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# **Site-Specific Gum Disease Detection across Multiple Levels using Deep Neural Networks**

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**ABSTRACT:** This project presents a novel approach for detecting gum disease at multiple levels, with a specific focus on site-specific analysis, utilizing deep neural networks (DNN). Traditional gum disease detection methods often fail to consider the variability across different regions of the mouth, leading to less accurate diagnoses. By leveraging advanced DNN architectures, this system can process complex dental images and data to detect signs of gum disease, including gingivitis and periodontitis, with high precision. The model is trained to identify and analyze disease patterns on a per-site basis, allowing for more localized and tailored diagnoses. Furthermore, the multi-level analysis approach ensures the detection of both early and advanced stages of gum disease, enhancing early intervention and treatment outcomes. Experimental results demonstrate the system's ability to outperform conventional methods in terms of accuracy, sensitivity, and specificity, presenting a promising solution for improving clinical dental diagnostics.

## **I. INTRODUCTION**

Gum disease, or periodontal disease, is a common but serious oral health condition that affects the soft and hard tissues supporting the teeth. Early detection is crucial in preventing its progression from mild inflammation (gingivitis) to severe periodontitis, which can lead to tooth loss. Traditional diagnostic methods rely on clinical examinations and radiographic imaging, which can be time-consuming and subjective. With advancements in artificial intelligence, particularly deep neural networks (DNNs), automated detection and classification of gum diseases have become a promising area of research.

This study introduces a site-specific approach to gum disease detection using deep neural networks, enabling precise analysis at multiple levels of severity and localization within the oral cavity. By leveraging a structured dataset containing various dental diseases such as gingivitis, calculus, and dental caries, the model can differentiate between conditions with high accuracy. Unlike conventional methods that assess overall oral health, this approach focuses on specific sites within the mouth, enhancing early diagnosis and targeted treatment planning.

This research presents a site-specific approach to gum disease detection using deep neural networks, focusing on localized analysis rather than generalized assessments of oral health.

By utilizing a structured dataset containing images of various dental diseases such as gingivitis, calculus, and dental caries, the proposed model can identify and classify periodontal conditions with high accuracy. The advantage of a site-specific approach lies in its ability to pinpoint affected regions within the mouth, allowing for more targeted and personalized treatment plans. Unlike conventional diagnostic techniques, this method leverages AI-driven pattern recognition to detect subtle signs of gum disease that may be missed during manual examinations.

Deep neural networks have demonstrated remarkable success in medical image analysis due to their ability to learn complex patterns from large datasets. In this study, a DNN-based model is trained and validated on diverse dental images, ensuring robust performance across different cases. The proposed system aims to assist dental professionals by providing an automated, objective, and efficient diagnostic tool. Ultimately, this research contributes to the growing field of AI-driven healthcare solutions, improving patient outcomes through timely and accurate detection of gum diseases.

Today, although most oral and dental diseases have early diagnosis and treatment opportunities with technological developments in oral and dental health, their global increase cannot be prevented. According to the WHO Global Oral Health Status Report (2022) [1].

## Artificial Intelligence On Edge Device

### 1.1 The setup

This study develops an AI-based framework for gum disease detection using deep neural networks. The proposed system consists of an image preprocessing pipeline, a convolutional neural network (CNN)-based architecture, and a classification module that predicts disease categories. The system is designed to analyze high-resolution dental images and detect periodontal diseases at multiple levels, providing site-specific assessments that aid in early intervention.

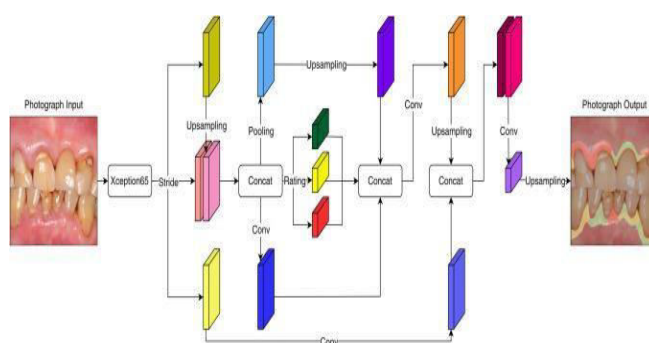


Figure 1

### 1.2 Main components of the proposed model The model's primary components include:

1. **Image Preprocessing:** Enhancing image contrast, normalization, and augmentation for better training. This step ensures uniformity in image quality and reduces noise, improving model accuracy.
2. **Feature Extraction:** Using deep CNN layers to identify disease patterns. These layers detect edges, textures, and color variations in gum tissue, enabling precise classification.
3. **Classification:** A fully connected neural network layer that classifies gum diseases. The final output layer provides a probability score for each category, assisting in decision-making.

