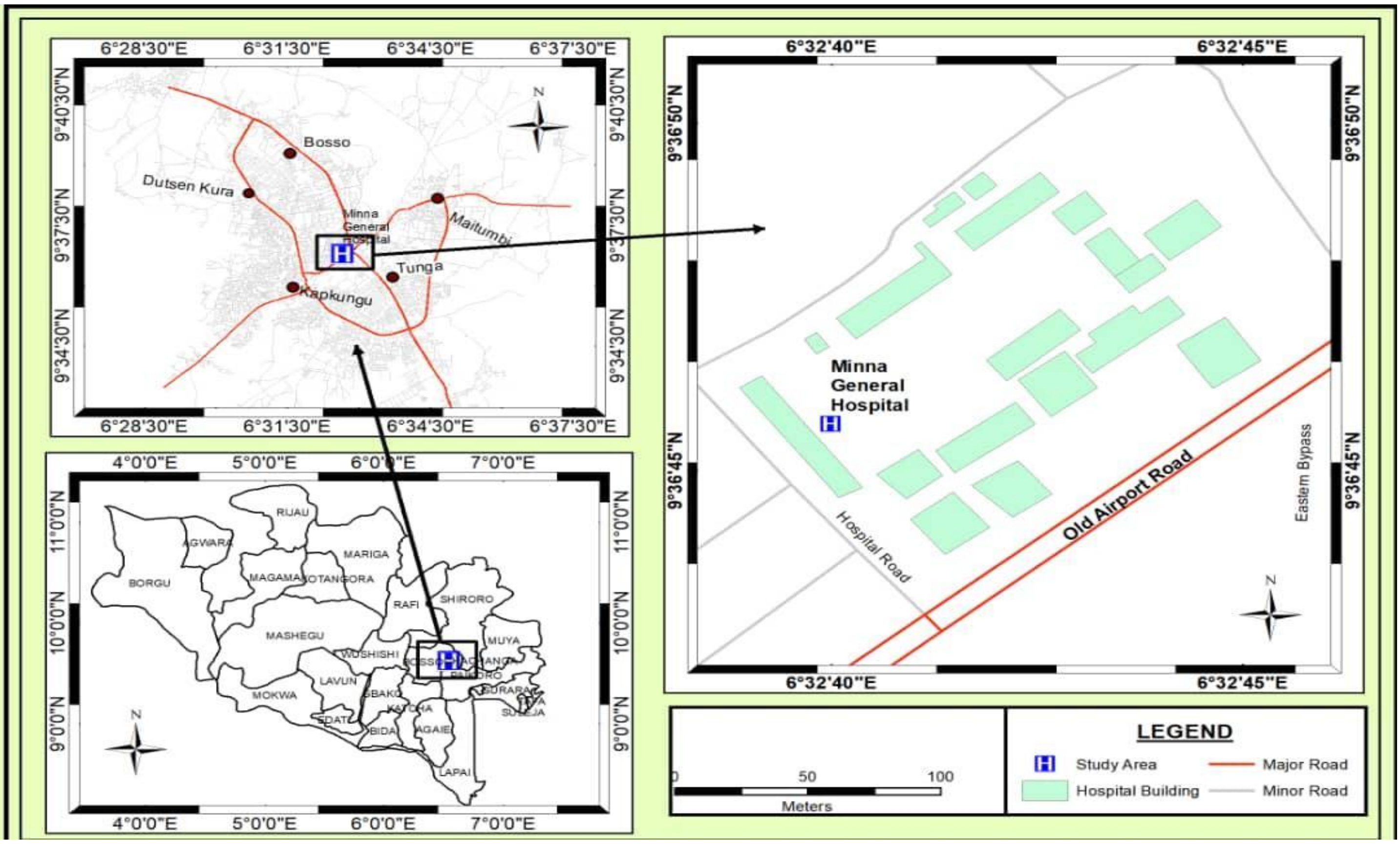

Fig. 2.1: Map Showing General Hospital Minna

Source: Department of Geography and Planning, Federal University of Technology, Minna (2023)

Sample size determination

The sample size was calculated based on the requirements for detecting a correlation between salivary glucose and blood glucose levels. Not less than 400 participants were enrolled for this study. With 5% error limit and 95% confidence limit respectively. Using the base sample size adopted in the equation of Vinodh, (2018), with a diabetes prevalence review of 5.77% in Nigeria (Andrew et al., 2018).

