

# Reliability and utility of blood glucose levels in the periodontal pockets of patients with type 2 diabetes mellitus: a cross-sectional study

Yutaka Terada<sup>1</sup>, Hiroyuki Watanabe<sup>1</sup>, Mari Mori<sup>1,2</sup>, Kotoko Tomino<sup>1</sup>, Masaya Yamamoto<sup>1</sup>, Mitsuru Moriya<sup>3,4</sup>, Masahiro Tsuji<sup>5</sup>, Yasushi Furuichi<sup>1,6,7</sup>, Tomofumi Kawakami<sup>1,4</sup> and Toshiyuki Nagasawa<sup>1,6,8</sup>

<sup>1</sup> Division of General Dentistry, Health Sciences University of Hokkaido Hospital, Sapporo, Hokkaido, Japan

<sup>2</sup> Division of General Dental Sciences, Department of Oral Rehabilitation, School of Dentistry, Health Sciences University of Hokkaido, Sapporo, Hokkaido, Japan

<sup>3</sup> Division of Internal Medicine, Psychosomatic Internal Medicine, Health Sciences University of Hokkaido Hospital, Sapporo, Hokkaido, Japan

<sup>4</sup> Institute of Preventive Medical Science, Health Sciences University of Hokkaido, Sapporo, Hokkaido, Japan

<sup>5</sup> Division of Diabetes and Metabolism, Tenshi Hospital, Sapporo, Hokkaido, Japan

<sup>6</sup> Division of Periodontology and Endodontology, Department of Oral Rehabilitation, School of Dentistry, Health Sciences University of Hokkaido, Ishikari-Tobetsu, Hokkaido, Japan

<sup>7</sup> Division of Dental Education Development, School of Dentistry, Health Sciences University of Hokkaido, Ishikari-Tobetsu, Hokkaido, Japan

<sup>8</sup> Division of Advanced Clinical Education, Department of Integrated Dental Education, School of Dentistry, Health Sciences University of Hokkaido, Ishikari-Tobetsu, Hokkaido, Japan

## ABSTRACT

**Background:** Several studies have measured gingival blood glucose (GBG) levels, but few have confirmed systematic bias using Bland–Altman analysis. This study compared the effectiveness of GBG levels with that of fingertip blood glucose (FTBG) levels using Bland–Altman and receiver operating characteristic (ROC) analyses.

**Methods:** A total of 15 healthy volunteers and 15 patients with type 2 diabetes were selected according to inclusion and exclusion criteria. Each group comprised eight male and seven female participants. The GBG and FTBG levels were measured using a self-monitoring blood glucose device after periodontal examination. Pearson's product-moment correlation and simple linear regression analyses were performed. In addition, Bland–Altman analysis was also performed to assess the degree of agreement between the two methods. ROC analysis was conducted to determine the sensitivity, specificity, and cutoff values for patients with diabetes. The area under the ROC curve (AUC) was used to identify significant differences.

**Results:** The mean GBG and FTBG levels were  $120 \pm 44.8$  mg/dL and  $137 \pm 45.1$ , respectively, for the whole sample. The mean GBG and FTBG levels were  $145 \pm 47.2$  mg/dL and  $163 \pm 49.1$ , respectively, in the diabetes group. The mean GBG and FTBG levels in the nondiabetes group were  $95.3 \pm 25.2$  and  $111 \pm 18.8$ , respectively. Patients with diabetes were more likely to have a probing pocket depth (PPD) of  $\geq 4$  mm at the sampled site. Pearson's product-moment correlation and simple linear regression analyses revealed a significant correlation between the GBG and FTBG

Submitted 7 May 2024  
Accepted 15 September 2024  
Published 6 November 2024

Corresponding author  
Toshiyuki Nagasawa,  
nagasawa@hoku-iryo.u.ac.jp

Academic editor  
Sonia Oliveira

Additional Information and  
Declarations can be found on  
page 19

DOI 10.7717/peerj.18239

© Copyright  
2024 Terada et al.

Distributed under  
Creative Commons CC-BY 4.0

OPEN ACCESS

measurements. Bland–Altman analysis revealed that GBG and FTBG measurements differed significantly among all participants; however, no significant differences were observed among the patients with diabetes (mean difference (MD)  $\pm$  standard deviation (SD) =  $-18.1 \pm 34.2$ , 95% confidence interval (CI) [-37.0 to 0.88]) or among the participants with a PPD of  $\geq 4$  mm (MD  $\pm$  SD =  $-15.2 \pm 30.4$ , 95% CI [-30.8 to 0.43]). The sensitivity, specificity, and cutoff values of the GBG measurements for detecting diabetes were 80%, 93%, and 123.5 mg/dL, respectively. The sensitivity, specificity, and cutoff values of the FTBG measurements for detecting diabetes were 73%, 87%, and 134.0 mg/dL, respectively. No significant differences were observed between the AUCs (0.078, 95% CI [-0.006 to 0.161]).

**Conclusions:** The GBG measurements aligned with the FTBG measurements in the patients with diabetes and among the participants with a PPD of  $\geq 4$  mm. Patients with diabetes were more likely to have a PPD of  $\geq 4$  mm at the sampled site, GBG levels can be used to screen for type 2 diabetes in dental clinics.

**Subjects** Dentistry, Diabetes and Endocrinology, Drugs and Devices

**Keywords** Type 2 diabetes mellitus, Periodontitis, Gingival blood glucose, Fingertip blood glucose, Bleeding on probing, Screening, Casual or random blood glucose, Point of care test, Dental setting, Non invasive

## INTRODUCTION

Type 2 diabetes mellitus, characterized by chronic hyperglycemia, can cause complications if not properly treated. Moreover, there is a bidirectional relationship between periodontal disease and diabetes. Patients with diabetes are at high risk of developing periodontal disease and its progression, which in turn affects the progression of diabetes mellitus. Periodontal disease also affects the progression of diabetes mellitus ([Graziani et al., 2018](#)). Appropriate periodontal treatment plays an important role in managing patients with diabetes, as periodontal treatment improves insulin resistance and blood glucose management ([Simpson et al., 2022](#)). The guidelines for periodontal surgery and tooth extraction recommend that hemoglobin (Hb) A1c levels be maintained at 6.9% for patients with diabetes ([Japanese Society of Periodontology, 2014](#)). Furthermore, dental treatment must be postponed if the blood glucose levels are  $>200$  or  $<70$  mg/dL ([Little et al., 2017](#)). However, measuring blood glucose levels using venous blood sampling is difficult in dental clinics; therefore, dental treatment commences based on physician information. Given the recent relationship between periodontal disease and diabetes, the inability to measure blood glucose levels in the dental outpatient setting is a major problem. Bleeding from gingiva can be a promising resource for measuring blood glucose for dentists as it would be less burden on the patient. If gingival blood glucose measurements are consistent with those of the fingertip, blood glucose measurement from the gingiva can be incorporated into dental blood glucose measurement.

Previous studies on gingival blood glucose (GBG) measurements concluded that GBG levels could be used for diabetes screening ([Stein & Nebbia, 1969](#); [Tsutsui, Rich & Schonfeld, 1985](#)). A self-monitoring blood glucose (SMBG) device enables patients to

measure their glucose levels by puncturing their fingertips. Several studies have reported strong correlations between fingertip blood glucose (FTBG) levels acquired using an SMBG device and GBG levels (Parker *et al.*, 1993; Beikler *et al.*, 2002; Khader *et al.*, 2006; Ardashani *et al.*, 2009). The measurement of GBG levels is a rapid, safe, noninvasive screening method for diabetes that can be performed during routine periodontal examinations (Parker *et al.*, 1993; Beikler *et al.*, 2002; Khader *et al.*, 2006; Ardashani *et al.*, 2009). Additionally, more patients with diabetes preferred measuring GBG levels over measuring FTBG (Rosedale & Strauss, 2012).

The intraclass correlation coefficient is often used as a measure of reliability to validate new measurement measures. However, what is important in actual measurement is the degree of disagreement. When introducing a new measure, it is necessary to know how much it may differ from previous measures. Since the acceptable measurement error in a clinical setting varies among the types of measurements, no standard can be set automatically by statistical methods (Müller & Behbehani, 2005). Therefore, Bland & Altman (1986, 1999) reported that an agreement analysis between the two methods was needed.

The Bland–Altman analysis has been used to clarify systematic bias (Bland & Altman, 1986, 1999). Only two previous studies have reported Bland–Altman analyses of GBG and FTBG levels (Müller & Behbehani, 2004, 2005; Strauss *et al.*, 2009). Half of the 46 participants in one group did not have periodontitis in the study by Müller & Behbehani (2004, 2005) and only 15% had diabetes. Moreover, Bland–Altman analysis of the GBG and FTBG measurements revealed low concordance between the GBG and FTBG levels (Müller & Behbehani, 2005). The severity of periodontitis was unknown in the study by Strauss *et al.* (2009) and only 9% of the participants had diabetes. Bland–Altman analysis revealed adequate agreement between the GBG and FTBG levels in this study (Strauss *et al.*, 2009). Thus, the Bland–Altman analysis results of GBG and FTBG levels have been inconsistent.

To date, several studies have reported that GBG and FTBG values are associated with diabetes and useful for diabetes screening (Suneetha & Rambabu, 2012; Gaikwad *et al.*, 2013; Shetty *et al.*, 2013; Kaur, Singh & Sharma, 2013; Gupta *et al.*, 2014; Dwivedi *et al.*, 2014; Shylaja *et al.*, 2016; Rajesh *et al.*, 2016; Parihar *et al.*, 2016; Partheeban *et al.*, 2017; Sibyl *et al.*, 2017; Mirza *et al.*, 2018; Sande *et al.*, 2020; Rapone *et al.*, 2020; Wu *et al.*, 2021; Patel *et al.*, 2023; Dash *et al.*, 2023; Alqazlan *et al.*, 2024). Alternatively, other researchers reported that GBG and FTBG values are not associated with diabetes and are not useful for diabetes screening (Debnath *et al.*, 2015; Ansari Moghadam *et al.*, 2024). A recently published systematic review and meta-analysis (Fakheran *et al.*, 2024), citing the three articles mentioned above (Müller & Behbehani, 2004, 2005; Strauss *et al.*, 2009), reported that the GBG values are useful if gingival inflammation is strong and bleeding on probing (BOP) is high.

This study aimed to evaluate the utility of GBG measurements compared with that of FTBG measurements *via* Bland–Altman and receiver operating characteristic (ROC) analyses by determining the GBG and FTBG levels in patients with and without diabetes

who visited the Division of General Dentistry, Health Sciences University of Hokkaido Hospital (Fig. 1).