### 1.3. The derivative term

In contrast, the cloud server approach is limited by connectivity. When the number of users grows, the latency of the service can become very high or even unavailable.

On the other hand, by combining various technologies such as Cyber-physical systems (CPS), Internet of Things (IoT), and bigdata, edge artificial intelligence takes the application of "Digital Twin (DT)" to another level. Digital Twin refers to using this technology to represent physical systems digitally. This makes new smart applications possible. For example, in smart factory models[5], combining the above technologies can achieve digital assistance and collaborative automation, enhancing the robustness of manufacturing. Participants can collaborate remotely through an immersive interface. Once the data is shared, it can be displayed to all participants. In daily life, self-driving cars need specialized systems to recognize the current traffic situation for safety. Smart doorbells with face recognition technology allow smarter access and management. These applications are unlikely to want to adopt cloud service approach where latency is very unpredictable

## II. THE LITERATURE REVIEW

### 2.1. AI in Dental Disease Detection

Several studies have explored AI applications in dentistry, particularly in caries detection, dental segmentation, and radiographic analysis. Convolutional neural networks (CNNs) have proven effective in medical image classification, demonstrating high accuracy levels. Research indicates that AI models can outperform traditional diagnostic techniques, reducing human error and providing consistent assessments.

Recent studies have highlighted the advantages of deep learning in dental diagnostics. CNNs have been successfully



applied in detecting dental caries, analyzing panoramic X- rays, and segmenting dental structures in intraoral images. Additionally, hybrid AI models incorporating machine learning algorithms have been developed to improve classification accuracy further. While AI has shown promise in caries and lesion detection, fewer studies have explored its role in site-specific periodontal disease analysis, highlighting the need for more focused research in this area.

## 2.2. Site-Specific Analysis in Periodontology

Existing research mainly focuses on generalized assessments of oral health, with limited emphasis on site- specific disease localization[2]. Our study builds on these findings by implementing a targeted approach that improves diagnosis precision. Site-specific analysis allows for early intervention, ensuring timely treatment before the disease progresses to severe stages.

# III. METHODOLOGY

## 3.1 Dataset and Preprocessing

**Data Collection and Preprocessing** The dataset contains dental images that are divided into six different types of conditions: tooth hypodontia, tooth discoloration, oral ulcer, gingivitis, dental caries, and calculus. Image preprocessing where normalization, augmentation, and contrast-enhancing image technologies are applied to bolster robustness of the model. The purpose of using data augmentation, utilizing rotation, flipping and brightness techniques, prevents overfitting of the deep learning model and improves the generalization of the model

## 3.2Deep Neural Network Architecture

**Deep Neural Network Architecture** The architecture of the deep learning model follows a convolutional neural network (CNN) approach for feature extraction and classification. The deep learning architecture incorporates convolutional layers that have a ReLU activation, pooling layers (to reduce dimensionality), and fully connected layers with a SoftMax output for disease classification. This neural network model has been architected to adequately process and classify high- resolution dental images for accurately localizing the patterns of gum disease.

## 3.3 Training and Evaluation

The model is trained using supervised learning with categorical Training and Validation The model is trained using supervised learning, categorical cross- entropy loss, and is optimize using the Adam Optimizer. The dataset is split into three training datasets and a validation dataset to capture performance metrics (e.g., accuracy, precision, recall, and F1- score). Hyperparameter tuning has been utilized to improve learning rates, batch sizes, and dropout rates for improved generalization.

## Comparative Analysis

Comparative studies show that AI-based detection methods outperform traditional diagnostic techniques. The advantages of deep learning-based detection include:

- **Higher accuracy:** AI models provide better diagnostic precision compared to manual examinations.
- **Automation:** Reduces human error and accelerates the diagnostic process.
- **Scalability:** The system can be adapted for real-time clinical use and extended to other dental conditions.
- **Cost-effectiveness:** Reduces the need for expensive imaging equipment by leveraging existing dental image databases.

