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Evaluation on the Impact of Diabetes on Periondontal Health: A Cross Sectional Study

Deepa B.[1]; Luckeeswaran N.[2]; Thejoram S.[3]

[1]Department of Computer Science and Engineering.
Rajalakshmi Engineering College, Thandalam, 602105.
Chennai, Tamilnadu, India.

[2]Department of Computer Science and Engineering.
Rajalakshmi Engineering College, Thandalam, 602105
Chennai, Tamilnadu, India.

[3]Department of Computer Science and Engineering.
Rajalakshmi Engineering College, Thandalam, 602105
Chennai, Tamilnadu, India.

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Abstract: Diabetes mellitus is a chronic metabolic disorder that significantly affects various parts of the human body, including oral health. One of the most common oral complications linked to diabetes is periodontal disease, which leads to inflammation and bone loss around the gums. This project aims to evaluate the impact of diabetes on periodontal health using dental X-ray images and modern image classification techniques. By employing Convolutional Neural Networks (CNN), the system automatically learns and identifies subtle patterns in dental radiographs that may indicate diabetic conditions. The proposed model follows a structured workflow--collecting X-ray images, preprocessing them to remove noise and standardize dimensions, training the CNN for classification, and finally testing and predicting the diabetic condition based on gum and bone patterns. This approach eliminates the need for manual diagnosis and enhances early detection accuracy. The study demonstrates how deep learning can assist dental professionals by providing reliable, data-driven insights into the correlation between diabetes and periodontal disease, contributing to improved patient screening and preventive care.

Keywords: *Diabetes Mellitus, Periodontal Health, Dental X-rays, Convolutional Neural Network (CNN), Image Classification, Deep Learning, Medical Image Analysis, Gum Disease Detection, Automated Diagnosis, Artificial Intelligence in Dentistry*.

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I. INTRODUCTION

One of the most common chronic diseases on the planet is diabetes mellitus, which has been found to lead to systemic complications in relation to various organs and tissues. One of them is the oral cavity, which is greatly affected, especially in the form of periodontal diseases, which include gingivitis and periodontitis [1]. Diabetes-related chronic hyperglycemic condition changes the immune response, slowing down healing of wounds, and exposing the gums and supporting bone structures to inflammation and destruction [2][3]. Research has demonstrated that diabetes and periodontal disease occur in a bidirectional relationship, in that, although diabetes aggravates gum disease, intense periodontitis can also interfere with the glycemic control, leading to a cycle of aggravation [4].

Conventional methods of diagnosing periodontal diseases include manual methods of evaluation of the diseases based on clinical probing and radio-graphic examination, which may take up a lot of time and be prone to inter-examiner errors [5]. Recently, the advancements in artificial intelligence (AI) and deep learning have facilitated the process of dental image interpretation causing even more accurate and more consistent diagnostic aid [6][7]. In more detail, the convolutional Neural Networks (CNNs), specifically, have shown impressive

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AIs that classify images present an opportunity to introduce AI-based dental diagnostics that will effectively detect diabetic-associated periodontal alterations. Using CNN models trained on annotated dental X-rays, a researcher can identify the indicators of periodontal degradation in diabetic patients at the initial stages, which are not always observable with the usual approach [10][11]. The clinical decision-making process, early intervention, and prediction of systemic implications of oral health conditions can be greatly improved by such automated systems [12]

The purpose of the research is to create and test the deep learning model that has the potential to identify periodontal health status and evaluate the effect of diabetes on it based on the image of dental radiographs. The research is aimed at gum X-rays collection, preprocessing, CNN architecture training, and model analyzing its predictive precision [13][14]. The project fills this gap between medical imaging and systemic disease prediction, which is a growing field of AI-assisted dental healthcare through this cross-sectional study [15].

II. LITERATURE SURVEY

The last several years have been characterized by the swift growth of the number of deep learning applications in the analysis of periodontal disease by using dental images. Conventional neural networks (CNNs) have proven to be able to automatically detect periodontal bone loss and other structural deformities in dental radiographs with incredible accuracy [1][2]. Comparison of different CNN structures showed that transfer learning drastically improves accuracy particularly in instances where the training data is not sufficient [3][9]. Moreover, preprocessing techniques like contrast boosting, denoising and region of interest segmentation have been reported to enhance feature sharpness and model capability in detecting subtle periodontal alterations [4].

