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BLOOD GLUCOSE LEVELS AND SALIVARY BACTERIAL PROFILE AMONG PATIENTS WITH DIABETES MELLITUS: A DESCRIPTIVE CROSS-SECTIONAL STUDY

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Abstract
Background: Diabetes mellitus (DM) is a chronic non-communicable disease characterized by prolonged hyperglycemia, which can increase salivary glucose levels and reduce salivary flow, thereby promoting bacterial growth and increasing the risk of oral infections.
Objective: To describe fasting blood glucose levels, salivary bacterial counts, and the Gram-staining characteristics of salivary bacteria among patients with diabetes mellitus.
Methods: This cross-sectional correlational study involved 32 diabetes mellitus patients selected using accidental sampling. Data were collected through questionnaires, fasting blood glucose measurement using POCT, salivary bacterial count using the TPC method, and Gram staining.
Results: All participants (100%) had fasting blood glucose levels within the diabetic range (≥126 mg/dL), indicating persistent hyperglycemia. Likewise, all saliva samples showed high bacterial counts (>100,000 CFU/mL). Gram-positive bacteria were more predominant than Gram-negative bacteria, accounting for 55.2% and 44.8% of the bacterial isolates, respectively.
Conclusions: Patients with diabetes mellitus exhibited persistent hyperglycemia, high salivary bacterial counts, and a predominance of Gram-positive bacteria. These findings provide baseline information on the salivary bacterial profile of patients with diabetes mellitus and emphasize the importance of maintaining glycemic control and oral hygiene as part of comprehensive diabetes care.

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INTRODUCTION

Diabetes mellitus (DM) is a non-communicable disease classified as a metabolic disorder. Its characteristic feature is an increase in blood glucose levels (hyperglycemia) caused by impaired insulin secretion, impaired insulin function, or a combination of both. Over time, chronic hyperglycemia due to DM can lead to various complications affecting multiple organ systems (1). DM complications not only include cardiovascular, renal, neurological, and ocular disorders but also have serious implications for oral health. In people with DM, several conditions that can be seen directly in the oral cavity include a distinctive mouth odor resembling the smell of acetone caused by complications of the disease, as well as dry mouth (xerostomia) caused by decreased saliva production (2–4).

Reduced salivary flow in patients with diabetes mellitus alters the oral environment by impairing the buffering system, changing salivary pH, and reducing the natural self-cleansing mechanism of the oral cavity. These changes facilitate the accumulation of food debris and microorganisms, thereby increasing the risk of bacterial colonization and oral infections (5–7). Furthermore, persistent hyperglycemia promotes the diffusion of glucose from the bloodstream into saliva, resulting in elevated salivary glucose concentrations. This increased glucose availability provides an additional nutrient source for oral bacteria, facilitating bacterial proliferation and biofilm formation. In addition, chronic hyperglycemia impairs host immune defenses, including neutrophil function and the antimicrobial activity of saliva, creating a more favorable environment for bacterial growth. Consequently, patients with poorly controlled diabetes are more likely to exhibit increased salivary bacterial counts and poorer oral health than individuals with normal glycemic status (8,9).

Based on the International Diabetes Federation (IDF) Diabetes Atlas 11th Edition (2025), Indonesia is among the countries with the highest number of diabetes mellitus (DM) cases worldwide. In 2024, approximately 20.4 million adults aged 20–79 years were estimated to be living with DM in Indonesia, with a prevalence of 11.3%. This number is projected to increase to 28.6 million by 2050, indicating a substantial and continuously growing burden of DM in the country. The high prevalence of DM in Indonesia highlights the importance of early prevention, proper disease management, and monitoring of DM-related complications, including oral health disorders (10). According to data from the Bali Provincial Health Office Profile, the number of diabetes mellitus (DM) cases in Bali Province increased from 30,856 in 2022 to 34,226 in 2023, indicating a continued rise in the burden of DM in the region (11).

Several previous studies have demonstrated that diabetes mellitus is associated with alterations in the oral microbiome, including increased bacterial colonization, reduced microbial diversity, and a higher prevalence of periodontal pathogens. Most of these studies have focused on identifying specific bacterial species or evaluating changes in the composition of the oral microbiota using culture-independent molecular techniques (8,9,12,13). However, relatively few studies have specifically evaluated whether fasting blood glucose levels are associated with the overall salivary bacterial burden as determined by quantitative bacterial count methods such as Total Plate Count (TPC). Moreover, evidence from Indonesian populations remains limited despite the high and increasing prevalence of diabetes mellitus in the country. Therefore, investigating the relationship between blood glucose levels and salivary bacterial counts may provide useful baseline

information regarding oral bacterial colonization among Indonesian patients with diabetes mellitus.