## MATERIALS AND METHODS

### Sample size setting

Previous studies were extracted from the PubMed database and examined to determine the number of participants required to evaluate the efficacy of GBG measurements compared with that of FTBG measurements. One study ([Rajesh et al., 2016](#)) had 24 participants, one study ([Gaikwad et al., 2013](#)) had 25 participants, and three studies ([Gupta et al., 2014](#); [Shylaja et al., 2016](#); [Sibyl et al., 2017](#)) with 30 participants reported a significant correlation between the GBG and FTBG measurements. G\*Power 3.1 ([Faul et al., 2007](#)) obtained from an internet website ([The G\\*Power Team, 2007](#)) was used to calculate the sample size. The  $\alpha$  and  $\beta$  errors were set to 0.05 and 0.2, respectively. According to a previous report, a correlation coefficient of 0.715 was selected for the correlation analysis ([Gupta et al., 2014](#)). The effect size was set as 0.8 for paired t tests evaluated *via* Bland–Altman analysis. The sample sizes were calculated as 12 for the correlation analysis and 15 for the paired t test using G\*Power 3.1. The total number of participants was 30, with 15 participants each in the diabetic and nondiabetic groups.

#### Inclusion criteria

1. Twenty years or older with at least one current tooth undergoing dental treatment at the Division of General Dentistry, Health Sciences University of Hokkaido Hospital.
2. We classified patients with diabetes based on the specialists' diabetes diagnoses.

Patients in the diabetes group underwent treatment at the Division of Internal Medicine, Health Sciences University of Hokkaido Hospital.

#### Exclusion criteria

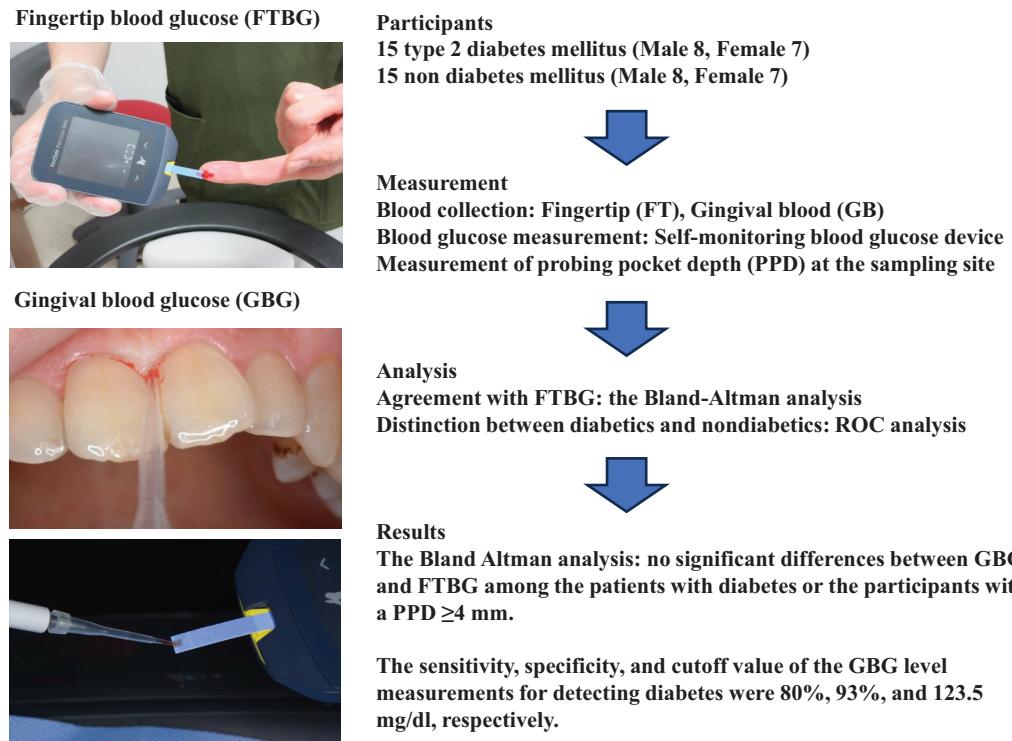
1. Pregnant or lactating women.
2. Patients without diabetes with GBG or FTBG levels greater than 200 mg/dL.

This study adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from the participants after the study was explained. This study was approved by the Ethics Committee of the Institute of Preventive Medical Science, Health Sciences University of Hokkaido (No. 2019\_028).

### Medical and dental examinations

Details regarding sex, age, the time at which the participants finished their last meal on the day of examination, whether they had visited a physician, and smoking history were recorded. In addition, the most recent HbA1c levels were also recorded, and patients with type 2 diabetes were assigned to the diabetes group.

Multiple examiners conducted periodontal examinations, and an interexaminer reliability assessment was conducted. Dental examinations were subsequently performed. The number of teeth present was recorded. In addition, the dental plaque was stained, and the plaque control record (PCR) was determined ([O'Leary, Drake & Naylor, 1972](#)). The probing pocket depth (PPD) and BOP were evaluated using a periodontal pocket probe (CP-11; Hu-Friedy, Chicago, IL, USA) and recorded. Tooth mobility was measured with



**Figure 1** Flow chart indicating the outline of this study. Participants were type 2 diabetics and non-diabetics. Fingertip (FT) and gingival (G) blood glucose (BG) levels were measured using a self-monitoring blood glucose device. The Bland-Altman analysis was used to test agreement with FTBG, and ROC analysis was used to distinguish diabetic and nondiabetic patients. The person in all images was the first author (Dr. Yutaka Terada). This figure has been drawn using PowerPoint 2019.

Full-size  DOI: 10.7717/peerj.18239/fig-1

dental tweezers using Miller's mobility index (*Japanese Society of Periodontology, 2017; Wu et al., 2018*) and classified as follows: Grade 0 (physiological mobility),  $\leq 0.2$  mm; Grade 1 (slight, labiolingual), 0.2–1 mm; Grade 2 (moderate, labiolingual and mesiodistal), 1–2 mm; and Grade 3 (severe, labiolingual and mesiodistal)  $\geq 2$  mm or vertical movement. The periodontal inflamed surface area (PISA) and periodontal epithelial surface area (PESA) were calculated (*Nesse et al., 2008*) using a spreadsheet (*Vissink et al., 2008a*) available on an internet website (*Vissink et al., 2008b*), and the PPD and BOP were entered. Periodontitis was diagnosed and classified based on the examinations and radiographs (*Tonetti, Greenwell & Kornman, 2018a, 2018b*). Stages indicating the severity and complexity of periodontitis were as follows: Stage I, initial; Stage II, moderate; Stage III, severe with potential for additional tooth loss; and Stage IV, severe with potential for loss of dentition. The extent was defined as generalized ( $>30\%$  of teeth involved) or localized for each stage. In addition, the grade, which indicates the risk of periodontitis progression, was defined as follows: Grade A, slow rate of progression; Grade B, moderate rate of progression; and Grade C, rapid rate of progression. Risk factors, including smoking and diabetes, were considered when the grade was determined.

## Blood glucose measurements

The dental plaque was gently removed with cotton pellets, and the sampling sites were isolated using cotton rolls to prevent contamination with saliva and dental plaque. A saliva ejector was also used. Periodontal probing of the sampling sites was subsequently performed. A micropipette (Eppendorf Reference 2, Eppendorf AG, Hamburg, Germany) collected approximately 1.0  $\mu$ L (the minimum volume required for a single blood glucose level measurement) of blood from the sampling site. The mandibular sampling sites were restricted to the labial or buccal sides of the teeth to prevent salivary contamination. The labial or palatal sides of the maxillary anterior teeth were sampled, whereas the palatal sides of the maxillary premolars or molars were sampled. Periodontal pockets with pus were excluded. Blood samples were also acquired from the fingertip. The blood glucose levels were measured using an SMBG device (FreeStyle Precision Neo; Abbott Diabetes Care, Inc., Alameda, CA, USA) immediately after blood collection.

## Statistical analysis

### ***Clinical characteristics of the participants***

All the statistical analyses were performed *via* SPSS Statistics Version 26 (IBM, Chicago, IL, USA). Categorical variables of the diabetic and nondiabetic groups were analyzed according to sex, smoking habits, diagnosis and classification of periodontitis, and PPDs of  $\geq 4$  and  $\leq 3$  mm at the blood sampling site. The chi-square or Fisher's exact tests were used to examine these parameters. Age and HbA1c levels in the diabetic group, blood glucose levels, and postprandial time were continuous variables. The continuous dental variables were the number of teeth present, PPD, BOP, PISA, PESA, PCR, and tooth mobility. The mean  $\pm$  standard deviation (SD) values were calculated. Continuous variables of the diabetic and nondiabetic groups were analyzed using a two-sample t tests.

### ***Correlation and regression analyses***

The correlation between the GBG and FTBG measurements was analyzed to determine whether the GBG measurements were as reliable as the FTBG measurements. The Pearson's product-moment correlation coefficient ( $r$ ) was used to evaluate the correlation. In addition, the simple linear regression equation {FTBG = constant + simple linear regression coefficient ( $R$ )  $\times$  GBG} and the coefficient of determination ( $R^2$ ) for simple linear regression analysis were determined ([Müller & Behbehani, 2005](#); [Rajesh et al., 2016](#)). In the case of simple linear regression analysis, there is only one explanatory variable, so the  $R$  is equal to the  $r$ .

### ***Bland–Altman analysis***

The Bland–Altman analysis was performed as follows ([Bland & Altman, 1986, 1999](#); [Müller & Behbehani, 2005](#); [Strauss et al., 2009](#); [IBM Support, 2020](#)). The interpretation of bias was based on the mean difference (MD) between the GBG and FTBG values. Bias and MD are synonymous. The limit of agreement (LOA) is the range corresponding to bias ( $MD \pm 1.96 \times SD$ ) for the 95% confidence interval (CI), and theoretically, 95% of the differences in the measured values converge to the LOA. The  $MD \pm SD$  between GBG and FTBG and the 95% confidence interval (95% CI) of the MD were calculated. A one-sample

t test was then used to compare GBG and FTBG, and a fixed bias was considered present if the 95% CI did not exceed zero. The coefficient of agreement (COA) and LOAs were determined. The COA was calculated as  $1.96 \times \text{SD}$ . The LOA was calculated as the  $\text{MD} \pm \text{COA}$ . The 95% CIs of the upper and lower LOAs were also calculated. A simple linear regression analysis was performed with the difference between GBG and FTBG as the objective variable and  $(\text{GBG} + \text{FTBG})/2$  as the explanatory variable to determine the presence of proportional bias, and the significance was tested. Proportional bias was considered present if the R was judged to be significant. Furthermore, only the  $\text{MD} \pm \text{SD}$  and evaluation up to 95% CIs were used to determine fixed bias in the presence of fixed and proportional bias. Sites with a PPD of  $\geq 4$  mm were considered suitable for obtaining the same GBG value as the FTBG value (Strauss *et al.*, 2009). A subgroup analysis for PPDs of  $\geq 4$  and  $\leq 3$  mm was also conducted.

### Receiver operating characteristic analysis

The ROC curves of the GBG and FTBG levels were plotted, and the areas under the curves (AUCs) were calculated. The sensitivity and specificity were also calculated. The optimal cutoff values for diabetes screening were subsequently determined. The cutoff values were calculated as the coordinate point, *i.e.*, the minimum value of  $(1-\text{sensitivity})^2 + (1-\text{specificity})^2$  from the coordinate point table of the ROC curve (Strauss *et al.*, 2012, 2015). The difference between the AUCs was determined *via* a one-sample t test if the AUCs of the GBG and FTBG values were significant. All significance levels were set at  $p < 0.05$ .

