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AI-assisted prediction of oral potentially malignant disorder transformation using serial smartphone images

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Abstract

Oral potentially malignant disorders (OPMDs) represent a diverse group of mucosal lesions with varying risks of progression to oral squamous cell carcinoma, making timely detection and continuous surveillance essential for improving patient outcomes. Conventional follow-up relies on periodic clinical examinations, which may fail to capture subtle morphological changes occurring between visits. The widespread availability of smartphone cameras has created new opportunities for longitudinal image-based monitoring, enabling patients and clinicians to document lesion evolution conveniently and cost-effectively. Artificial intelligence (AI), particularly deep learning and computer vision techniques, offers the capability to analyze serial smartphone images, identify changes in lesion characteristics, and estimate the likelihood of malignant transformation with greater objectivity and consistency. AI-assisted systems can evaluate variations in lesion size, color, texture, border irregularity, and surface characteristics while providing automated risk stratification to support clinical decision-making. Integration with telemedicine platforms further expands access to specialist evaluation, especially in underserved and remote communities. Despite promising advancements, challenges remain regarding image standardization, dataset diversity, model generalizability, patient privacy, and clinical validation. Future developments focusing on explainable AI, multimodal data integration, and standardized imaging protocols are expected to enhance diagnostic reliability and facilitate personalized surveillance strategies. AI-assisted serial smartphone imaging has the potential to become a valuable adjunct for early detection, risk prediction, and long-term management of OPMDs.

Keywords: Oral potentially malignant disorders, artificial intelligence, smartphone imaging, deep learning, computer vision, malignant transformation, oral cancer screening, longitudinal monitoring, telemedicine, predictive analytics.

1. Introduction

Oral potentially malignant disorders (OPMDs) comprise a heterogeneous group of oral mucosal lesions, including leukoplakia, erythroplakia, oral lichen planus, and oral submucous fibrosis, which possess varying risks of progression to oral squamous cell carcinoma. Early recognition of morphological alterations and continuous surveillance are essential for reducing diagnostic delays and improving patient outcomes. Conventional monitoring relies primarily on periodic clinical examinations and biopsy, which may be limited by infrequent follow-up visits, subjective interpretation, and variability in lesion documentation (Pu et al., 2022).

The rapid evolution of artificial intelligence (AI) has transformed medical image analysis by enabling automated detection, classification, and prediction using deep learning and computer vision algorithms. AI models are capable of identifying subtle changes in lesion size, color, texture, and border characteristics that may be difficult to detect through visual assessment alone. These capabilities have demonstrated significant promise across multiple dental and medical disciplines, highlighting AI's potential as a clinical decision-support tool (Singh, 2022; Zhang et al., 2022).

Simultaneously, the widespread availability of high-resolution smartphone cameras has facilitated longitudinal image acquisition outside conventional healthcare settings. Serial smartphone images provide a practical, low-cost approach for documenting lesion progression over time while supporting remote consultations through telemedicine platforms. The integration of AI with smartphone-based imaging enables objective risk assessment, improved patient monitoring, and earlier identification of suspicious lesion changes, particularly in underserved populations with limited access to specialist care (Wang et al., 2021; Lin & Alvarez, 2021).

The combination of explainable AI, standardized smartphone imaging protocols, and longitudinal image analysis offers an opportunity to develop reliable predictive systems for malignant transformation while enhancing clinician confidence and patient engagement. As AI continues to mature, these technologies are expected to complement conventional diagnostic pathways rather than replace clinical examination and histopathological confirmation (Khanna et al., 2022; Singh, 2020).