Formula: $n = t^2 * p (1 - p) / m^2$………………..Eq. (2.3.1)

Description:
n = required sample sizea
t = confidence level at 95% (standard value of 1.96)
p = estimated prevalence of diabetes mellitus in the study area is 5.77% (0.0577) (Andrew et al., 2018)
m = margin of error at 5% (standard value of 0.05)
Calculation:
$n = 1.96^2 \times 0.0577(1-0.0577) / 0.05^2$
$n = 3.8416 \times 0.9967/0.05^2$
$n = 0.9872 / 0.0025$
$n = 394.88$

Enrolment = 420 sample size (With at least 140 subjects comprising each of the three groups)

Inclusion and exclusion criteria

Inclusion criteria:

- Subjects diagnosed with DM in age range 18–65 years
- Age and gendermatched healthy individuals for control.

Exclusion criteria:

- Participants having any other systemic diseases and on regular medication for the same
- Pregnant or lactating women
- Mentally compromised
- Uncooperative patients
- Participants with poor oral hygiene or tumor of the salivary gland

Sample collection

Salivary sample collection

The unstimulated whole saliva was used for the estimation of salivary glucose (Bapat et al., 2021). Unstimulated whole saliva was then collected (2ml) by passive drooling (spitting method). Participants were instructed to spit the pooled saliva in a sterile, disposable plastic container.

Blood sample collection

A volume of 2 ml of peripheral venous blood was collected from the antecubital vein with syringe into a glucose-specific tube (Glucomedics) containing NaF/KOx, citrate and EDTA to minimize glycolysis (Dimeski et al., 2015), before immediate analysis at the clinical chemistry laboratory.

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Salivary glucose and blood glucose estimation

Each unstimulated saliva sample and blood sample were centrifuged at 3000 rpm for 20 min. Clear supernatants were processed immediately for estimation of glucose. Glucose was analysed with (GOD-PAP Spectrum Diagnostic Glucose kit, Ismailia Free Zone, Egypt) via the enzymatic Glucose Oxidase Peroxidase (GOD-POD) end-point method, using RT-9200 Semi-auto Chemistry Analyser.

Statistical analysis

Descriptive statistics (mean values ± standard deviation [SD], range, proportions and percentages) were used to express the concentrations of analytes, and entered into SPSS version 26.0, and double-checked for accuracy. Group analysis to compare blood glucose versus salivary measurements was conducted using student *t*-test while one way Analysis of variance (ANOVA) was used to compare between groups (diabetes versus control). Pearson correlation (*r*) was used to assess the relationship between fasting blood glucose and salivary electrolytes and salivary glucose. A *p*-value of < 0.05 was considered statistically significant.

Ethical considerations

Informed consent was sort from all participants in this study using structural questionnaire, after being educated on the benefits of the study, and ethical approval was obtained from the Research, Ethics and Publication Committee of General Hospital Minna, Niger State (HMB/GHM/24/VOL.II/117).

RESULTS

No study participant left the research project for any reason. No side effects or complications were observed during the study period. Baseline characteristics of the patients are shown in (Table 1). No statistically significant difference was found between the 2 groups in terms of sex and family history (p>0.05). Most of diabetic patients were from urban regions (73%) while (27%) were from rural areas. The mean age of the participants under control group was 25.76 years, compared to 46.74 years for participants from the diabetic group.

The mean fasting blood glucose (FBG), random blood glucose (RBG) and fasting saliva glucose (FSG), random salivary glucose (RSG) was compared among Group C, Group B and Group A using the Kruskal–Wallis test. There was a significant difference across the 3 groups as seen in Tables 2-4.