Although several studies have reported oral health problems in patients with diabetes mellitus, descriptive data on fasting blood glucose levels and salivary bacterial profiles remain limited, particularly in the Indonesian population. Therefore, this study aimed to describe fasting blood glucose levels, salivary bacterial counts, and the Gram-staining characteristics of salivary bacteria among patients with diabetes mellitus.

Microbiological examination of saliva is important for assessing oral health and identifying bacterial colonization associated with diabetes mellitus. Total Plate Count (TPC) is a simple, cost-effective, and widely used microbiological method for estimating the total viable bacterial load in biological samples, including saliva. Unlike methods that identify specific bacterial species, TPC provides an overall quantitative measure of culturable bacteria and is therefore useful for evaluating the general bacterial burden in the oral cavity.

MATERIALS AND METHODS

This study was conducted using a descriptive cross-sectional design. This study has undergone an ethical review procedure and has obtained an ethical clearance letter from the Chair of the Health Research Ethics Commission of the Denpasar Ministry of Health Polytechnic with NO.DP.04.02/F.XXXII.25/372/2025 on April 17, 2025.

The research sample collection location was at the UPTD. Puskesmas I Denpasar Timur from April to June 2025. The population in this study were DM patients aged 30-70 years with a sample size of 32 people and accidental sampling technique. Fasting blood glucose (FBG) levels were measured after an overnight fast of at least 8 hours. Capillary blood samples were obtained from the fingertip using sterile disposable lancets and analyzed immediately using a Point-of-Care Testing (POCT) glucometer Accu-Chek Active® glucometer (Roche Diagnostics, Mannheim, Germany) according to the manufacturer's instructions. The instrument was calibrated and quality-controlled following the manufacturer's recommendations before sample analysis. Blood glucose results were recorded in milligrams per deciliter (mg/dL)., measuring the number of bacteria in the saliva of DM patients using the Total Plate Count (TPC) method, and Gram staining. Data were analyzed descriptively using frequency, percentage, mean ± standard deviation (or median and range), and presented in tables and figures.

RESULTS AND DISCUSSIONS

This study was conducted at UPTD Puskesmas I Denpasar Timur, a primary healthcare center in Denpasar, Bali, Indonesia, which provides healthcare and laboratory services for patients with diabetes mellitus.

Table 1. Characteristics of Research Subjects

Variable	Category	Frequency (n)	Percentage (%)
Age	30–59 years	20	62.5
	60–70 years	12	37.5
Gender	Male	14	43.8
	Female	18	56.3
Duration of DM	1–5 years	15	46.9
	>5 years	17	53.1

Family History of DM	Present	19	59.4
	Not present	13	40.6
Medication History	Yes	32	100
	No	0	0
Tooth-brushing Hygiene	1 time/day	0	0
	2 times/day	32	100
	>2 times/day	0	0

Table 2. Results of Fasting Blood Sugar Level Examination of Respondents

No	Fasting Blood Glucose Level	Frequency (N)	Percentage (%)
1	Normal < 100mg/dL	0	0
2	Prediabetes 100-126 mg/dL	0	0
3	Diabetes > 127 mg/dL	32	100,0
	Total	**32**	**100,0**

Based on Table 2, all participants (100%) had fasting blood glucose levels within the diabetic range (≥126 mg/dL), confirming persistent hyperglycemia among the study population. **Table 3.** Results of Bacterial Count Examination in Respondents' Saliva

No	Bacterial count in Saliva	Frequency (N)	Percentage (%)
1	Low < 100.000 CFU/mL	0	0
2	High > 100.000 CFU/mL	32	100,0
	Total	**32**	**100,0**

Based on Table 3, all respondents were in the high category (> 100,000 CFU/mL), which was 100%