## RESULTS

Informed consent was obtained from 37 participants between November 2020 and June 2021. The diabetic and nondiabetic groups comprised 15 and 22 participants, respectively. Therefore, case-control matching was performed in the diabetic and nondiabetic groups for 15 participants. Eight male and seven female participants matched perfectly. The analysis was conducted under these conditions, as the minimum age difference possible was within 8 years. The [Supplemental File \(Data S1\)](#) presents the raw data before analysis.

The diabetic group did not include patients with Grade A periodontitis; in contrast, 14 of the 15 participants (93%) in the nondiabetic group had Grade A or B periodontitis ([Table 1](#)), indicating a significant difference ( $p = 0.001$ ). The participants in the diabetic group were significantly more likely to have generalized chronic periodontitis (14 of the 15 patients, 93%) ( $p = 0.040$ ). The mean number of present teeth was  $19.9 \pm 4.85$  and  $23.7 \pm 3.81$  in the diabetic and nondiabetic groups, respectively, indicating a significant difference ( $p = 0.026$ ; [Table 2](#)).

[Figure 2](#) shows the correlation and simple linear regression between the GBG and FTBG levels in all participants. The correlation coefficient and the simple linear regression equation were  $r = 0.827$  ( $p < 0.001$ ) and  $\text{FTBG value} = 36.970 + 0.827 \times \text{GBG value}$  (95% CI for R [0.613–1.051],  $p < 0.001$ ),  $R^2 = 0.684$ , respectively.

The Bland–Altman analysis revealed a significant difference in fixed bias ( $\text{MD} \pm \text{SD} = -16.8 \pm 26.4 \text{ mg/dL}$ , 95% CI for MD [−26.7 to −6.94 mg/dL],  $p = 0.002$ ; [Fig. 3](#) and [Table 3](#)). The LOA ranged from −68.6 to 35.0 mg/dL. Proportional bias was considered nil,

**Table 1** Categorical variables of the participants.

	Non diabetes mellitus <i>n</i> (%)	Diabetes mellitus <i>n</i> (%)	<i>p</i> value
Sex			NA
Female	7 (23.3)	7 (23.3)	
Male	8 (26.7)	8 (26.7)	
Smoking habits			0.299 <sup>†</sup>
Non-smoker	14 (46.7)	12 (40.0)	
Smoker	1 (3.3)	3 (10.0)	
Periodontitis stage			0.605 <sup>†</sup>
I	1 (3.3)	0 (0.0)	
II	4 (13.3)	6 (20.0)	
III	7 (46.7)	8 (53.3)	
IV	3 (10.0)	1 (3.3)	
Periodontitis grade			0.001 <sup>†</sup>
A	8 (26.7)	0 (0.0)	
B	6 (20.0)	9 (30.0)	
C	1 (3.3)	6 (20.0)	
Periodontitis extent			0.040 <sup>†</sup>
Localized	6 (20.0)	1 (3.3)	
Generalized	9 (30.0)	14 (46.7)	
PPD of the sampled site			0.010 <sup>‡</sup>
≤3 mm	10 (33.3)	3 (10.0)	
≥4 mm	5 (16.7)	12 (40.0)	

**Notes:**<sup>†</sup> Fisher's exact test<sup>‡</sup> chi-square test.*n*, number; NA, not applicable; PPD, probing pocket depth.

as no significant difference was observed ( $R = -0.006$ , 95% CI for  $R$  [-0.244 to 0.232],  $p = 0.959$ ).

**Figure 4** presents the correlation and simple linear regression between the GBG and FTBG levels in the nondiabetic group. The correlation coefficient and the simple linear regression equation were  $r = 0.756$  ( $p < 0.001$ ) and FTBG value =  $57.028 + 0.756 \times$  GBG value (95% CI for  $R$  = 0.272 to 0.858,  $p = 0.001$ ),  $R^2 = 0.572$ , respectively.

The Bland-Altman analysis revealed a significant difference in fixed bias among the participants without diabetes ( $MD \pm SD = -15.5 \pm 16.5$  mg/dL, 95% CI for  $MD$  [-24.7 to -6.41 mg/dL],  $p = 0.003$ ; **Fig. 5** and **Table 3**). LOA ranged from -47.8 to 16.8 mg/dL. Proportional bias was considered nil, as no significant difference was observed ( $R = 0.329$ , 95% CI for  $R$  [-0.107 to 0.765],  $p = 0.127$ ).

**Figure 6** depicts the correlation and simple linear regression between the GBG and FTBG levels in the diabetic group. The correlation coefficient and the simple linear regression equation were  $r = 0.748$  ( $p < 0.010$ ) and FTBG value =  $49.966 + 0.748 \times$  GBG value (95% CI for  $R$  [0.365–1.194],  $p = 0.001$ ),  $R^2 = 0.560$ , respectively.

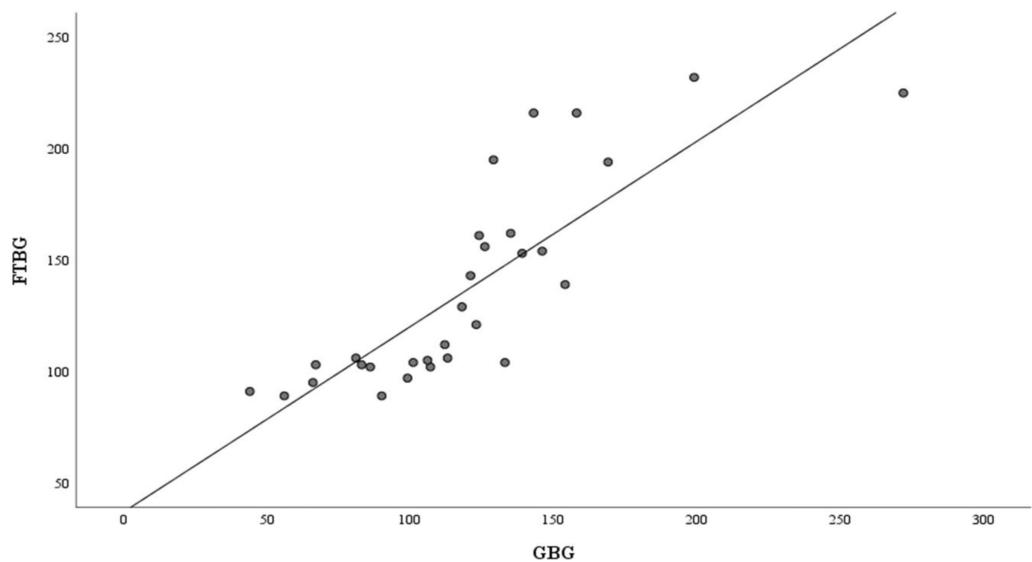
The Bland-Altman analysis revealed no significant difference in fixed bias among the participants with diabetes ( $MD \pm SD = -18.1 \pm 34.2$  mg/dL, 95% CI for  $MD$  [-37.0 to 0.88

**Table 2** Continuous variables of the participants.

	Total participants (n = 30)		Non diabetes mellitus (n = 15)		Diabetes mellitus (n = 15)		<i>p</i> value
	Mean ± SD	Min	Max	Mean ± SD	Mean ± SD		
Age (years)	67.1 ± 8.79	48	85	66.8 ± 9.18	67.4 ± 8.68	0.855	
HbA1c (%)	6.86 ± 0.82	5.8	9.1	NA	6.86 ± 0.82	NA	
GBG (mg/dL)	120 ± 44.8	44	272	95.3 ± 25.2	145 ± 47.2	0.001	
FTBG (mg/dL)	137 ± 45.1	89	232	111 ± 18.8	163 ± 49.1	0.001	
GBG-FTBG (mg/dL)	-16.8 ± 26.4	-73	47	-15.5 ± 16.5	-18.1 ± 34.2	0.799	
Postprandial time (minutes)	187 ± 76.2	60	360	203 ± 88.4	175 ± 61.7	0.324	
Number of present teeth	21.8 ± 4.69	9	28	23.7 ± 3.81	19.9 ± 4.85	0.026	
Mean PPD (mm)	2.67 ± 1.05	1.61	5.99	2.51 ± 0.94	2.84 ± 1.15	0.409	
PPD of the sampled site (mm)	4.13 ± 1.80	2	10	3.60 ± 1.96	4.67 ± 1.50	0.105	
BOP (%)	25.7 ± 22.5	2.30	88.2	20.2 ± 19.1	31.2 ± 24.9	0.185	
PISA (mm <sup>2</sup> )	421 ± 634	9.4	2,721.3	335 ± 494	508 ± 757	0.465	
PESA (mm <sup>2</sup> )	1,111 ± 567	308.4	2,997.4	1,123 ± 573	1,099 ± 581	0.910	
Number of teeth with PPD ≥6 mm	2.37 ± 5.41	0	21	1.93 ± 5.43	2.80 ± 5.55	0.669	
Number of teeth with more than grade 2 of Miller's mobility index	1.40 ± 4.28	0	22	0.87 ± 2.30	1.93 ± 5.66	0.505	
Sites of PPD ≥4 mm (%)	25.7 ± 29.1	0	100	22.0 ± 26.1	29.5 ± 32.4	0.493	
Sites of PPD ≥5 mm (%)	15.0 ± 28.0	0	95.8	12.1 ± 25.3	17.8 ± 31.1	0.585	
Sites of PPD ≥6 mm (%)	11.1 ± 24.8	0	88.2	9.40 ± 22.8	12.7 ± 27.4	0.722	
PCR (%)	34.5 ± 16.8	8.3	69.1	31.2 ± 16.1	37.7 ± 17.4	0.297	

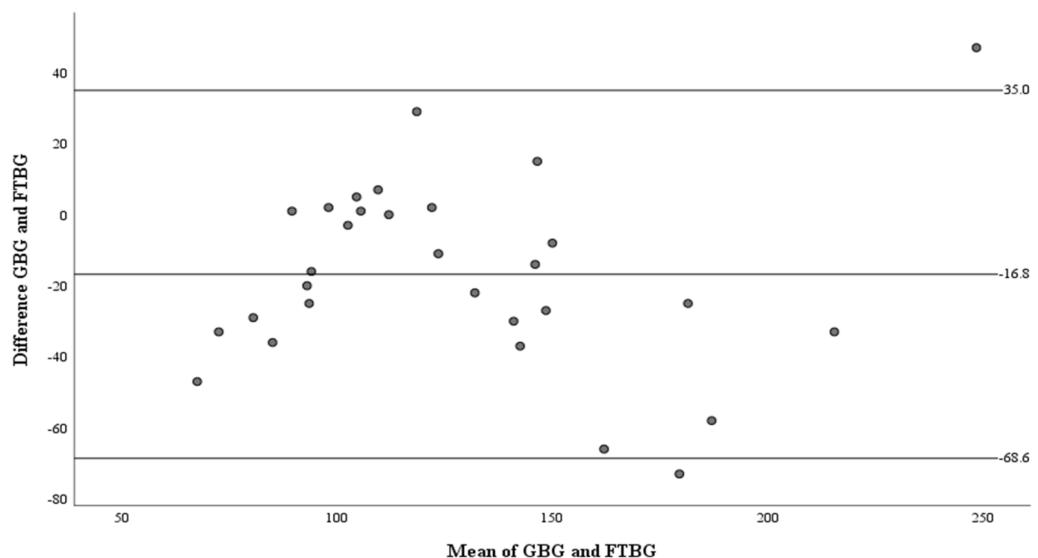
**Notes:**

*p* value for two-sample t test. *n*, number; SD, standard deviation; Min, minimum; Max, maximum; HbA1c, hemoglobin A1c; NA, not applicable; GBG, gingival blood glucose; FTBG, fingertip blood glucose; PPD, probing pocket depth; BOP, bleeding on probing; PISA, periodontal inflamed surface area; PESA, periodontal epithelial surface area; PCR, plaque control record.