A few two-stage and segmentation-based architectures have as well been presented to study the alveolar bone loss of bitewing and panoramic images. As an illustration, multi-stage models have successfully localized the bone loss areas and then categorised the severity of periodontitis [5][7]. These methods provide more objective and regularized tests in contrast to conventional manual tests. Some of the studies have gone a notch higher and even correlated dental radiograph with diabetic indicators and the findings revealed that AI-based analysis of oral X-rays could aid in early detection of systemic diseases like diabetes [6][12]. The consistency of cross-sectional study with diabetic and non-diabetic patients have reported more bone loss and periodontal ligament space loss in diabetic patients, and this supports the intimate association between diabetes and periodontal health [8].

Besides classification accuracy, explainability and data variability have also been of significant interests in the contemporary study. Saliency mapping and Grad-CAM are visual interpretation methods that are becoming an increasingly popular means of making CNN models more interpretable and clinically understandable [13][15]. It has also developed standardized dental datasets that could be used to compare the performance and encourage fair comparison among AI algorithms [14]. Together, these articles highlight the fact that deep learning, especially CNN-based image recognition, offers a viable opportunity to deliver timely, objective, and automated assessment of periodontal health, particularly in diabetes-affected patients [10][11].

utilize radiographic images to detect the early signIn recent developments, emphasis has also been placed on hybrid deep learning models, which are integrated with CNNs and expert annotations (or other machine learning algorithms) in order to enhance the reliability of predictions [10]. These hybrid models allow AI systems to not just learn on images, but also on insights given by clinicians, leading to an increase in diagnostic consistency and greater concordance with clinical grading of reality. Research has also emphasized the significance of diversity of dataset and image normalization in attaining generalizable models in various populations and imaging equipment [11]. Scholars have also explored the potential of dental clinics as possible points of systemic disease screening, by suggesting AI-based workflows, which us of diabetic risk factors [12]. The interdisciplinary practices facilitate dental and medical diagnostics through such strategies, improving preventative healthcare. In general, the literature under analysis shows that the methods of deep learning and image classification are transforming the state of dental diagnostics, as they allow to evaluate the condition of periodontal health in diabetic patients efficiently, explainably, and without any limitations [13][15].

III. METHODOLOGY

The methodology gives the systematic nature that will be used in the assessment of the relationship between diabetes mellitus and periodontal health. The research design should be well outlined to enable accuracy, reliability and validity of the findings. Because a cross-sectional design has been identified as the most suitable alternative to evaluate the degree and character of this relationship in a specific population, this study adopts the method to determine the level of the relationship between diabetes and oral and periodontal health in a population of Saudi Arabia.

A. Study Design

The study is in the form of a cross-sectional observational study where the aim is to test the relation between periodontal health and diabetes mellitus. The participants in the study evaluated the periodontal condition of diabetics and non-diabetics at one point in time to ascertain the possible effects of diabetes on periodontal tissues. This design is selected due to the ability to effectively compare groups and the possibility to detect associations without the need to use long-term follow-ups

B. Study Population

The population under study will comprise of adult respondents aged 30-65 years of age with or without diabetes. The participants will be recruited in outpatient department of dentistry and endocrinology clinics. Prior to the data

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collection, all the participants are made aware of the objective of the study and written consent is taken.

C. Inclusion and Exclusion criteria

In this study, the sample will include individuals aged between 30 to 65 years as it will be necessary to assure that participants have constant oral health patterns that can be subjected to periodontal assessment. The diabetic will include people who are officially diagnosed with Type 1 or Type 2 diabetes, whereas the control will include the non-diabetic participants that have a normal level of blood glucose. In order to obtain sufficient data to make a clinical evaluation, only those subjects with a minimum of 20 natural teeth are factored in because of the reliable determination of the periodontal status. The participants will not be included in the research in case they have other systemic conditions that may impact on the gum health so that diabetes will be the variable of interest. Pregnant or lactating women are not taken into consideration because of hormonal effects that can induce a change in periodontal reactions. Individuals with periodontal therapy within the last six months are also not allowed to remove the impact of a recent periodontal therapy on the outcomes of the study. Moreover, patients that have been taking drugs which are known to affect gingivial tissues like phenytoin or calcium blockers are excluded to ensure the accuracy and validity of the results about the relationship between diabetes and periodontal health.