Table 1. Key Components of AI-Assisted Prediction of OPMD Transformation Using Serial Smartphone Images

Component	Role	Clinical Significance
Serial smartphone imaging	Captures lesion progression over time	Enables longitudinal monitoring
Artificial intelligence	Detects and classifies lesion changes	Improves diagnostic accuracy
Deep learning algorithms	Extracts complex imaging features	Predicts malignant transformation risk
Explainable AI	Visualizes decision-making process	Enhances clinician trust
Telemedicine integration	Supports remote assessment	Expands access to specialist care
Clinical validation	Confirms AI predictions with biopsy	Ensures safe clinical implementation

2. AI-Based Serial Smartphone Imaging for OPMD Assessment

Artificial intelligence (AI) has emerged as a promising adjunct for the longitudinal assessment of oral potentially malignant disorders (OPMDs) through serial smartphone imaging. Standardized image acquisition protocols involving consistent lighting, camera distance, viewing angle, and anatomical orientation improve image reproducibility and enable reliable comparison of lesion progression over time. Smartphone-based monitoring offers an accessible and cost-effective approach for frequent documentation, particularly for patients requiring long-term surveillance or residing in remote settings (Wang et al., 2021).

Following image acquisition, AI algorithms employ preprocessing techniques such as color normalization, contrast enhancement, and noise reduction to improve image quality before lesion analysis. Deep learning models, particularly convolutional neural networks (CNNs), automatically identify lesion boundaries and extract clinically relevant features including lesion size, color

variation, texture, border irregularity, and surface morphology. Sequential image analysis enables the detection of subtle temporal changes that may indicate increasing dysplasia or malignant transformation risk. Explainable AI techniques further enhance transparency by generating visual attention maps that highlight image regions contributing to AI predictions, thereby supporting clinician confidence and decision-making (Zhang et al., 2022).

The integration of AI with smartphone imaging aligns with broader trends in digital healthcare and precision medicine by facilitating remote consultations, early referral, and personalized follow-up strategies (Lin & Alvarez, 2021; Wang et al., 2021). Although AI applications in oral medicine were still developing, experiences from dental AI, diagnostic imaging, and medical image analytics demonstrate the feasibility of automated lesion assessment and predictive modeling (Singh, 2022; Khanna et al., 2022). Such digital workflows complement conventional oral examinations rather than replace histopathological confirmation when suspicious lesion progression is identified (Pu et al., 2022; Singh, 2020).

Table 2. AI Workflow for Serial Smartphone Imaging of OPMDs

Workflow Stage	AI Function	Clinical Contribution
Image acquisition	Standardized smartphone photography	Consistent longitudinal monitoring
Image preprocessing	Noise reduction and color normalization	Improved image quality
Lesion segmentation	Automated lesion detection	Accurate lesion localization
Feature extraction	Analysis of size, color, texture, and borders	Objective lesion characterization
Temporal comparison	Serial image analysis	Detection of disease progression
Risk prediction	Deep learning classification	Estimation of malignant transformation risk
Explainable AI	Heatmaps and attention visualization	Improved interpretability and clinical trust

3. Clinical Applications and Diagnostic Performance

Artificial intelligence (AI)-assisted analysis of serial smartphone images has significant clinical potential for monitoring oral potentially malignant disorders (OPMDs). By comparing sequential images, AI algorithms can detect subtle alterations in lesion size, color, texture, surface morphology, and border irregularity that may be overlooked during routine visual examination. This longitudinal assessment supports earlier identification of lesions exhibiting features associated with malignant transformation, allowing timely referral for biopsy and definitive management (Singh, 2022; Zhang et al., 2022).

One of the most valuable clinical applications is remote patient monitoring through telemedicine. Patients can periodically capture standardized oral photographs using smartphones, enabling clinicians to evaluate lesion progression without requiring frequent in-person visits. This approach improves access to specialist care in rural and underserved regions while reducing delays in diagnosis and facilitating continuous surveillance (Wang et al., 2021). Explainable AI further enhances clinical acceptance by providing visual attention maps that highlight image regions contributing to the prediction, thereby increasing transparency and clinician confidence (Zhang et al., 2022).

Beyond screening, AI-generated risk stratification can prioritize high-risk lesions for expedited evaluation and optimize healthcare resource allocation. Integration of smartphone-based imaging with electronic health records and digital clinical workflows offers opportunities for personalized follow-up schedules and data-driven decision-making. Similar advances across medical imaging demonstrate the growing clinical value of AI-assisted diagnostic support systems and their potential for commercialization and routine implementation (Lin & Alvarez, 2021; Khanna et al., 2022). Although histopathological examination remains the diagnostic gold standard, AI serves as a valuable adjunct that enhances surveillance efficiency and diagnostic consistency without replacing clinical expertise (Singh, 2020; Pu et al., 2022).