**Figure 2** Correlation and regression analyses for all participants. Linear regression of GBG (mg/dL) sample measurements on FTBG (mg/dL) sample readings for all participants. The solid line represents the regression line.

Full-size DOI: 10.7717/peerj.18239/fig-2



**Figure 3** The Bland-Altman plot for all participants. Means of GBG (mg/dL) and FTBG (mg/dL) glucose readings and differences in GBG (mg/dL) and FTBG (mg/dL) glucose readings, with the lines representing the upper and lower 95% limits of agreement and the mean of the differences for all participants.

[Full-size](#) DOI: 10.7717/peerj.18239/fig-3

**Table 3** Main analysis of the repeatability/agreement of the measurements of the blood glucose levels (mg/dL) in the GBG and FTBG samples.

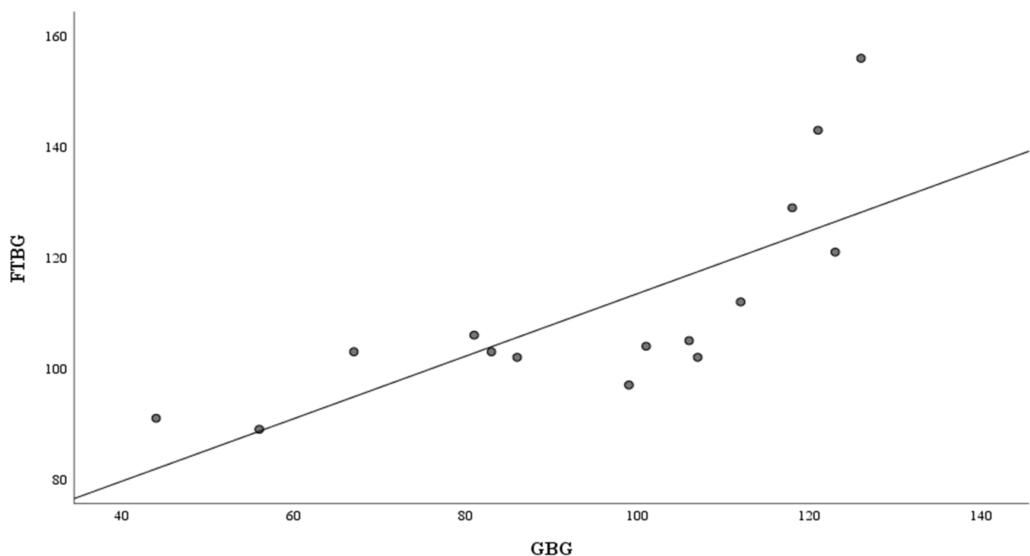
Measures	Total participants ( <i>n</i> = 30)	Non-DM ( <i>n</i> = 15)	Type 2 DM ( <i>n</i> = 15)
Minimum difference	-73	-47	-73
Maximum difference	47	5	47
Mean difference $\pm$ SD	-16.8 $\pm$ 26.4	-15.5 $\pm$ 16.5	-18.1 $\pm$ 34.2
95% CI of mean difference	-26.7 to -6.94	-24.7 to -6.41	-37.0 to 0.88
Coefficient of agreement	51.8	32.3	67.0
Limits of agreement	-68.6, 35.0	-47.8, 16.8	-85.1, 49.0
95% CI of the lower limit	-85.7 to -51.5	-63.6 to -32.0	-118 to -52.4
95% CI of the upper limit	17.9 to 52.1	1.00 to 32.6	16.3 to 81.7

**Notes:**

GBG, gingival blood glucose; FTBG, fingertip blood glucose; DM, diabetes mellitus; *n*, number; SD, standard deviation; CI, confidence interval.

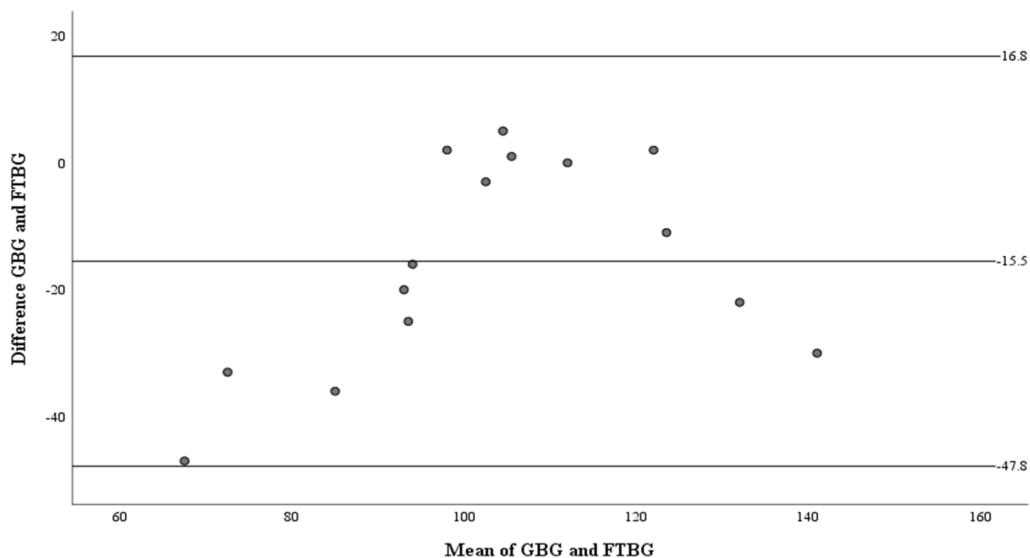
mg/dL],  $p$  = 0.060; **Fig. 7** and **Table 3**). The LOA ranged from -85.1 to 49.0 mg/dL. Proportional bias was considered nil, as no significant difference was observed ( $R$  = -0.047, 95% CI for  $R$  [-0.501 to 0.408],  $p$  = 0.827).

**Figure 8** depicts the correlation and simple linear regression between the GBG and FTBG levels in the subgroups with a PPD of  $\geq 4$  mm at the GBG sampling sites ( $n$  = 17). The correlation coefficient and the simple linear regression equation were  $r$  = 0.838 ( $p$  < 0.001) and FTBG value =  $43.750 + 0.838 \times$  GBG value (95% CI for  $R$  [0.499–1.055],  $p$  < 0.001),  $R^2$  = 0.572, respectively, which is significant (**Fig. 8**).



**Figure 4** Correlation and regression analyses for patients without DM. Linear regression of GBG (mg/dL) sample measurements on FTBG (mg/dL) sample readings for patients without DM. The solid line represents the regression line.

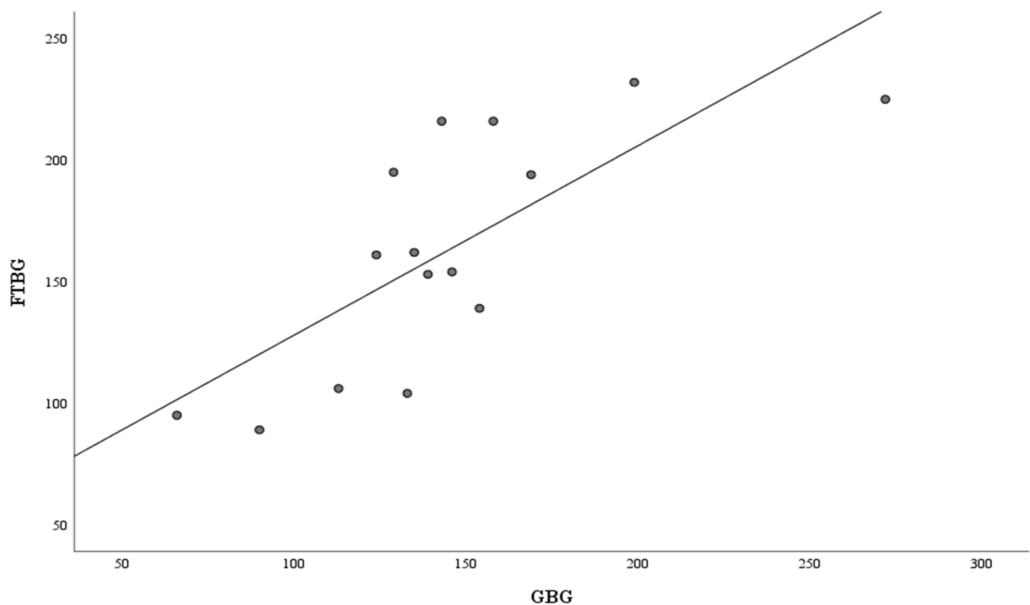
[Full-size](#) DOI: 10.7717/peerj.18239/fig-4



**Figure 5** The Bland-Altman plot for patients without DM. Means of GBG (mg/dL) and FTBG (mg/dL) glucose readings and differences in GBG (mg/dL) and FTBG (mg/dL) glucose readings, with the lines representing the upper and lower 95% limits of agreement and the mean of the differences for participants without DM.

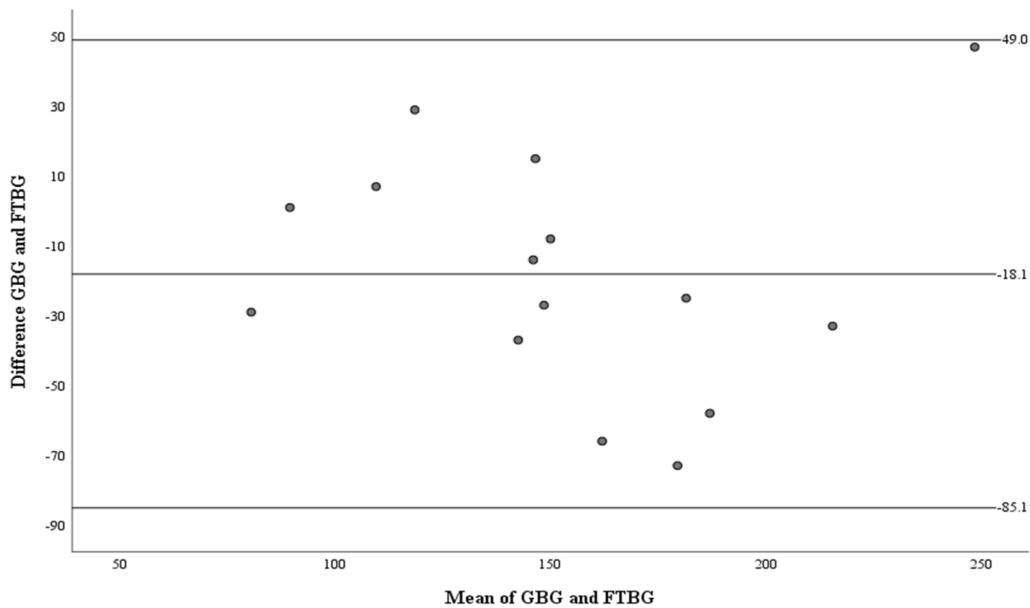
[Full-size](#) DOI: 10.7717/peerj.18239/fig-5

The Bland-Altman analysis of the PPD  $\geq 4$  mm subgroup revealed no significant differences in fixed bias ( $MD \pm SD = -15.2 \pm 30.4$  mg/dL, 95% CI for MD [-30.8 to 0.43 mg/dL],  $p = 0.056$ ; [Fig. 9](#) and [Table 4](#)). LOA ranged from -74.7 to 44.3 mg/dL. Proportional bias was considered nil, as no significant difference was observed ( $R = -0.082$ , 95% CI for  $R$  [-0.244 to 0.408],  $p = 0.599$ ).



