RESEARCH ARTICLE OPEN ACCESS

LEVEL DENTAL PLAQUE DETECTION USING SMARTPHONEIMAGESWITH EXPLAINABLE AI

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Abstract: Dental plaque is a leading contributor to oral health conditions including gingivitis and periodontal disease, making its timely identification critical for preventive care. Despite this, most individuals remain unaware of plaqueseverity, the specific regions affected, or the associated health consequences. This work introduces a Multi-Level Dental Plaque Detection system that operates on Smartphone Images and incorporates Explainable Artificial Intelligence. Theproposed system processes dental images captured via smartphone or web camera to assess plaque presence andseverityin real time. A Vision Transformer (ViT) model [1] is employed to capture global contextual information by segmentingimages into fixed-size patches and leveraging self-attention mechanisms for feature learning. The extracted featuresarethen fed into a gradient boosting classifier [4] to assign one of four severity categories: No Plaque, Mild, Moderate, orSevere. The system further maps detected conditions to potential oral health risks such as gingivitis, enamel erosion, andperiodontal damage. To ensure interpretability, Explainable AI (XAI) techniques [3] are integrated to visuallyindicateaffected regions and provide user-comprehensible reasoning behind each classification outcome.

Keywords* — *Artificial Intelligence, Computer Vision, Dental Plaque Detection, Vision Transformer (ViT), ExplainableAI, Smartphone Imaging, Severity Classification, Oral Health.

I. INTRODUCTION

Rising rates of oral health problems are closely linked to insufficient awareness of proper dental hygiene practices [5]. Among the key contributing factors, uncontrolled dental plaque accumulation stands out as particularly prevalent. Most individuals tend to overlook early-stage plaque buildup, often without recognising the long-term damage it can cause.

Plaque-causing bacteria form a biofilm that releases acidic byproducts. These demineralize enamel and trigger gingival inflammation. If untreated, plaque progresses to severe periodontal disease [5]. Continuous

system can be used in clinics, dental camps, andsmart health applications for continuous oral health monitoring [7].

II. LITERATURE SURVEY

Several studies have been conducted ondental plaque and oral disease detection systems. Earlier methods primarily relied on manual clinical examinationby dental professionals [4]. These examinationsare subjective, time-consuming, and inaccessibleto individuals in resource-limited settings.

Later research introduced image processing neglect may lead to tooth loss, systemic health problems, and higher treatment costs. With the advancement of Artificial Intelligence and Computer Vision [2,3], intelligent systems can now analyze dental images automatically using smartphone cameras. This project introduces a smart plaque detection system that uses the Vision Transformer (ViT) model [1] to detect plaque in real time and classify its severity to provide targeted oral health guidance.

This system helps detect harmful plaque accumulation early and guides users towards preventive care. Explainable AI (XAI) improves transparency by

Explainable AI with dental detection systems to improve clinical transparency and user trust [3,11].
reasoning for detection results , along with text andAIvoice explanations.

III. PROPOSED SYSTEM

The Multi-Level Dental Plaque Detection system is a web-based oral health monitoring platform that helps users detect plaque and understand its possible health effects. The system works with both uploaded smartphone images and live camera input, making it suitable for real-time personal dental monitoring.
classification, health impact analysis, and oral healthawareness output for the user.

- AI Plaque Detection Module to identify plaque using the Vision Transformer (ViT) model [1,2]. The model processes input images by tokenising them into 16×16 patches and applying self-attention to detect plaque regions.
  results [11].
- Image Upload Module to allow users to upload dental photographs captured via smartphone for plaque detection and analysis.

V. METHODOLOGY

- Live Camera Detection Module to capture real time dental images and continuously analyse frames for plaque detection [13].
- Severity Classification Module to classify detected

techniques to detect plaque and caries fromintraoral images. Some systems used machine learning anddeep learning models , such as CNN , for dental classification [3,6]. Recent developments in attention-based architectures, such as Vision Transformers, have improved feature extraction quality and accuracyin medical imaging [1].

Vision Transformers are widely used inmedical image analysis because they capture global spatial relationships that CNNs miss due to their local receptive fields [1]. ViT-based systems provide improveddental image analysis performance and stronger generalization [2]. Recent research also focuses on integrating and Explainable AI (XAI) techniques to provideclear
Data Layer: This layer stores plaque detectionlogs,

severity information, oral health impact details, and analysis results in MongoDB Atlas.