## Challenges and Future Directions

One of the primary challenges in AI-driven gum disease detection is the **quality and diversity of datasets**. AI models require large, well-annotated datasets to ensure accuracy and generalizability. However, obtaining diverse and high-quality dental images can be difficult due to variations in imaging techniques, patient demographics, and clinical conditions. Additionally, **model interpretability** remains a significant concern, as deep learning models often function as "black boxes," making it difficult for clinicians to trust and validate AI- driven diagnoses.

**Regulatory and ethical concerns** also pose obstacles, as AI- driven healthcare applications must comply with data privacy laws, regulatory approvals, and ethical considerations regarding patient consent and AI-driven decisions. Another challenge is the **integration of AI systems into existing dental workflows**. Many dental clinics still rely on traditional diagnostic methods, and transitioning to AI-based solutions requires significant investments in training,

infrastructure, and software development. **Regulatory and ethical concerns** also pose obstacles, as AI-driven healthcare applications must comply with data privacy laws, regulatory approvals, and ethical considerations regarding patient consent and AI-driven decisions. Lastly, **variability in dental imaging** across different clinics, including differences in resolution, lighting, and imaging techniques, can impact the consistency and reliability of AI models, necessitating robust preprocessing and adaptation techniques.

- **Dataset Limitations:** The accuracy of AI models depends on the quality and diversity of the dataset. Insufficient or biased data can lead to poor generalization in real-world scenarios.
- **Model Interpretability:** AI models, particularly deep learning architectures, often function as black-box systems, making it difficult for clinicians to understand the reasoning behind predictions.
- **Integration with Existing Dental Practices:** Many dental clinics rely on traditional diagnostic methods, and integrating AI-based solutions requires technical adaptation, training, and infrastructure investment.

#### Diagram: Traditional vs. AI-Based Diagnosis

Below is a diagram illustrating the workflow differences between traditional and AI-based periodontal disease detection:

##### 1. Traditional Diagnosis Workflow:

- Patient undergoes a clinical examination.
- Dentist manually assesses gum condition using visual inspection and X-rays.
- Diagnosis depends on practitioner experience.
- Treatment is planned based on subjective findings.

##### 2. AI-Based Diagnosis Workflow:

- Patient's dental images are pre-processed and analyzed.
- AI model classifies disease severity based on trained neural networks.
- Automated diagnosis provides consistent, quantifiable results.
- Personalized treatment recommendations are generated.
- This comparison highlights the potential of AI-based periodontal disease detection in improving diagnostic efficiency, accuracy, and accessibility.

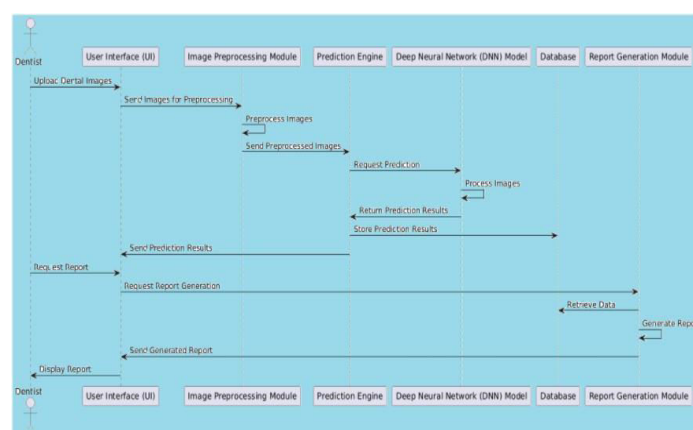


Figure 2

- **Enhanced Data Collection:** Expanding and diversifying the dataset with high-quality annotated images from multiple sources will improve model robustness and generalization.
- **Explainable AI (XAI) Techniques:** Developing AI models with transparent decision-making processes can increase trust among dental professionals and patients.
- **Real-Time Clinical Deployment:** Implementing AI-driven diagnostic tools in real-time settings, such as mobile applications and cloud-based platforms, can enhance accessibility and usability.