**Figure 6** Correlation and regression analyses for patients with DM. Linear regression of GBG (mg/dL) sample measurements on FTBG (mg/dL) sample readings for patients with DM. The solid line represents the regression line.

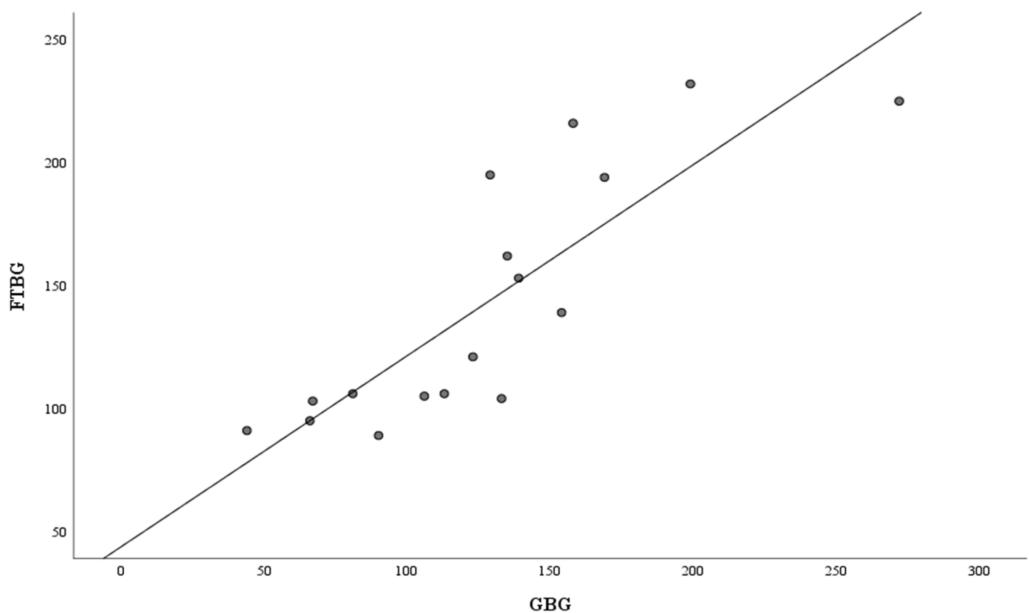
[Full-size](#) DOI: 10.7717/peerj.18239/fig-6



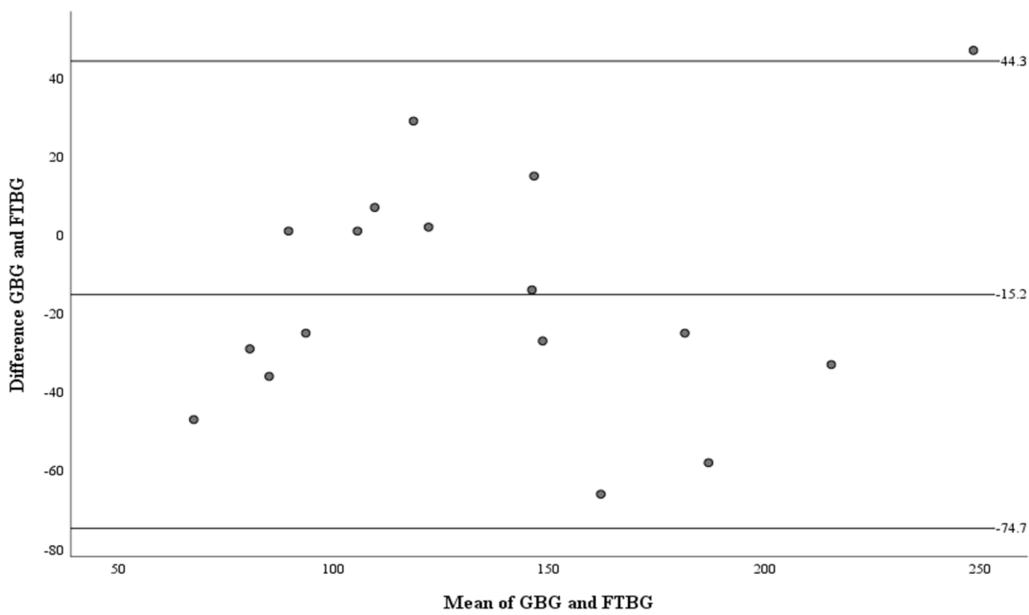
**Figure 7** The Bland-Altman plot for patients with DM. Means of GBG (mg/dL) and FTBG (mg/dL) glucose readings and differences in GBG (mg/dL) and FTBG (mg/dL) glucose readings, with the lines representing the upper and lower 95% limits of agreement and the mean of the differences for patients with DM.

[Full-size](#) DOI: 10.7717/peerj.18239/fig-7

Figure 10 depicts the correlation and simple linear regression between the GBG and FTBG levels in the PPD  $\leq 3$  mm subgroup ( $n = 13$ ). The correlation coefficient and the simple linear regression equation were  $r = 0.823$  ( $p < 0.001$ ) and FTBG value =  $-2.804 +$



**Figure 8** Correlation and regression analyses for patients with PPD of  $\geq 4$  mm. Linear regression of GBG (mg/dL) sample measurements on FTBG (mg/dL) sample readings for patients with PPD of  $\geq 4$  mm. The solid line represents the regression line. [Full-size](#) [DOI: 10.7717/peerj.18239/fig-8](#)



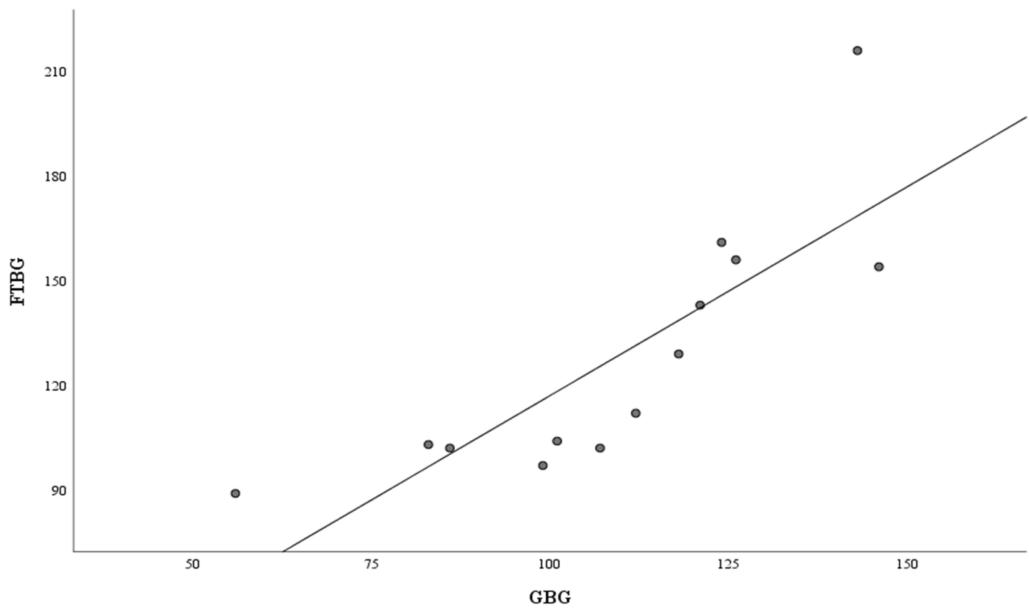
**Figure 9** The Bland-Altman plot for patients with PPD of  $\geq 4$  mm. Means of GBG (mg/dL) and FTBG (mg/dL) glucose readings and differences in GBG (mg/dL) and FTBG (mg/dL) glucose readings, with the lines representing the upper and lower 95% limits of agreement and the mean of the differences for patients with PPD of  $\geq 4$  mm. [Full-size](#) [DOI: 10.7717/peerj.18239/fig-9](#)

**Table 4** Subgroup analysis of the repeatability/agreement of the measurements of blood glucose levels (mg/dL) in the GBG and FTBG samples.

Measures	Sample site of PPD of $\geq 4$ mm ( <i>n</i> = 17)	Sample site of PPD of $\leq 3$ mm ( <i>n</i> = 13)
Minimum difference	-66	-73
Maximum difference	47	5
Mean difference $\pm$ SD	$-15.2 \pm 30.4$	$-18.9 \pm 21.2$
95% CI of mean difference	-30.8 to 0.43	-31.7 to -6.11
Coefficient of agreement	59.5	NA
Limits of agreement	-74.7, 44.3	NA
95% CI of the lower limit	-103 to -46.7	NA
95% CI of the upper limit	16.3 to 72.3	NA

**Notes:**

GBG, gingival blood glucose; FTBG, fingertip blood glucose; *n*, number; PPD, probing pocket depth; SD, standard deviation; CI, confidence interval; NA, not applicable.

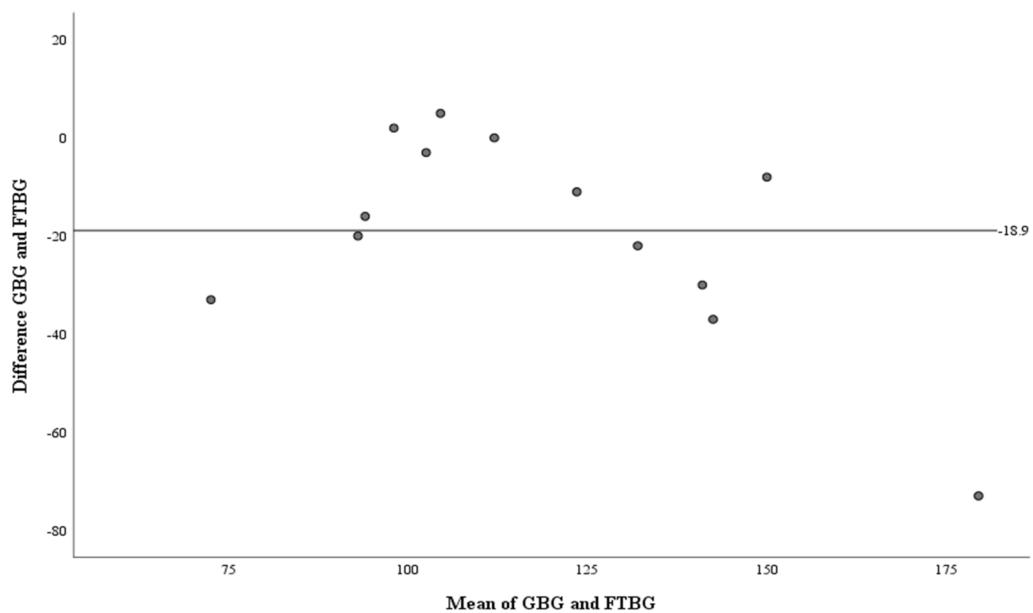


**Figure 10** Correlation and regression analyses for patients with PPD of  $\leq 3$  mm. Linear regression of GBG (mg/dL) sample measurements on FTBG (mg/dL) sample readings for patients with PPD of  $\leq 3$  mm. The solid line represents the regression line. [Full-size](#) DOI: [10.7717/peerj.18239/fig-10](https://doi.org/10.7717/peerj.18239/fig-10)

$0.823 \times \text{GBG value}$  (95% CI for  $R$  [0.650 to 1.748],  $p = 0.001$ ),  $R^2 = 0.677$ , respectively (Fig. 10).