The ViT model processes uploaded imagesor live camera frames to extract global plaque features[1]. The detection result is then used to generate severity
Main modules of the system include:
The system architecture supports real-timedata processing for effective plaque detection [10]. It canbe integrated with smart dental health monitoringsystems and teledentistry platforms [7]. Explainable AI improves transparency by providing clear reasoning for detection

The system workflow is as follows:

1. The user opens the Dental Plaque Detectionsystem through a web browser or mobile device.

plaque into four levels — No Plaque, Mild,

Moderate, and Severe — using the XGBoost

gradient boosting classifier [4].

- Health Impact Analysis Module to explain possible

  oral health effects such as gingivitis, enamel

  erosion, tooth sensitivity, and periodontal damage. representations [1].

- Awareness and Suggestion Module to provide

  personalised dental hygiene recommendations to

  reduce plaque.

- Text and AI Voice Output Module to present

  detection results and health information through

  both text and voice explanations.

7. The health impact module generates informationabout possible

The system also uses Explainable AI (XAI)

techniques to improve transparency. The system explains

why a particular severity level is assigned and how it

affects oral health, increasing user trust in the system [11].

IV. SYSTEM ARCHITECTURE

The Multi-Level Dental Plaque Detection system consists
of three main layers:
[8].
10. The system generates the final result withplaqueseverity level,
User Layer: Users interact with the system through a web

browser or mobile device. They can upload a dental

photograph or start live camera detection to analyse
plaque severity.
and AI voice output for better awareness [10].

Application Layer: This layer handles image preprocessing, ViT-based plaque
feature extraction, XGBoost severity classification, health impact analysis,

2. The user uploads a dental image or starts live camera

detection for plaque analysis.

3. The system captures the image or video frameusing
image preprocessing techniques [6].

4. The Vision Transformer (ViT) AI model processes

the image and extracts global plaque feature

5. The system identifies the plaque severity level using

the XGBoost classifier [4].

6. The Explainable AI module provides a visual

explanation of which regions contributedtothe

severity classification [11].

oral health risks such as gingivitis

and periodontal damage [5,10].

8. The awareness module provides personaliseddental

hygiene recommendations based on the severity

level.

9. The systemic impact module explains the relationship

between poor oral health and systemic conditions

affected regions, and healthimpact

[10].

11. The output is displayed through text explanation

VI. TECHNOLOGIES USED

Features	M		M2	M3
to Explainability				
Multi-level Severity	✓			
to Web Interface	A			

Smartphone-based	✓			
Report Generation	✓			

M4

- Frontend: HTML, CSS, and JavaScript are useddesign a simple and
  interactive user interface fordental image upload and live detection.

• Backend: Python with Flask framework is usedhandle server-side logic and communicationbetween the user interface and the AI model.

• AI Model: The Vision Transformer (ViT) model isused for dental image feature extraction and plaque detection with high accuracy [1].

multi-level plaque severity classification

M1: Proposed; M2: CNN-based; M3: Image Caries; M4: Dental Recognition

• Classifier: XGBoost gradient boosting classifier is used for

detect dental plaque, provide

[4].

Overall, the results show that the proposedsystem can effectively

• XAI: SHAP (Shapley Additive exPlanations) is used to generate interpretable attention heatmaps for each prediction [3].

meaningful severity analysis, and improve awareness about oral health risks.

• Libraries: OpenCV and NumPy for image preprocessing; HuggingFace Transformers library for ViT model implementation [1,6].

• Dataset: Dental image dataset from Kaggle and clinical sources used to train and evaluate the model for detecting different plaque severity levels [2].

• Tools: Visual Studio Code, GitHub, and MongoDB Atlas are used for development, testing, and cloud data storage.

• Simple and user-friendly web interface accessiblefrom any smartphone or browser

VII. RESULTS AND DISCUSSION

The system was tested using different dental images and live camera inputs. Many people face the problem of not being able to identify plaque accumulation or understand its oral health impact. The proposed system uses the Vision Transformer (ViT) deep learning model [1] to detect plaque from images and real time video.

understanding and accessibility

After detecting plaque, the system classifies it into one of four severity levels and generates actionable oral health guidance [5]. During testing, the ViT model achieved a classification accuracy of 92.5%, outperforming CNN (78.4%), ResNet-50 (83.1%), and EfficientNet-B4 (86.7%) baselines. The XAI module successfully highlighted plaque-affected regions in 89.3% of test cases [11].