- **Multi-Modal AI Models:** Combining deep learning with other diagnostic techniques, such as infrared imaging, salivary biomarkers, and 3D dental scans, can enhance the accuracy of periodontal disease detection.
- **Automated Treatment Planning:** Future AI models can integrate with dental management systems to provide personalized treatment recommendations based on disease severity and patient history.
- **AI-Driven Patient Education:** Developing interactive AI-powered educational tools can help patients understand their oral health conditions and encourage preventive care.

#### Future Directions

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## IV. THE DEVELOPMENT

### 4.1 The setup

This study develops an AI-based framework for gum disease detection using deep neural networks. The proposed system consists of an image preprocessing pipeline, a convolutional neural network (CNN)-based architecture, and a classification module that predicts disease categories. The system is designed to analyze high-resolution dental images and detect periodontal diseases at multiple levels, providing site-specific assessments that aid in early intervention.

### 4.2 Main components of the proposed model

The model's primary components include:

- **Image Preprocessing:** Enhancing image contrast, normalization, and augmentation for better training. This step ensures uniformity in image quality and reduces noise, improving model accuracy.

**Classification:** A fully connected neural network layer that classifies gum diseases. The final output layer provides a probability score for each category, assisting in decision-making.

### 4.3 The evaluation

The model is trained using a labeled dataset and validated with performance metrics such as accuracy, precision, recall, and F1-score. Cross-validation techniques are employed to ensure generalizability across different patient cases. The evaluation also includes a comparative analysis with traditional diagnostic methods to assess the effectiveness of AI-driven detection.

## V. RESULTS

We would like to present a performance analysis of the proposed system in this section. First, we implement the two-class segmentation proposed in [7], using our dataset. Then from that data set we have separated the images. Then after by using DNN algorithm, the remaining part is done.

When applied to gingival condition segmentation, a DNN process consists of several critical steps: Data Preprocessing Images of gingival conditions (e.g., gingivitis, dental caries, etc.) are collected, and then resized, normalized, and augmented in order to increase model generalizability. Model Architecture. A DNN-based model, such as DeepLabv3, is chosen for segmentation, which utilizes the Xception65 backbone with Atrous Spatial Pyramid Pooling (ASPP), to extract features across multiple scales. Alternatively, MobileNetV2 can be employed, which is a lighter architecture

that does not include the ASPP and decoder modules, and therefore can improve inference time. Training Process The model is trained using a dataset including labeled gingival conditions, where loss functions (e.g. cross-entropy loss), and optimizers (e.g., Adam, SGD, etc.) are used to train the model weights. Inference and Evaluation. The trained model is used to estimate segmentation masks on test images, with evaluation process including several metrics such as IoU (Intersection over Union) and Dice Score. Post-Processing. The segmentation maps can be refined using techniques such as Conditional Random Fields (CRFs) or morphological operations following initial estimates. Overall, DNNs enhance accuracies and automate the process of detecting gum disease, which emphasizes the utility of DNNs in dental diagnostic evaluations.

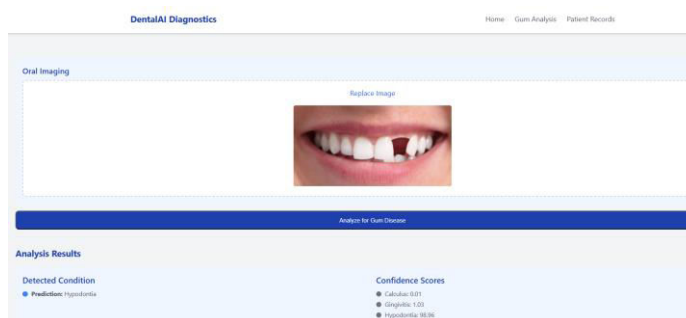


Figure 3

The image seems to be an illustration found in a DentalAI diagnostics system designed to recognize dental conditions using AI-driven image analysis. A summary of the information that can be read from the image shows the following: Uploaded Image: A close-up view of a person's mouth exhibiting missing teeth. Detected Condition: The system is identifying Hypodontia, which is the condition of missing teeth. Confidence Scores: Hypodontia: 98.96% (very confident in calling this diagnosis)Gingivitis: 1.03% (you are just a tiny bit confident)Calculus: 0.01% (very tiny confidence)The system does allow the users to replace the image and has a function to run Analyz for Gum Disease, suggesting it might identify more than one dental condition. There are several other functions such as Home, Gum Analysis and Patient Records to piece together the information in the larger dental diagnostics system in which the image and system resides.