The correlation between FBG and FSG was assessed for all 3 groups using the Pearson's correlation test. There was a significant correlation between FBG and FSG as seen in Fig 1- 3.

In the present study, statistically significant correlation was found between salivary glucose level (SGL) and BGL in patients with diabetes and controls as well. Significantly higher mean SGL was found in group with diabetes compared to healthy nondiabetic group. For Group A Controlled Diabetic group, the mean FBG was 77.76 ± 10.60 mg/dL, and the mean FSG was 0.85 ± 0.26 mg/dL. Pearson's correlation test showed significant correlation at 0.57 level (Table 2).

The mean salivary and blood glucose levels of Group B (IFG) is significantly lower compared to Group C (PDM), but is significantly higher when compared to Group A (NFG) (1 < 2 < 3). This suggests that blood glucose correlates with the levels of glucose in the saliva.

Figures 2-4 show that there were highly significant positive correlation observed between blood and salivary glucose levels in the diabetic group. Both blood and salivary glucose levels are higher in patient group (impaired, diabetic) than normal group with a highly statistically significant difference (p<0.001).

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Table 1: Demographic data of diabetic subjects and controls.

	Control group N= 140	**Subject group N=283**	***p* value**
Age Mean±SD	25.76±2.91 (range 20-63)	46.74±3.37 (range 24-65)	0.296
Sex Female (%) Male (%)	64(46%) 76(54%)	139(49%) 144(51%)	0.671
Residence Rural % Urban %	11(8%) 129(92%)	76(27%) 207(73%)	0.000**
Family history Negative % Positive %	126(90%) 14(10%)	235(83%) 48(17%)	0.148 NS

p-value >0.05: Non significant (NS).

**p-value <0.01: Highly significant.

Table 2: Comparison of mean FBG and FSG levels (mg/dL) among Group A using Kruskal-wallis test.

Group A	**Range (mg/dL)**	**Mean±SD (mg/dL)**
FBG	53.90 - 98.90	77.76±10.60
FSG	0.40 - 2.00	0.85±0.26
p value Pearson's correlation n	1.3802 0.5713 140	

**Correlation is significant at the 0.01 level. SD: standard deviation, FSG: Fasting saliva glucose, FBG: Fasting blood glucose, n: number of samples analysed

Table 3: Comparison of mean FBG and FSG levels (mg/dL) among Group B using Kruskal-wallis test.

Group B	**Range (mg/dL)**	**Mean±SD (mg/dL)**
FBG	100.00 - 125.00	112.43±6.54
FSG	1.24 - 2.74	2.19±0.16
p value Pearson's correlation n	8.0534 0.7106 141	

**Correlation is significant at the 0.01 level. SD: standard deviation, FSG: Fasting saliva glucose, FBG: Fasting blood glucose, n: number of samples analysed

Table 4: Comparison of mean FBG and FSG levels (mg/dL) among Group C using Kruskal-wallis test.

Group C	**Range (mg/dL)**	**Mean±SD (mg/dL)**
FBG	53.90 - 315.00	225.40±27.37
FSG	0.40 - 4.71	3.15±0.43
p value Pearson's correlation n	3.5570 0.6609 142	

**Correlation is significant at the 0.01 level. SD: standard deviation, FSG: Fasting saliva glucose, FBG: Fasting blood glucose, n: number of samples analysed