The Bland–Altman analysis of the PPD  $\leq 3$  mm subgroup revealed a significant difference in fixed bias ( $MD \pm SD = -18.9 \pm 21.2$  mg/dL, 95% CI for  $MD$  [-31.7 to -6.11 mg/dL],  $p = 0.007$ ; Fig. 11 and Table 4). Proportional bias was considered significant ( $R = -0.774$ , 95% CI for  $R$  [-1.533 to -0.016],  $p = 0.046$ ).

The AUC of the GBG value was 0.880 (95% CI [0.752 to 1.000],  $p < 0.001$ ; Fig. 12). The AUC of the FTBG values was 0.802 (95% CI [0.641 to 0.963],  $p = 0.005$ ; Fig. 12). The sensitivity, specificity, and cutoff values were obtained, as both AUC values were significant. The sensitivity, specificity, and cutoff values of the GBG values were 0.800,



**Figure 11** The Bland-Altman plot for patients with PPD of  $\leq 3$  mm. Means of GBG (mg/dL) and FTBG (mg/dL) levels and differences in GBG (mg/dL) and FTBG (mg/dL) levels, with the line representing the mean of the differences for patients with PPD of  $\leq 3$  mm.

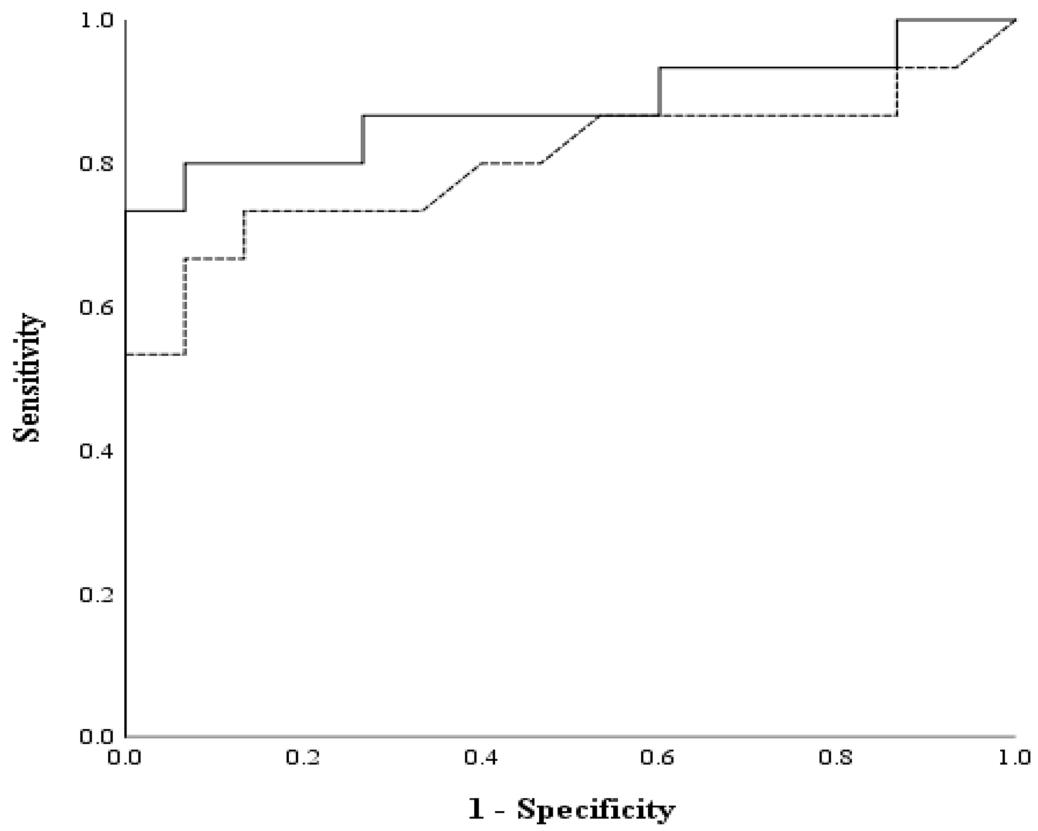
[Full-size](#) DOI: 10.7717/peerj.18239/fig-11

0.933, and 123.5 mg/dL, respectively (Table 5). The sensitivity, specificity, and cutoff values of the FTBG values were 0.733, 0.867, and 134.0 mg/dL, respectively (Table 6). The significant difference in AUCs between the GBG and FTBG levels was tested. The difference between the AUCs of the GBG and FTBG values was 0.078 (95% CI [-0.006 to 0.161],  $p = 0.068$ ), which was not significant (Fig. 12).

## DISCUSSION

Periodontal treatment improves glycemic control in patients with type 2 diabetes by improving insulin resistance caused by periodontal inflammation. Therefore, measuring the blood glucose levels in the gingiva of patients with periodontitis may be helpful in screening untreated diabetic patients. Nonetheless, definitive diabetes diagnosis requires HbA1c and an oral glucose tolerance test, limiting the use of GBG to screening. The Bland-Altman analysis revealed a significant difference between all participants' GBG and FTBG levels. Consistent with our findings, the Bland-Altman analysis revealed a significant difference between the GBG and FTBG levels for all participants in a previous report (Müller & Behbehani, 2005). The Bland-Altman analysis revealed no significant difference between GBG and FTBG levels in the diabetes or PPD  $\geq 4$  mm groups. Similarly, a Bland-Altman analysis revealed no significant difference between the GBG and FTBG levels in a group with PPD  $\geq 4$  mm in a previous study (Strauss *et al.*, 2009).

The sensitivity, specificity, and cutoff value of the GBG measurements for detecting diabetes were 80%, 93%, and 123.5 mg/dL, respectively. The sensitivity, specificity, and cutoff value of the FTBG measurements for detecting diabetes were 73%, 87%, and 134.0 mg/dL, respectively. No significant differences were observed between the AUCs



**Figure 12** ROC for the GBG and FTBG levels corresponding to the diagnosis of type 2 diabetes mellitus. The outer solid line represents GBG, and the inner dashed line represents FTBG.

Full-size DOI: [10.7717/peerj.18239/fig-12](https://doi.org/10.7717/peerj.18239/fig-12)

**Table 5** Coordinates of the ROC curve: GBG cutoff values for diagnosing type 2 DM.

Criterion value for a GBG mg/dL cutoff	Sensitivity	1-Specificity
43.0	1.000	1.000
50.0	1.000	0.933
61.0	1.000	0.867
66.5	0.933	0.867
74.0	0.933	0.800
82.0	0.933	0.733
84.5	0.933	0.667
88.0	0.933	0.600
94.5	0.867	0.600
100.0	0.867	0.533
103.5	0.867	0.467
106.5	0.867	0.400
109.5	0.867	0.333
112.5	0.867	0.267

**Table 5** (continued)

Criterion value for a GBG mg/dL cutoff	Sensitivity	1-Specificity
115.5	0.800	0.267
119.5	0.800	0.200
122.0	0.800	0.133
123.5	0.800	0.067
125.0	0.733	0.067
127.5	0.733	0.000
131.0	0.667	0.000
134.0	0.600	0.000
137.0	0.533	0.000
141.0	0.467	0.000
144.5	0.400	0.000
150.0	0.333	0.000
156.0	0.267	0.000
163.5	0.200	0.000
184.0	0.133	0.000
235.5	0.067	0.000
273.0	0.000	0.000

**Notes:**

ROC, receiver operating characteristic; GBG, gingival blood glucose; DM, diabetes mellitus.

**Table 6** Coordinates of the ROC curve: FTBG cutoff values for diagnosing type 2 DM.

Criterion value for an FTBG mg/dL cutoff	Sensitivity	1-Specificity
88.0	1.000	1.000
90.0	0.933	0.933
93.0	0.933	0.867
96.0	0.867	0.867
99.5	0.867	0.800
102.5	0.867	0.667
103.5	0.867	0.533
104.5	0.800	0.467
105.5	0.800	0.400
109.0	0.733	0.333
116.5	0.733	0.267
125.0	0.733	0.200
134.0	0.733	0.133
141.0	0.667	0.133
148.0	0.667	0.067
153.5	0.600	0.067
155.0	0.533	0.067
158.5	0.533	0.000

(Continued)

**Table 6** (continued)

Criterion value for an FTBG mg/dL cutoff	Sensitivity	1-Specificity
161.5	0.467	0.000
178.0	0.400	0.000
194.5	0.333	0.000
205.5	0.267	0.000
220.5	0.133	0.000
228.5	0.067	0.000
233.0	0.000	0.000

**Notes:**

ROC, receiver operating characteristic; FTBG, fingertip blood glucose; DM, diabetes mellitus.

(0.078, 95% CI [−0.006 to −0.161]). The specificity and sensitivity of the GBG measurements for detecting diabetes in the present study were comparable with those of previous studies (Koneru & Tanikonda, 2015; Partheeban et al., 2017; Sibyl et al., 2017).

The optimal FTBG level for screening for diabetes is 120–140 mg/dL (Rolka et al., 2001; Zhang et al., 2005). Furthermore, the follow-up of dental patients with FTBG levels of  $\geq 121$  mg/dL detected during screening facilitates the early diagnosis of diabetes (Engström et al., 2013). Casual blood glucose monitoring can be performed easily and reliably in dental practice (Barasch et al., 2013; Harase et al., 2015; Al-Sebæi et al., 2023). The optimal fasting GBG level for diabetes screening has been reported to be 125 mg/dL (Partheeban et al., 2017); however, the optimal range for casual GBG levels remains unknown. In this study, the cutoff value was determined *via* the ROC curve, and the value at which it was greatest was 123.5 mg/dL. This value was close to the standard for abnormal fasting blood glucose values, but given the sample size of this study, we should be cautious about whether this value is an absolute standard.