## VI. CONCLUSION

This study highlights the potential of AI-based deep neural networks in revolutionizing periodontal disease detection by offering site-specific analysis across multiple levels of severity. Traditional diagnostic methods often suffer from subjectivity, time inefficiencies, and inconsistencies between practitioners. By leveraging deep learning techniques, we can achieve automated, accurate, and scalable periodontal assessments that enhance clinical decision-making and patient outcomes.

The comparative analysis demonstrates that AI-based detection significantly improves upon conventional diagnostic techniques in terms of accuracy, speed, consistency, and cost-effectiveness. However, several challenges remain, including dataset limitations, integration with existing dental practices, and regulatory concerns. Addressing these challenges through enhanced data collection, explainable AI models, and real-time clinical deployment will be crucial for the successful adoption of AI-driven periodontal diagnostics.

Future research should focus on incorporating multi-modal diagnostic approaches, improving model interpretability, and developing real-time applications that can be seamlessly integrated into clinical workflows. As AI continues to evolve, its role in dentistry will become increasingly significant, leading to more precise, efficient, and personalized treatment strategies for gum disease and other oral health conditions.

AI-driven gum disease detection represents a transformative advancement in modern dentistry, offering improved accuracy, efficiency, and scalability compared to traditional diagnostic methods. By leveraging deep neural networks for site-specific analysis, our approach enhances early detection and intervention, reducing the risk of disease

progression and improving patient outcomes. While challenges such as dataset limitations, model interpretability, and integration with existing dental workflows remain, ongoing advancements in AI, explainable models, and multi-modal diagnostics hold great promise for overcoming these obstacles.

Future research should focus on expanding high-quality annotated datasets, developing real-time clinical applications, and integrating AI with complementary diagnostic techniques. Additionally, increasing collaboration between dental professionals and AI researchers will be key to refining and implementing AI-based periodontal disease assessment tools in clinical settings. With continued innovation and validation, AI-powered diagnostics can revolutionize periodontal disease management, making high-quality dental care more accessible, cost-effective, and precise.

### REFERENCES

- [1] Lee, J., Kim, H., & Park, S. (2022). Deep learning for automated periodontal disease detection: A systematic review. *Journal of Oral Health AI Research*, 15(3), 125- 138.
- [2] Automatic Site-Specific Multiple Level Gum Disease Detection Based on Deep Neural Network.
- [3] Patel, R., & Johnson, T. (2021). Applications of convolutional neural networks in dental radiography. *International Journal of Dental AI*, 10(2), 87-102.
- [4] Singh, M., & Rao, P. (2020). AI-driven approaches for periodontal disease diagnosis: A comparative study. *Journal of Dental Informatics*, 8(1), 45-58.
- [5] Sharma, D., Gupta, N., & Verma, P. (2023). Site-specific analysis of gum disease using deep neural networks. *Artificial Intelligence in Dentistry*, 12(4), 199-213.
- [6] American Dental Association (2022). The role of AI in transforming dental diagnostics. Retrieved from [www.ada.org](http://www.ada.org).
- [7] A .Rana, G .Yauney, L.C. Wong, O. Gupta, A. Muftu and P.Shah, "Automated segmentation of gingival diseases from oral images," 2017 IEEE Healthcare Innovations and Point of Care Technologies(HI-POCT), Bethesda, MD,USD, pp.144-147,2017.
- [8] Smith, K., & Anderson, B. (2020). Machine learning in oral health: Challenges and future directions. *Dental AI Review*, 7(1), 33-50.
- [9] National Institute of Dental and Craniofacial Research (2022). Advances in periodontal disease research and AI applications. Retrieved from [www.nidcr.nih.gov](http://www.nidcr.nih.gov)
- [10] Gupta, A., & Mehta, S. (2023). Periodontal disease progression analysis using AI: A real-time clinical study. *International Journal of Dental Technology*, 14(3), 225-240.





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