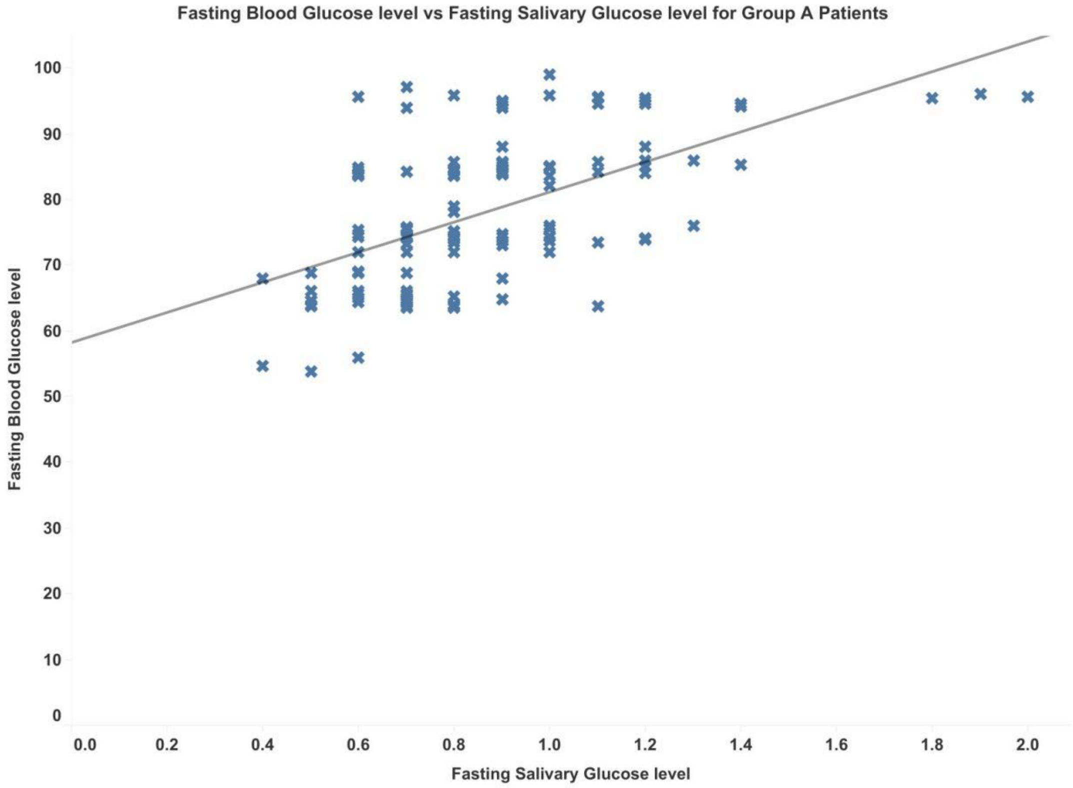

Fig 1. Correlation between fasting blood glucose and salivary glucose levels in Group A subjects.