To the best of the authors' knowledge, this is the first study to directly compare the GBG levels with the FTBG levels of patients in Japan and examine the accuracy of these diabetes screening methods. Periodontal treatment reportedly improves HbA1c by approximately 0.5% (Simpson et al., 2022), and the possibility that the severity of periodontitis may affect blood glucose levels cannot be ruled out. Differences in GBG due to periodontitis status should be explored in future studies. Furthermore, the sample size of 15 participants per group might limit the generalizability of the findings. Future studies with larger sample sizes are necessary to validate these results.

## CONCLUSIONS

This study hypothesizes that measurement of the GBG measurements may be an effective method for screening tool for type 2 diabetes mellitus, as periodontitis tends to be more severe, and BOP tends to be greater in patients with type 2 diabetes mellitus. The GBG and FTBG levels were reliable in the diabetic group and patients with a PPD  $\geq 4$  mm. Furthermore, the sensitivity and specificity were as high as those reported in previous studies. Therefore, random blood glucose levels measured from periodontal pockets of patients with diabetes and patients with periodontitis with a PPD of  $\geq 4$  mm may be useful

for screening for type 2 diabetes mellitus. These findings are expected to contribute to the early detection of type 2 diabetes through the dental setting.

The limitation of this study is a small sample size that cannot allow us to current data as a standard for the general population. Although measurement using Bland-Altman, correlation, and regression analyses determined the usefulness of the GBG, however, more accurate measurements need to be confirmed using a large number of participants with a variety of clinical conditions. This study suggests that GBG may be useful for screening for diabetes in dentistry. In contrast, there may be limitations regarding the degree of concordance with FTBG. Local factors such as inflammatory cytokines in periodontal tissues may influence GBG, and further investigation of these factors may allow GBG to be applied in diagnosing and treating diabetes-related periodontitis.

## ACKNOWLEDGEMENTS

We appreciate Dr. Nobuyoshi Kitaichi, MD, Ph.D., Director of Health Sciences University of Hokkaido Hospital, for his great cooperation throughout this study. We would like to thank Editage for editing and reviewing this manuscript for English language.

## ADDITIONAL INFORMATION AND DECLARATIONS

### Funding

This study was supported by Grants-in-Aid from Northern Advancement Center for Science & Technology of Hokkaido Japan (The Development Grants for Medical Institution Needs). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

### Grant Disclosures

The following grant information was disclosed by the authors:

Grants-in-Aid from Northern Advancement Center for Science & Technology of Hokkaido Japan (The Development Grants for Medical Institution Needs).

### Competing Interests

The authors declare that they have no competing interests.

### Author Contributions

- Yutaka Terada conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
- Hiroyuki Watanabe performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
- Mari Mori conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
- Kotoko Tomino performed the experiments, prepared figures and/or tables, and approved the final draft.

- Masaya Yamamoto performed the experiments, prepared figures and/or tables, and approved the final draft.
- Mitsuru Moriya conceived and designed the experiments, analyzed the data, authored or reviewed drafts of the article, and approved the final draft.
- Masahiro Tsuji conceived and designed the experiments, analyzed the data, authored or reviewed drafts of the article, and approved the final draft.
- Yasushi Furuchi conceived and designed the experiments, performed the experiments, analyzed the data, authored or reviewed drafts of the article, and approved the final draft.
- Tomofumi Kawakami conceived and designed the experiments, performed the experiments, analyzed the data, authored or reviewed drafts of the article, and approved the final draft.
- Toshiyuki Nagasawa conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.

### Human Ethics

The following information was supplied relating to ethical approvals (*i.e.*, approving body and any reference numbers):

The Institute of Preventive Medical Science, Health Sciences University of Hokkaido, Ethics Committee granted ethical approval to carry out the study within its facilities (Ethical Application Ref: 2019\_028).

### Data Availability

The following information was supplied regarding data availability:

The raw measurements are available in the [Supplemental File](#).

### Supplemental Information

Supplemental information for this article can be found online at <http://dx.doi.org/10.7717/peerj.18239#supplemental-information>.

## REFERENCES

Al-Sebaei MO, Bamashmous M, Bassyoni L, Alsubaie R, Alnahdi DO. 2023. Pre-procedure blood sugar levels in diabetic and high-risk patients visiting King Abdulaziz University Dental Hospital: the role of the dentist in diabetes screening. *Diabetes, Metabolic Syndrome and Obesity* **16**:1021–1027 DOI [10.2147/DMSO.S405676](https://doi.org/10.2147/DMSO.S405676).

Alqazlan FSA, Alazmi SO, Syed NK, Alshumaym AAA, Aloyouni AAA, Alfuryah KAG, Almuzaini SSS. 2024. Glucose monitoring from gingival crevicular fluid blood among chronic periodontitis patients at Ar Rass, Saudi Arabia. *Bioinformation* **20**(4):337–340 DOI [10.6026/973206300200337](https://doi.org/10.6026/973206300200337).

Ansari Moghadam S, Abbaszade H, Sartipi M, Ansari Moghadam A. 2024. Evaluating the association between gingival crevicular blood glucose levels and finger capillary blood glucose levels according to periodontal status. *European Journal of Medical Research* **29**(1):86 DOI [10.1186/s40001-023-01611-8](https://doi.org/10.1186/s40001-023-01611-8).

**Ardakani MR, Moeintaghavi A, Haerian A, Ardakani MA, Hashemzadeh M. 2009.** Correlation between levels of sulcular and capillary blood glucose. *The Journal of Contemporary Dental Practice* **10**(2):10–17 DOI [10.5005/jcdp-10-2-10](https://doi.org/10.5005/jcdp-10-2-10).

**Barasch A, Gilbert GH, Spurlock N, Funkhouser E, Persson LL, Safford MM, DPBRN Collaborative Group. 2013.** Random plasma glucose values measured in community dental practices: findings from the dental practice-based research network. *Clinical Oral Investigations* **17**(5):1383–1388 DOI [10.1007/s00784-012-0825-y](https://doi.org/10.1007/s00784-012-0825-y).

**Beikler T, Kuczek A, Petersilka G, Flemmig TF. 2002.** In-dental-office screening for diabetes mellitus using gingival crevicular blood. *Journal of Clinical Periodontology* **29**(3):216–218 DOI [10.1034/j.1600-051x.2002.290306.x](https://doi.org/10.1034/j.1600-051x.2002.290306.x).

**Bland JM, Altman DG. 1986.** Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1**:307–310 DOI [10.1016/S0140-6736\(86\)90837-8](https://doi.org/10.1016/S0140-6736(86)90837-8).

**Bland JM, Altman DG. 1999.** Measuring agreement in method comparison studies. *Statistical Methods in Medical Research* **8**(2):135–160 DOI [10.1177/096228029900800204](https://doi.org/10.1177/096228029900800204).

**Dash KC, Ramanna PK, Varghese LJ, Reddy U, Nambiar S, Patel A, Mishra D. 2023.** Estimation of gingival crevicular blood as noninvasive method to determine the blood glucose level: a comparative study. *The Journal of Contemporary Dental Practice* **24**(6):381–384 DOI [10.5005/jp-journals-10024-3473](https://doi.org/10.5005/jp-journals-10024-3473).

**Debnath P, Govila V, Sharma M, Saini A, Pandey S. 2015.** Glucometric assessment of gingival crevicular blood in diabetic and non-diabetic patients: a randomized clinical trial. *Journal of Oral Biology and Craniofacial Research* **5**(1):2–6 DOI [10.1016/j.jobcr.2014.12.004](https://doi.org/10.1016/j.jobcr.2014.12.004).

**Dwivedi S, Verma SJ, Shah M, Jain K. 2014.** Can gingival crevicular blood be relied upon for assessment of blood glucose level? *The New York State Dental Journal* **80**:38–42.

**Engström S, Berne C, Gahnberg L, Svärdsudd K. 2013.** Effectiveness of screening for diabetes mellitus in dental health care. *Diabetic Medicine* **30**(2):239–245 DOI [10.1111/dme.12009](https://doi.org/10.1111/dme.12009).

**Fakheran O, Bencze B, Mischak I, Vegh D, Payer M. 2024.** The reliability of using gingival crevicular blood to measure blood glucose and hba1c levels in the dental setting: a systematic review and meta-analysis. *Clinical Oral Investigations* **28**(5):299 DOI [10.1007/s00784-024-05685-4](https://doi.org/10.1007/s00784-024-05685-4).

**Faul F, Erdfelder E, Lang AG, Buchner A. 2007.** G\*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods* **39**(2):175–191 DOI [10.3758/BF03193146](https://doi.org/10.3758/BF03193146).

**Gaikwad S, Jadhav V, Gurav A, Shete AR, Dearda HM. 2013.** Screening for diabetes mellitus using gingival crevicular blood with the help of a self-monitoring device. *Journal of Periodontal & Implant Science* **43**(1):37–40 DOI [10.5051/jpis.2013.43.1.37](https://doi.org/10.5051/jpis.2013.43.1.37).

**Graziani F, Gennai S, Solini A, Petrini M. 2018.** A systematic review and meta-analysis of epidemiologic observational evidence on the effect of periodontitis on diabetes ana update of the EFP-AAP review. *Journal of Clinical Periodontology* **45**(2):167–187 DOI [10.1111/jcpe.12837](https://doi.org/10.1111/jcpe.12837).

**Gupta A, Gupta N, Garg R, Jain N, Atreja G, Walia SS. 2014.** Developing a chair side, safe and non-invasive procedure for assessment of blood glucose level using gingival crevicular bleeding in dental clinics. *Journal of Natural Science, Biology, and Medicine* **5**(2):329–332 DOI [10.4103/0976-9668.136177](https://doi.org/10.4103/0976-9668.136177).

**Harase T, Nishida W, Hamakawa T, Hino S, Shigematsu K, Kobayashi S, Sako H, Ito S, Murakami H, Nishida K, Inoue H, Fujisawa M, Yoshizu H, Kawamura R, Takata Y, Onuma H, Shimizu K, Hamakawa H, Osawa H. 2015.** Clinical implication of blood glucose monitoring in general dental offices: the ehime dental diabetes study. *BMJ Open Diabetes Research & Care* **3**(1):e000151 DOI [10.1136/bmjdrc-2015-000151](https://doi.org/10.1136/bmjdrc-2015-000151).

**IBM Support. 2020.** The Bland-Altman plot. Available at <https://www.ibm.com/support/pages/bland-altman-plot> (accessed 23 September 2021).

**Japanese Society of Periodontology. 2014.** Periodontal treatment guidelines for patients with diabetes (Revised version 2). Available at [https://www.perio.jp/english/files/Guidelines\\_diabetes.pdf](https://www.perio.jp/english/files/Guidelines_diabetes.pdf) (accessed 19 February 2023).

**Japanese Society of Periodontology. 2017.** JSP clinical practice guideline for the periodontal treatment, 2015 the first edition first published (English version). Available at [https://www.perio.jp/publication/upload\\_file/guideline\\_perio\\_plan2015\\_en.pdf](https://www.perio.jp/publication/upload_file/guideline_perio_plan2015_en.pdf) (accessed 1 November 2020).

**Kaur H, Singh B, Sharma A. 2013.** Assessment of blood glucose using gingival crevicular blood in diabetic and non-diabetic patients: a chair side method. *Journal of Clinical and Diagnostic Research: JCDR* 7:3066–3069 DOI [10.7860/JCDR/2013/7705.3854](https://doi.org/10.7860/JCDR/2013/7705.3854).