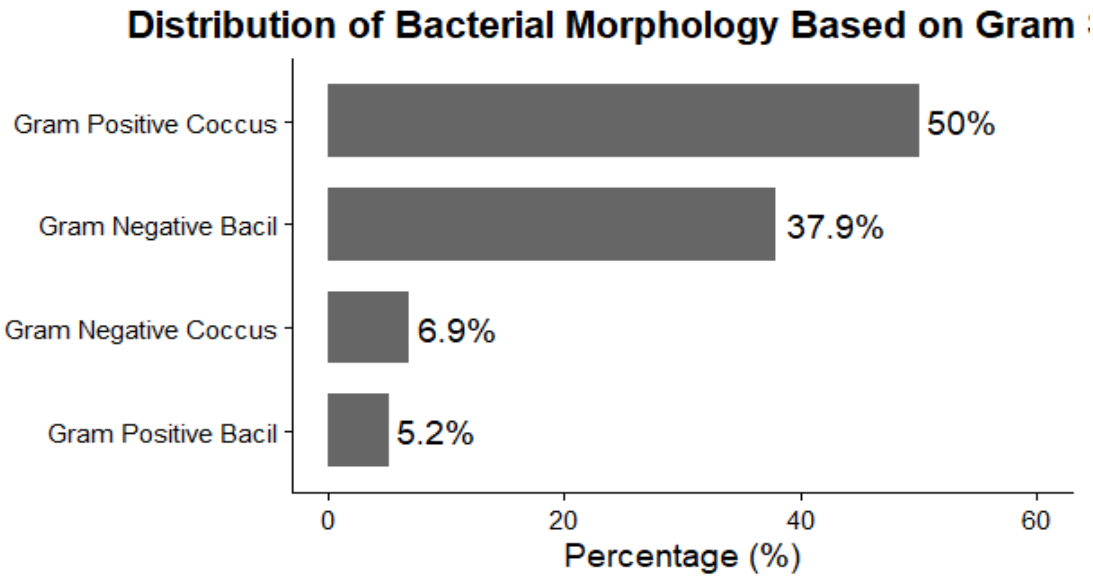

Figure 1. Results of Gram-Positive and Gram-Negative Bacteria Examination in Respondents' Saliva

d. Results of Gram-positive and Gram-negative bacteria examination in the respondents' saliva

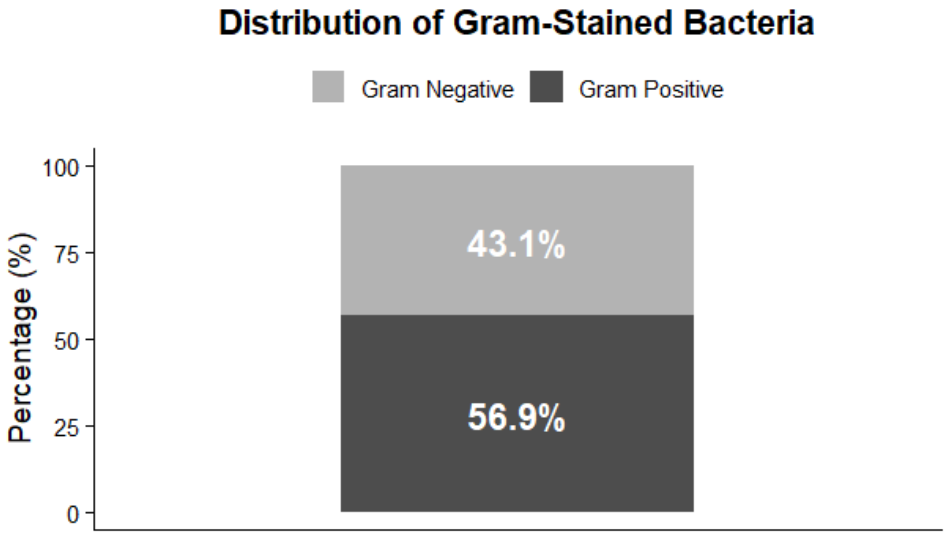

Figure 2. Results of Gram-Positive and Gram-Negative Bacteria Examination in Respondents' Saliva

Based on Figure 2, there are 51 types of bacteria that can be identified. Based on their characteristics, the most common type is Gram-positive bacteria, accounting for 56.9%.

The percentage of fasting blood sugar levels in DM patients is entirely in the high (>127 mg/dL) category. This aligns with research stating that most fasting blood sugar levels of DM patients at the Ciputat Tangerang Selatan Community Health Center are high (>127 mg/dL). According to the American Diabetes Association (ADA) standards, a fasting blood glucose level≥126 mg/dL is one of the diagnostic criteria for DM. Thus, the results of this study confirm that all respondents were in a state of hyperglycemia, which is consistent with the criteria for diabetes (10). The percentage of bacterial counts in the saliva of DM patients showed that all respondents had high bacterial growth (>100,000 CFU/mL). This increase in bacterial numbers may raise the risk of periodontal disease and other oral infections, common complications of DM (12,13). In DM patients, chronic hyperglycemia can lead to increased salivary glucose levels (5,6,8).

The results of bacterial count tests on the saliva of patients with high levels (>100,000 CFU/mL) in all respondents indicate that hyperglycemia in DM patients plays a major role in supporting bacterial growth, consistent with the strong correlation observed in this study. This figure shows a significant level of bacterial colonization in the oral cavities of DM patients, which may increase the risk of oral infections. These findings highlight the importance of controlling blood sugar levels to reduce the risk of oral infections in people

with diabetes, along with maintaining oral hygiene. In addition, immune system disorders that commonly occur in people with diabetes also contribute to high microbial colonization. Decreased mucosal immunity prevents optimal suppression of bacterial growth, leading to the accumulation of large numbers of microorganisms (14,15).