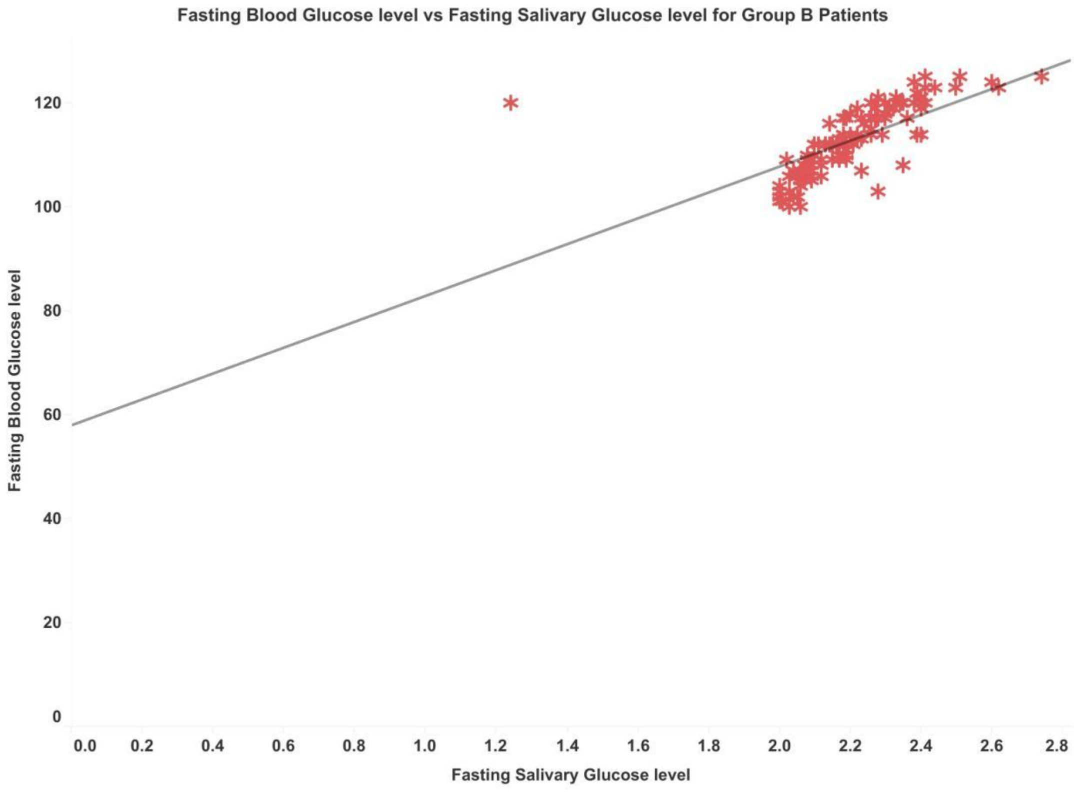

Fig 2. Correlation between fasting blood glucose and salivary glucose levels in Group B subjects.

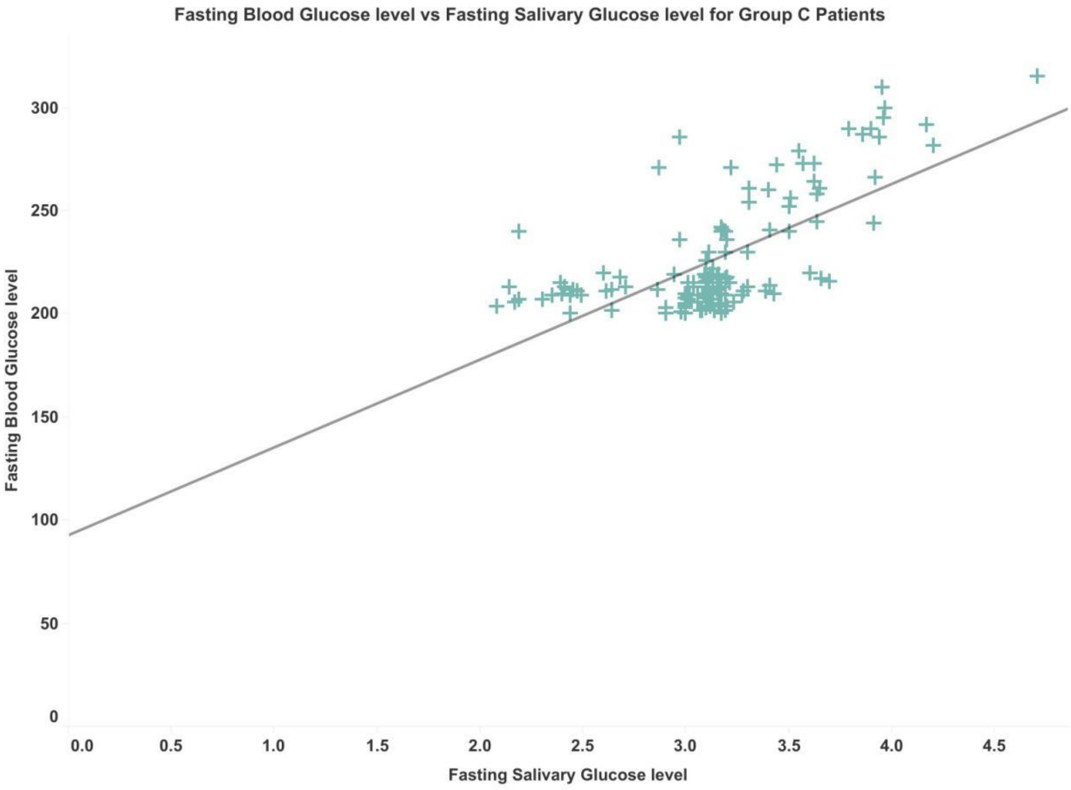

Fig 3. Correlation between fasting blood glucose and salivary glucose levels in Group C subjects.