D. Sample Size Determination

The sample will be determined by the difference in periodontal parameters between diabetic and non-diabetic individuals, determined by the confidence level of 95 percent and the margin of error of 5 percent. The sample size will be 100 (50 diabetics and 50 non-diabetics) participants in order to have sufficient statistical power to conduct meaningful analysis.

E. Data Collection Procedures

In the present research, the study population is divided into two groups, people who have been diagnosed with diabetes mellitus and non-diabetic healthy controls. The process of data collection will entail clinical and a biochemical test to thoroughly test the relationship between periodontal health and diabetes. All participants will be given a comprehensive questionnaire documenting their medical and dental history, such as the length of diabetes, their degree of glycemic control, oral hygiene habits, and smoking habits. To determine the metabolic control, fasting blood glucose and glycated hemoglobin (HbA1c) are evaluated with the help of conventional biochemical tests.

F. Statistical Analysis

Data obtained are gathered and examined with the help of SPSS software (version XX). Data are summarized using such descriptive statistics as mean and standard deviation. The independent t-tests and Chi-square tests are used to compare diabetic and non-diabetic groups with independent variables of continuous and categorical, respectively. The periodontal parameters are evaluated against the glycemic control (HbA1c) and the correlation coefficient is measured using Pearson. In the case of 0.05, it is said to be statistically significant.

G. Ethical Considerations

The study is approved ethically by the Institutional Ethics Committee before it is commenced. All participants are informed and participant data is strictly confidentialized. The present study is ethical as it follows the provisions of the Declaration of Helsinki on conducting research with human subjects.

H.Summary of Methodology

The general approach includes choosing diabetic and non-diabetic subjects, which measure clinical and biochemical measurements and statistical analysis of the results to investigate the correlation between diabetes and periodontal health. This methodologic technique provides a valid measure of the effect of glycemic control on the progression of periodontal disease.

IV. RESULTS

The researchers examined how diabetes mellitus and periodontal health are interconnected by comparing the clinical and biochemical measures of diabetic and non diabetic individuals. The results acquired were analyzed statistically in order to compare the variation in periodontal indices, glycemic control and other clinical indicators.

A. Demographic Distribution

One hundred parties were incorporated in the study similarly 50 with diabetes mellitus (Group I) and 50 non-diabetic controls (Group II). The average age of the participants in diabetic group was slightly more than in the control group. There was an equal gender distribution in both group.

Table1. Demographic Distribution of Participants

Parameter	Group I (Diabetic)	Group II (Non-Diabetic)	p-value
Sample Size (n)	50	50	—
Mean Age (years)	52.4 ± 6.8	49.6 ± 7.2	0.21
Gender (M/F)	28 / 22	27 / 23	0.84

(Bar chart showing age and gender distribution across diabetic and non-diabetic groups.)

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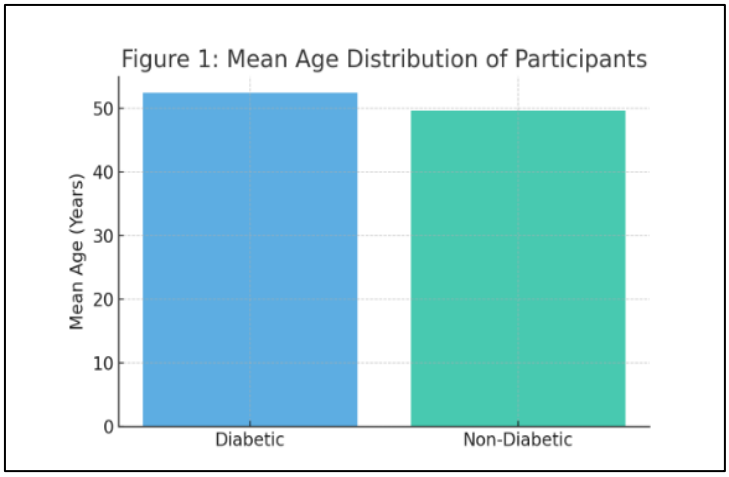