The percentage of Gram-positive and Gram-negative bacteria found in the saliva of DM patients, A total of 51 bacterial colony isolates obtained from the cultured saliva samples were subjected to Gram staining. Of these isolates, 55.2% were classified as Gram-positive and 44.8% as Gram-negative... This is consistent with research stating that Gram-positive bacteria are the most common in the saliva of DM patients (16,17). The results of this study show that the oral environment of DM patients is dominated more by Gram-positive bacteria than Gram-negative bacteria. The dominance of Gram-positive bacteria at 55.2% is consistent with the characteristics of oral microflora in individuals with high blood sugar levels. In chronic hyperglycemia in DM patients, the saliva environment becomes richer in glucose, which can support the growth of fermentative Gram-positive bacteria that produce acid and damage oral tissue (18).

Gram-negative bacteria produce endotoxins (lipopolysaccharides/LPS) that are highly proinflammatory and can worsen periodontal tissue inflammation (19). These Gram-negative bacteria are often involved in severe periodontitis, especially in diabetic patients with compromised immunity. Gram-positive Coccus bacteria, namely the *Streptococcus sp*. genus, are found on the surface of teeth, saliva, and mucosa. Examples of Gram-positive Bacillus bacteria include Actinomyces, Lactobacillus, and Eubacterium, which can cause early caries, root caries, gingivitis, dental plaque, and calculus. Meanwhile, Gram-negative bacteria such as Neisseria and Veillonella generally inhabit the tongue, saliva, oral mucosa, tongue surface, and dental plaque (13).

In this study, the respondents' high blood glucose levels, accompanied by elevated bacterial counts, support the hypothesis that a high-glucose oral environment creates ideal conditions for the growth of Gram-positive bacteria. Similarly, the presence of Gram-negative bacteria can pose a risk of periodontal disease in respondents, mainly due to hyperglycemia, which can increase the immune response and enhance the virulence of Gram-negative anaerobic bacteria. Although their numbers are smaller than Gram-positive bacteria, the presence of Gram-negative bacteria is still clinically relevant, as these bacteria are often more pathogenic and contribute to chronic inflammation of the gum tissue.

CLINICAL IMPLICATION

The findings of this study demonstrate a significant association between blood glucose levels and salivary bacterial counts in patients with diabetes mellitus. Clinically, these findings highlight the importance of routine blood glucose monitoring as part of comprehensive diabetes management. Early identification of elevated blood glucose levels enables healthcare providers to implement timely interventions, including dietary counseling, promotion of physical activity, and appropriate pharmacological treatment, to improve glycemic control and reduce the risk of diabetes-related complications. Furthermore, these findings emphasize the need for an integrated approach to oral healthcare in patients with diabetes mellitus. Maintaining good oral hygiene through

regular dental examinations and effective glycemic control may help limit excessive bacterial colonization in the oral cavity, thereby reducing the risk of oral infections and improving overall oral health.

LIMITATIONS

This study has several limitations. First, its cross-sectional design does not allow causal inferences regarding the relationship between fasting blood glucose levels and salivary bacterial counts. Second, the sample size was relatively small and participants were recruited from a single primary healthcare center, which may limit the generalizability of the findings. Third, important salivary parameters, including salivary glucose concentration, salivary pH, and salivary flow rate, were not measured. These variables are considered important biological mediators linking hyperglycemia to bacterial proliferation and may have provided a more comprehensive understanding of the mechanisms underlying the observed findings. Finally, bacterial identification was limited to Gram staining and total bacterial counts without species-level identification, preventing further characterization of the oral microbiota.

CONCLUSIONS

The blood sugar levels of all respondents (100%) were in the high category, the bacterial count of all respondents (100%) was in the high category, Gram-positive bacteria were present in 55.2% of cases, and Gram-negative bacteria were present in 44.8% of cases. All diabetes mellitus patients included in this study had elevated fasting blood glucose levels and high salivary bacterial counts. Gram-positive bacteria were more predominant than Gram-negative bacteria. These findings indicate that uncontrolled diabetes is accompanied by substantial bacterial colonization in the oral cavity.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTOR CONTRIBUTIONS

All Authors have accepted responsibility for the entire content of this manuscript and approved its submission.

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DECLARATION OF ARTIFICIAL INTELLIGENCE USE

The authors used artificial intelligence (AI) tools, including OpenAI ChatGPT and Grammarly, solely for language editing and grammar improvement. The authors take full responsibility for the content of the manuscript.

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