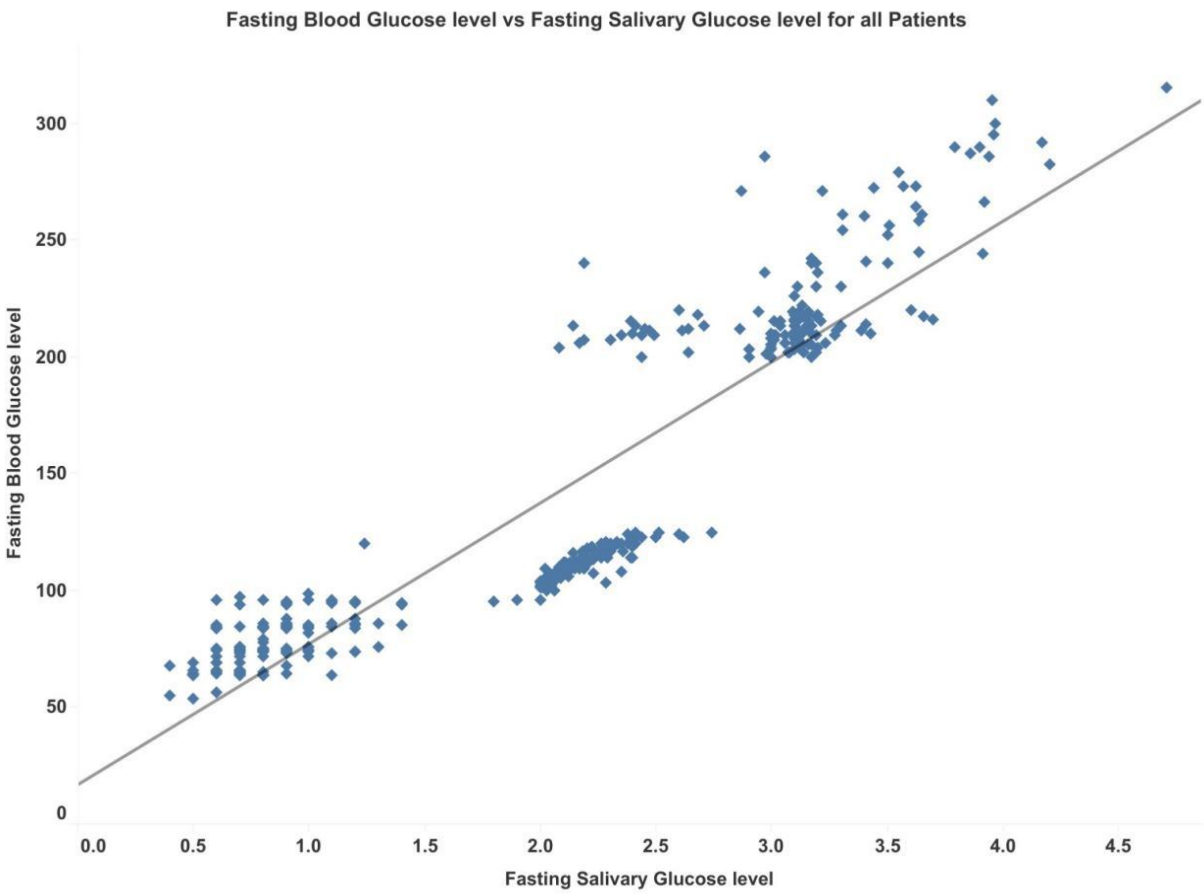

Fig 4. Correlation between fasting blood glucose and salivary glucose levels in all subjects.