**Khader YS, Al-Zu’bi BN, Judeh A, Rayyan M. 2006.** Screening for type 2 diabetes mellitus using gingival crevicular blood. *International Journal of Dental Hygiene* 4(4):179–182 DOI [10.1111/j.1601-5037.2006.00206.x](https://doi.org/10.1111/j.1601-5037.2006.00206.x).

**Koneru S, Tanikonda R. 2015.** Reliability of gingival blood sample to screen diabetes in dental hospital. *International Journal of Preventive Medicine* 6(1):23 DOI [10.4103/2008-7802.153538](https://doi.org/10.4103/2008-7802.153538).

**Little JW, Falace DA, Miller CS, Rhodus NL. 2017.** Diabetes mellitus. In: Little JW, Falace DA, Miller CS, Rhodus NL, eds. *Dental Management of the Medically Compromised Patient*. Ninth Edition. St. Louis: Elsevier, 230–254.

**Mirza W, Saleem MS, Patel G, Chacko P, Reddy S, Schaefer R, Jones R, Dheer N, Dharampuri S, Sandhu A. 2018.** Early screening strategies for diabetes mellitus by leveraging dental visits using optimal screening tools available onsite. *Cureus* 10:e3641 DOI [10.7759/cureus.3641](https://doi.org/10.7759/cureus.3641).

**Müller HP, Behbehani E. 2004.** Screening of elevated glucose levels in gingival crevice blood using a novel, sensitive self-monitoring device. *Medical Principles and Practice: International Journal of the Kuwait University, Health Science Centre* 13(6):361–365 DOI [10.1159/000080474](https://doi.org/10.1159/000080474).

**Müller HP, Behbehani E. 2005.** Methods for measuring agreement: glucose levels in gingival crevice blood. *Clinical Oral Investigations* 9(1):65–69 DOI [10.1007/s00784-004-0290-3](https://doi.org/10.1007/s00784-004-0290-3).

**Nesse W, Abbas F, van der Ploeg I, Spijkervet FKL, Dijkstra PU, Vissink A. 2008.** Periodontal inflamed surface area: quantifying inflammatory burden. *Journal of Clinical Periodontology* 35(8):668–673 DOI [10.1111/j.1600-051X.2008.01249.x](https://doi.org/10.1111/j.1600-051X.2008.01249.x).

**O’Leary TJ, Drake RB, Naylor JE. 1972.** The plaque control record. *Journal of Periodontology* 43(1):38 DOI [10.1902/jop.1972.43.1.38](https://doi.org/10.1902/jop.1972.43.1.38).

**Parihar S, Tripathi R, Parihar AV, Samadi FM, Chandra A, Bhavsar N. 2016.** Estimation of gingival crevicular blood glucose level for the screening of diabetes mellitus: a simple yet reliable method. *Journal of Oral Biology and Craniofacial Research* 6(3):198–203 DOI [10.1016/j.jobcr.2016.05.004](https://doi.org/10.1016/j.jobcr.2016.05.004).

**Parker RC, Rapley JW, Isley W, Spencer P, Killoy WJ. 1993.** Gingival crevicular blood for assessment of blood glucose in diabetic patients. *Journal of Periodontology* 64(7):666–672 DOI [10.1902/jop.1993.64.7.666](https://doi.org/10.1902/jop.1993.64.7.666).

**Partheeban IK, Chaly P, Priyadarshni I, Junaid M, Nijesh JE, Vaishnavi S. 2017.** Evaluation of gingival blood as a minimally invasive screening tool for diabetes mellitus among 40-59-year-old adults in dental clinics: a cross-sectional study. *Indian Journal of Dental Research* 28(2):144–150 DOI [10.4103/ijdr.IJDR\\_304\\_16](https://doi.org/10.4103/ijdr.IJDR_304_16).

**Patel C, Dave B, Patel R, Kumar S, Dattani V, Joshi S, Haque M. 2023.** Gingival crevicular blood glucose as a novel method for screening diabetes mellitus in periodontally compromised patients. *Cureus* 15:e39444 DOI [10.7759/cureus.39444](https://doi.org/10.7759/cureus.39444).

**Rajesh KS, Irshana R, Arun Kumar MS, Hegde S. 2016.** Effectiveness of glucometer in screening diabetes mellitus using gingival crevicular blood. *Contemporary Clinical Dentistry* 7(2):182–185 DOI 10.4103/0976-237X.183072.

**Rapone B, Ferrara E, Santacroce L, Topi S, Converti I, Gnoni A, Scarano A, Scacco S. 2020.** Gingival crevicular blood as a potential screening tool: a cross sectional comparative study. *International Journal of Environmental Research and Public Health* 17(20):7356 DOI 10.3390/ijerph17207356.

**Rolka DB, Narayan KM, Thompson TJ, Goldman D, Lindenmayer J, Alich K, Bacall D, Benjamin EM, Lamb B, Stuart DO, Engelgau MM. 2001.** Performance of recommended screening tests for undiagnosed diabetes and dysglycemia. *Diabetes Care* 24(11):1899–1903 DOI 10.2337/diacare.24.11.1899 Erratum in: *Diabetes Care* 25: 413.

**Rosedale MT, Strauss SM. 2012.** Diabetes screening at the periodontal visit: patient and provider experiences with two screening approaches. *International Journal of Dental Hygiene* 10(4):250–258 DOI 10.1111/j.1601-5037.2011.00542.x.

**Sande AR, Guru S, Guru R, Gaduputi S, Thati DK, Siddeshappa ST. 2020.** Gingival crevicular blood glucose levels: is it a reliable tool for screening diabetes in a dental office? *The Journal of Contemporary Dental Practice* 21(4):421–425 DOI 10.5005/jp-journals-10024-2752.

**Shetty N, Shankarapillai R, Mathur LK, Manohar B, Mathur A, Jain M. 2013.** Gingival crevicular blood: as a non-invasive screening tool for diabetes mellitus in dental clinics. *Journal of Indian Society of Periodontology* 17(4):472–477 DOI 10.4103/0972-124X.118319.

**Shylaja MD, Punde PA, Sam G, Khan SN, Latheef AA, Thorat AJ. 2016.** Noninvasive technique for estimating blood glucose levels among diabetic patients. *The Journal of Contemporary Dental Practice* 17(3):248–252 DOI 10.5005/jp-journals-10024-1835.

**Sibyl S, Bennadi D, Kshetrimayum N, Manjunath M. 2017.** Correlations between gingival crevicular blood glucose and capillary blood glucose: a preliminary report. *Journal of Laboratory Physicians* 9(4):260–263 DOI 10.4103/JLP.JLP\_141\_16.

**Simpson TC, Clarkson JE, Worthington HV, MacDonald L, Weldon JC, Needleman I, Iheozor-Ejiofor Z, Wild SH, Qureshi A, Walker A, Patel VA, Boyers D, Twigg J. 2022.** Treatment of periodontal disease for glycaemic control in people with diabetes mellitus. *The Cochrane Database of Systematic Reviews* 4(4):CD004714 DOI 10.1002/14651858.CD004714.pub4.

**Stein GM, Nebbia AA. 1969.** A chairside method of diabetic screening with gingival blood. *Oral Surgery, Oral Medicine, and Oral Pathology* 27(5):607–612 DOI 10.1016/0030-4220(69)90092-9.

**Strauss SM, Rosedale MT, Pesce MA, Rindskopf DM, Kaur N, Juterbock CM, Wolff MS, Malaspina D, Danoff A. 2015.** The potential for glycemic control monitoring and screening for diabetes at dental visits using oral blood. *American Journal of Public Health* 105(4):796–801 DOI 10.2105/AJPH.2014.302357.

**Strauss SM, Tuthill J, Singh G, Rindskopf D, Maggiore JA, Schoor R, Brodsky A, Einhorn A, Hochstein A, Russell S, Rosedale M. 2012.** A novel intraoral diabetes screening approach in periodontal patients: results of a pilot study. *Journal of Periodontology* 83(6):699–706 DOI 10.1902/jop.2011.110386.

**Strauss SM, Wheeler AJ, Russell SL, Brodsky A, Davidson RM, Gluzman R, Li L, Malo RG, Salis B, Schoor R, Tzvetkova K. 2009.** The potential use of gingival crevicular blood for measuring glucose to screen for diabetes: an examination based on characteristics of the blood collection site. *Journal of Periodontology* 80(6):907–914 DOI 10.1902/jop.2009.080542.

**Suneetha K, Rambabu T. 2012.** Gingival crevicular blood glucose assessment as a chairside test for diabetic patients with chronic periodontitis: a clinical study. *Indian Journal of Endocrinology and Metabolism* 16(4):665–666 DOI 10.4103/2230-8210.98044.

**The G\*Power Team.** 2007. G\*Power statistical power analyses for Mac and Windows. Available at <https://www.psychologie.hhu.de/en/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower> (accessed 1 November 2020).

**Tonetti MS, Greenwell H, Kornman KS.** 2018a. Staging and grading of periodontitis: framework and proposal of a new classification and case definition. *Journal of Clinical Periodontology* 45(Suppl. 20):S149–S161 DOI 10.1111/jcpe.12945 Erratum in: *Journal of Clinical Periodontology* 46:787 DOI: 10.1111/jcpe.13152.

**Tonetti MS, Greenwell H, Kornman KS.** 2018b. Staging and grading of periodontitis: framework and proposal of a new classification and case definition. *Journal of Periodontology* 89(Suppl. 1):S159–S172 DOI 10.1002/JPER.18-0006 Erratum in: *Journal of Periodontology* 89:1475 DOI: 10.1002/jper.10239.

**Tsutsui P, Rich SK, Schonfeld SE.** 1985. Reliability of intraoral blood for diabetes screening. *Journal of Oral Medicine* 40:62–66.

**Vissink A, Abbas F, Dijkstra P, Spijkervet FKL, Nesse W.** 2008a. Calculate PISA using probing pocket depth. Available at <https://www.parsproto.info/pisa.html> (accessed 1 November 2020).

**Vissink A, Abbas F, Dijkstra P, Spijkervet FKL, Nesse W.** 2008b. parsproto.info. Available at <https://www.parsproto.info/> (accessed 1 November 2020).

**Wu J, Lin L, Zhang R, Liu S, Sun W.** 2021. Can gingival crevicular blood effectively screen for diabetes in Chinese patients with moderate to severe periodontitis? A pilot study. *Journal of Dental Sciences* 16(1):1–6 DOI 10.1016/j.jds.2020.08.013.

**Wu CP, Tu YK, Lu SL, Chang JH, Lu HK.** 2018. Quantitative analysis of Miller mobility index for the diagnosis of moderate to severe periodontitis—a cross-sectional study. *Journal of Dental Sciences* 13(1):43–47 DOI 10.1016/j.jds.2017.11.001.

**Zhang P, Engelgau MM, Valdez R, Cadwell B, Benjamin SM, Narayan KM.** 2005. Efficient cutoff points for three screening tests for detecting undiagnosed diabetes and pre-diabetes: an economic analysis. *Diabetes Care* 28(6):1321–1325 DOI 10.2337/diacare.28.6.1321.