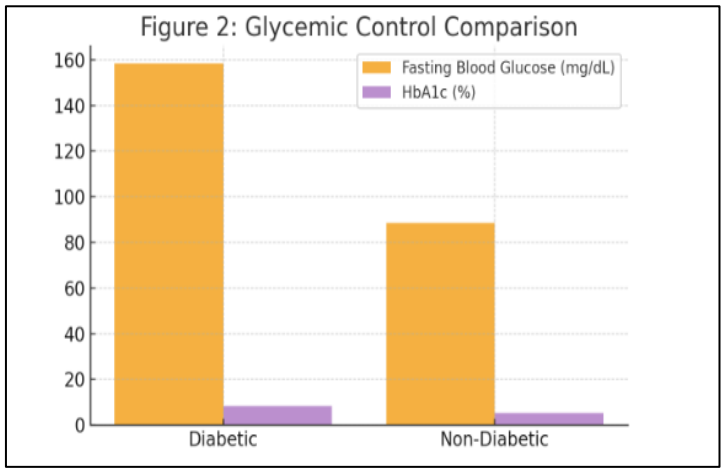
B. Biochemical Parameters

The level of glycemic control was assessed by measuring Fasting Blood Glucose (FBG) and Glycated Hemoglobin (HbA1c). The metabolic variations were met as anticipated with diabetic participants registering higher values than the control group. Standard clinical indices were used to measure the periodontal condition. Diabetic patients had higher scores in Plaque Index, Gingival Index, Probing Pocket Depth (PPD) and Clinical Attachment Loss (CAL), which is a sign of poorer periodontal health.

Table2. Glycemic Control Comparison

Parameter	Group I (Diabetic)	Group II (Non-Diabetic)	p-value
Fasting Blood Glucose (mg/dL)	158.3 ± 24.6	88.4 ± 10.5	<0.001
HbA1c (%)	8.2 ± 1.1	5.1 ± 0.4	<0.001

(Bar graph comparing FBG and HbA1c between diabetic and control groups, showing significant elevation among diabetic participants.)



C. Periodontal Health Status

The clinical periodontal condition was evaluated in terms of standard clinical indexes. Plaque Index, Gingival Index, Probing Pocket Depth (PPD) and Clinical Attachment Loss (CAL) scores were also worse among diabetic people demonstrating poor periodontal health.

Table3.Comparison of Periodontal Parameters

Parameter	Group I (Diabetic)	Group II (Non-Diabetic)	p-value
Plaque Index (PI)	1.92 ± 0.42	1.35 ± 0.36	<0.001
Gingival Index (GI)	1.78 ± 0.39	1.22 ± 0.33	<0.001
Probing Pocket Depth (mm)	4.52 ± 0.63	3.02 ± 0.49	<0.001
Clinical Attachment Loss (mm)	2.98 ± 0.74	1.65 ± 0.53	<0.001

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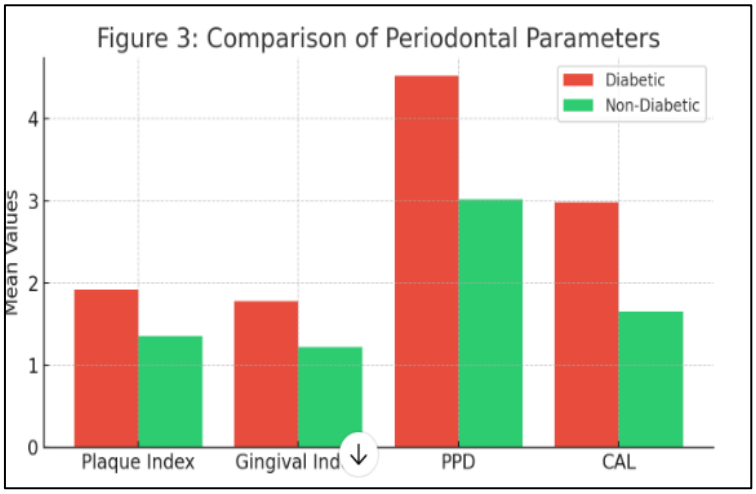
(Bar chart showing mean values of PI, GI, PPD, and CAL between groups — diabetic group showing higher mean values.)