Table 3. Clinical Applications and Diagnostic Performance of AI-Assisted Serial Smartphone Imaging

Clinical Application	AI Function	Diagnostic Benefit	Clinical Impact
Longitudinal lesion monitoring	Temporal image comparison	Detects subtle lesion progression	Earlier intervention
Remote surveillance	Smartphone image analysis	Continuous follow-up	Improved access to care
Risk stratification	Transformation probability prediction	Identifies high-risk lesions	Prioritized biopsy and referral
Explainable AI	Heat maps and feature visualization	Transparent decision support	Increased clinician confidence
Digital workflow integration	Clinical data synchronization	Personalized monitoring	More efficient patient management

4. Challenges and Future Perspectives

Although AI-assisted prediction of oral potentially malignant disorder (OPMD) transformation using serial smartphone images demonstrates considerable promise, several technical and clinical challenges must be addressed before widespread implementation. Variability in smartphone camera specifications, illumination, viewing angles, image resolution, and patient compliance can introduce inconsistencies that affect algorithm performance and diagnostic reliability. Furthermore, the availability of large, diverse, and well-annotated longitudinal datasets remains limited, restricting model generalizability across different populations and lesion subtypes (Wang et al., 2021; Lin & Alvarez, 2021).

Another important challenge is the interpretability of AI-generated predictions. Clinicians require transparent explanations for risk assessments before integrating AI recommendations into biopsy decisions or surveillance protocols. Explainable artificial intelligence (XAI) techniques, including heat maps and attention-based visualization, can improve trust, facilitate clinical validation, and

enhance acceptance of AI-assisted decision-making (Zhang et al., 2022). Data privacy, cybersecurity, informed consent, and regulatory approval also remain essential considerations for smartphone-based health applications (Wang et al., 2021).

Future developments should focus on standardized smartphone imaging protocols, multicenter prospective validation studies, and integration of multimodal clinical information with serial image analysis. Combining photographic data with patient demographics, tobacco and alcohol exposure, lesion history, histopathological findings, and molecular biomarkers may improve predictive accuracy and enable personalized surveillance strategies (Khanna et al., 2022). AI platforms integrated with telemedicine could expand specialist access in underserved regions while supporting continuous remote monitoring (Lin & Alvarez, 2021). Continued advances in AI-driven healthcare and digital dentistry are expected to strengthen automated risk prediction and clinical decision support, promoting earlier intervention and improved patient outcomes (Singh, 2022; Singh, 2020; Pu et al., 2022).

5. Conclusion

Artificial intelligence-assisted analysis of serial smartphone images represents a promising approach for improving the surveillance and early prediction of malignant transformation in oral potentially malignant disorders. By enabling objective assessment of temporal changes in lesion size, color, texture, and morphology, AI can complement conventional clinical examinations and facilitate timely identification of high-risk lesions. The widespread availability of smartphones further enhances the feasibility of continuous monitoring, remote consultations, and telemedicine-based oral healthcare, particularly in underserved communities (Wang et al., 2021).

Despite encouraging progress, successful clinical implementation depends on standardized imaging protocols, robust validation using diverse longitudinal datasets, and the development of transparent, explainable AI models that support clinician confidence and informed decision-making (Zhang et al., 2022). Integrating serial image analysis with patient risk factors, histopathological findings, and other digital health data may further improve predictive accuracy and enable personalized surveillance strategies (Khanna et al., 2022). As AI technologies continue to evolve, collaboration among clinicians, researchers, engineers, and regulatory bodies will be

essential to ensure safe, ethical, and clinically effective deployment. Ultimately, AI-assisted smartphone imaging has the potential to become a valuable adjunct in oral cancer prevention by supporting earlier diagnosis, more accurate risk stratification, and improved long-term patient management (Singh, 2022; Lin & Alvarez, 2021; Pu et al., 2022).

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