DISCUSSION

Diabetes mellitus is a major global public health challenge characterised by chronic hyperglycemia resulting from deficient insulin secretion by pancreatic β-cells, impaired insulin action at target tissues (insulin resistance), or both. These defects disrupt glucose homeostasis and lead to abnormal metabolism of carbohydrates, lipids, and proteins (ADA, 2014). Blood glucose measurement remains the gold standard for diagnosis and monitoring; however, repeated capillary or venous sampling is invasive, painful and often associated with poor patient compliance, particularly among pediatric, geriatric and needle-phobic populations. Salivary glucose assessment has therefore emerged as a promising non-invasive alternative. Saliva collection is painless, rapid, cost-effective and easily performed in both clinical and home settings, aligning with the WHO ASSURED criteria for ideal diagnostic tools. Recent advances in biosensor technology have further enhanced its feasibility, with several enzymatic and non-enzymatic electrochemical and optical platforms demonstrating clinically relevant detection ranges (14.5–213 mg/dL), high sensitivity, rapid response times (<3 min) and strong correlations with blood glucose levels ($r = 0.90–0.97$) in diabetic cohorts (Panwar et al., 2025). Despite these advantages, significant challenges limit the immediate clinical translation of salivary glucose monitoring. A 2026 systematic review and meta-analysis of 25 studies reported only weak overall correlations between salivary and blood glucose ($r^2 \approx 0.05$ for whole-mouth saliva; $r^2 \approx 0.11$ for parotid saliva), accompanied by extremely high heterogeneity (I^2 approaching 100%). This variability stems from differences in saliva collection protocols, diurnal fluctuations, xerostomia, oral contaminants, dietary influences and analytical methodologies (Haba et al., 2026). Earlier meta-analyses indicated moderate to large effect sizes in type 2 diabetes mellitus (T2DM) (Hedge's $g = 1.37$; overall $r \approx 0.49$), with stronger associations observed at higher glycemic levels (Mascarenhas et al., 2014). Salivary glucose concentrations are typically 10–100 times lower than blood levels, which necessitates highly sensitive detection methods. Current evidence suggests salivary glucose is more reliable for monitoring poorly controlled diabetes than for diagnosis or fine glycemic titration in well-controlled patients (Shettigar et al., 2024). The present study demonstrated a significant positive correlation between salivary and blood/plasma glucose concentrations in individuals with T2DM, consistent with multiple observational studies reporting moderate to strong correlations ($r = 0.56–0.715$) and elevated salivary glucose levels in diabetic patients compared with healthy controls (Cui et al., 2022; Tiongco et al., 2018). Several authors have proposed that salivary glands function as filters of blood glucose, with concentrations modulated by hormonal and neural regulation (Zhang et al., 2021). Chronic hyperglycemia induces microvascular changes and alters the basement membrane of salivary glands, increasing glucose leakage into saliva (Gupta et al., 2020). These mechanisms explain the significantly higher salivary glucose levels observed in diabetic patients relative to controls ($p < 0.001$), a finding corroborated by earlier studies in both type 1 and type 2 diabetes (Shahbaz et al., 2014; Nagalaxmi et al., 2011; Iqbal et al., 2011). Nevertheless, conflicting results across the literature have prevented consensus on whether salivary glucose can fully replace blood-based monitoring (Cui et al., 2022; Haba et al., 2026; Shettigar et al., 2024). While saliva offers clear practical advantages, especially for frequent monitoring across all age groups, its clinical utility requires further standardisation of collection and analytical protocols, improved sensor technologies and large-scale validation studies before widespread adoption.

CONCLUSION

This study reveals that salivary glucose is increased in diabetics. Significant correlation was found between FSG level and FBG level of controlled diabetes, uncontrolled diabetes and healthy individuals. This means that saliva can be used as adjuvant diagnostic tool to blood in early diagnosis for DM. Saliva also finds great advantage over blood in case of children, elderly, critically ill and debilitated patients. However, further studies should be conducted to assess the potential of saliva as an alternative diagnostic fluid. Furthermore, the researchers recommend further investigations that would fully support the claims of this study. A longitudinal large-scale study should be conducted due to the limitations of this cross-sectional study. Other parameters such as glycemic control, insulin resistance, and metabolic syndrome are also recommended to be included. The researchers also recommend future studies to elaborate further other salivary analytes that can be used for the diagnosis of diabetes as well as other factors that contribute to their excretion in saliva.

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