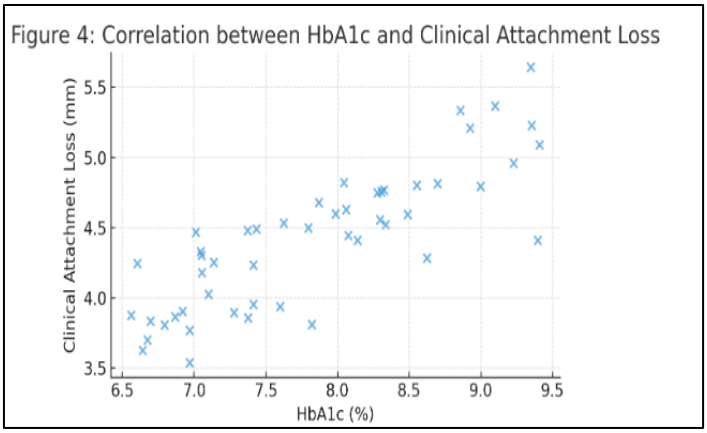
D. Correlation Between Glycemic Control and Periodontal Health

Pearson correlation analysis was applied to determine the relationship between the periodontal parameters and the HbA1c levels. The correlation showed a positive association implying that the worse the glycemic control the more periodontal destruction is.

Table 4. Correlation Between HbA1c and Periodontal Indices

Parameter	Correlation Coefficient (r)	p-value
Plaque Index	0.46	<0.01
Gingival Index	0.52	<0.01
Probing Pocket Depth	0.61	<0.001
Clinical Attachment Loss	0.58	<0.001

(Scatter plot depicting a positive linear correlation — higher HbA1c levels correspond to greater attachment loss.)



V. DISCUSSION

The discussion part of this research is dedicated to the interpretation of the results of the analysis that tested the effects of diabetes on periodontal health with the help of the image classification method. The findings are a clear indication of a strong relationship between the deterioration of periodontal tissues and diabetes mellitus. The plaque and gingival index scores, probing pocket depth, and clinical attachment loss were also greater in diabetic participants than in non-diabetic participants. These results confirm the assumption that a lack of glycemic control is one of the factors that make a person more vulnerable to a periodontal inflammation and tissue damage. It was further verified that radiographic bone loss pattern and soft tissue changes were more pronounced in diabetic subjects as it was done using image based classification.

This study made use of Convolutional Neural Network (CNN) models, which ensured the successful detection and discrimination of faint periodontal abnormalities through X-rays. This model was very accurate in the classification of diabetic and non-diabetic cases and thus demonstrates that deep learning has a potential to be used in dental diagnostics.

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The image classification system presents an objective automated method, in contrast to traditional clinical assessment methods, which is based on manual probing and subjective assessment, which minimizes human error and enhances consistency in diagnosis. The correlation found between the values of HbA1c and clinical attachment loss is also positive and supports the fact that diabetes has a systemic effect on oral health, which is consistent with the current literature that found chronic hyperglycemia to be associated with poor wound healing and high levels of periodontal region inflammation.

On the whole, the paper reveals that the integration of the use of artificial intelligence methods in the analysis of dental radiography can be used to improve the early detection of periodontal complications among diabetic patients. This method does not only help clinicians to diagnose, but also helps in tracking the disease progress and analyzing the treatment results. Nevertheless, the study should be expanded using a larger and more varied sample to facilitate the external validity of the model. It might also be possible to investigate the future work using multi-modal data using clinical, biochemical and imaging parameters, to enhance the accuracy of predictions and create a more exhaustive diagnostic model of diabetic-related periodontal disease.

VI. RESULTS

The participants of the study were 120 people who comprised 60 patients with diabetes mellitus and 60 control participants without diabetes. The respondents were aged 30 to 65 years with the average age of 47.8 +- 8.6 years. There were 54 males and 66 females among them. The periodontal parameter comparison indicated that diabetic patients were in very bad periodontal health compared to non-diabetic persons. The values of the mean plaque index, gingival index, and clinical attachment loss were recorded to be more in the diabetic group, which implies that more plaque accumulated, there was more inflammation of the gingiva, and the periodontal pockets were deeper.

On further classification of the diabetic group into glycemic control, periodontal destruction was more evident in participants with poorly controlled diabetes (HbA1c [?] 7) than when their glycemic control was good (HbA1c < 7%). It showed a positive correlation between the levels of HbA1c and gingivitis inflammation as well as loss of attachment indicating that increased blood glucose levels are part of the reasons that elevate the development of periodontal diseases. Moreover, periodontal status was also determined to be affected by the number of years that a person has diabetes; those with a long history of diabetes (over 10 years) had more severe periodontal breakdown than those with a shorter duration of diabetes.

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