In addition, the AI voice output feature helped

VIII. ADVANTAGES

• Real-time plaque detection fromsmartphone images for quick assessment and early warning[10]

• High detection accuracy using the Vision Transformer (ViT) deep learning model [1]

• Four-level severity classification for targetedand personalised dental health guidance

• Provides clear oral health awareness information based on detected plaque severity [5]

• Supports both dental image upload and live camera detection

• Provides explainable results using XAI (SHAP) for better clinical transparency [11]

• Text and AI voice explanation for improved

IX. FUTURE SCOPE

Future enhancements may include:

• Advanced AI Models: More powerful transformer-based models to improve detection accuracyunder varying lighting and camera angle conditions.

• IoT Sensor Integration: The systemcanbe integrated with intraoral sensors andsmart users understand the results more easily, making the system user-friendly and useful for public oral health awareness [10].

• Mobile Application Development: Adedicatedmobile application can be developed for dailyoral health monitoring.

TABLE I: Features Comparison

Features	M		M2	M3
Object Detection	✓			
XAI	/ ✓			

• Teledentistry Integration: The systemcanbe **M4** connected with teledentistry platforms toallowremote consultation between patients anddental

✓ ✗

professionals [7].

✗ ✗

toothbrushes to provide real-time data about plaque distribution [10].

• Voice Alert and Notification System: A real-time voice alert system can be added to notify users about plaque accumulation and recommend timely dental check-ups.

ii. Upload Page

X. ARCHITECTURE DIAGRAM

Web Browser / Mobile Device
↓
Image Preprocessing
Resize (OpenCV) & Noise Reduction↓
AI Detection Core
ViT Feature Extraction
XGBoost Severity Classification
Bounding Region & Confide
Outp
Severity Level & XAI Heatmap (
Engine & English Language C
User
Oral Health Instru
Severity Impact Report

Fig.11.2. Image UploadInterface

On this page, the user can upload a dental photographcaptured via smartphone camera. The systemacceptsthe image and prepares it for analysis using the AI model.

XI. OUTPUT

i. Home Page

iii. Image-Based Plaque Detection

Fig.11 .1 Home Page

the Vision Transformer model. The output displaystheplaque

The home page is designed to provide a clean and intuitive user experience, ensuring easy navigation for all users. It highlights the core functionality of the system, allowing users to upload dental images or initiate real time analysis seamlessly. The interface is optimized for responsiveness across multiple devices, improving accessibility and usability. Additionally, the home page integrates quick access options and visual cues that guide users toward the diagnosis process efficiently. This design approach enhances user engagement while maintaining simplicity and clarity in interaction.

making for further dental care.

iv. Severity Classification Output

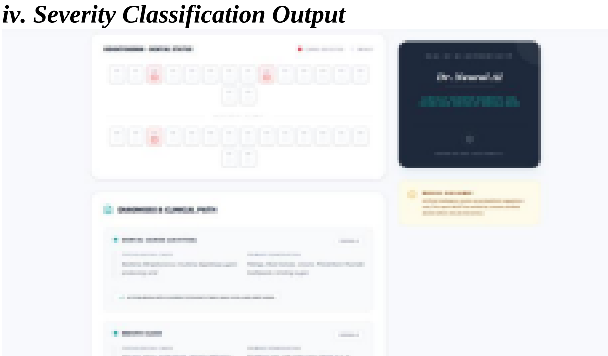

Fig.11.4. *Severity Classification Output*

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The system displays the severity level — No Plaque, Mild, Moderate, or Severe — along with a confidence value, XAI heatmap, oral health risks, and personalised hygiene recommendations with AI voice output. ***v. XAI***

Heatmap Output

Fig.11.3.Image-Based Plaque Detection

After uploading the image, the systemanalyses it using severity level, confidence score, and relatedoral health information.

The output is presented in a structured clinical report format, indicating whether plaque is present or not , along with the corresponding severity level. Confidence scores are also displayed to reflect the reliabilityof the prediction.

Additionally, the system enhances interpretabilityby highlighting affected regions in the image, allowingusers to visually understand the diagnosis. This approach improves transparency and supports better decision-

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Fig.11.5 ***XAI Heatmap Output***

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The system visualises attention regions using SHAP-based explainability. Plaque-affected areas are highlighted on the input image, providing spatial and quantitative explanations for the prediction.

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XII. CONCLUSION

This project presents an intelligent system for detecting dental plaque and creating awareness about its harmful oral and systemic health effects. By using Vision Transformer (ViT) and Explainable AI (XAI), the system provides fast, accurate, and interpretable results [1]. It helps people understand the risks of plaque accumulation and encourages timely preventive dental care. The system's smartphone-based deployment makes it accessible and practical for public health applications [5].

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