



ISSN: 2230-9926

Available online at <http://www.journalijdr.com>

IJDR

International Journal of Development Research
Vol. 16 Issue, 04, pp. 70285-70293, April, 2026
<https://doi.org/10.37118/ijdr.30810.04.2026>



RESEARCH ARTICLE

OPEN ACCESS

ARTIFICIAL INTELLIGENCE IN ORAL HEALTHCARE: FOCUS ON ORAL MEDICINE AND RADIOLOGY

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ARTICLE INFO

Article History:

Received 14th January, 2026
Received in revised form
28th February, 2026
Accepted 17th March, 2026
Published online 30th April, 2026

Key Words:

Artificial Intelligence in Oral Healthcare:
Focus on Oral Medicine and Radiology.

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ABSTRACT

Artificial Intelligence (AI) has emerged as a transformative technology in dentistry, particularly in the fields of Oral Medicine and Oral and Maxillofacial Radiology, where accurate diagnosis relies heavily on the interpretation of radiographic findings and clinical patterns. In Oral Medicine, AI has been extensively explored for the early detection, classification, and risk assessment of oral cancer and potentially malignant disorders. Advanced computational approaches, including machine learning algorithms, fuzzy logic systems, and probabilistic neural networks, have demonstrated promising results in enhancing diagnostic accuracy and predicting disease progression. In Oral and Maxillofacial Radiology, AI applications encompass automated analysis of panoramic radiographs and cone-beam computed tomography (CBCT) images for the detection of dental caries, periapical pathologies, periodontal bone loss, temporomandibular joint disorders, and maxillofacial fractures. Furthermore, advancements in digital imaging and automated diagnostic systems highlight the expanding role of AI in improving image interpretation, reducing diagnostic errors, and optimizing clinical workflow. This review aims to provide a comprehensive overview of the current applications, benefits, and limitations of AI in Oral Medicine and Radiology, while emphasizing the need for robust validation and ethical implementation. Overall, AI holds significant potential to enhance diagnostic precision, support clinical decision-making, and improve patient outcomes in modern dental practice.

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Citation: Dr. Sindhuja Tamilmani, Dr. Deivanayagi M, Dr. Elamparithi B, Dr. Hemaharini S and Kavi Bharathi S, 2026. "Artificial Intelligence in oral Healthcare: Focus on oral Medicine and Radiology". *International Journal of Development Research*, 16, (04), 70285-70293.

INTRODUCTION

Artificial Intelligence refers to computer-based systems that can perform tasks normally requiring human intelligence, such as learning, reasoning, classifying information, and making decisions^{1,2}. In dentistry, AI research has grown rapidly due to improvements in digital imaging technologies and increased computational capacity. Machine learning and deep learning form the foundation of current AI applications in dentistry. These systems are trained using labeled datasets so they can recognize patterns in radiographic images and clinical data³. Artificial neural networks, convolutional neural networks, and probabilistic models are frequently discussed as effective tools for classification and prediction in dental diagnosis^{4,5}. These computational approaches aim to reduce subjectivity in interpretation and improve consistency in radiographic evaluation. In Oral Medicine, AI has been applied for detecting and assessing the risk of oral cancer and potentially malignant disorders. Oral and Maxillofacial Radiology is a key field for AI integration because it relies heavily on image-based diagnosis. Systematic studies indicate that AI algorithms can assist in interpreting panoramic radiographs

and CBCT images for identifying periapical lesions, bone loss, impacted teeth, and other maxillofacial conditions^{6,7}. Digital radiography systems combined with automated tooth identification algorithms further enhance efficiency and diagnostic precision^{8,9}. Overall, AI serves as a supportive diagnostic tool that enhances — rather than replaces — professional expertise in Oral Medicine and Radiology.

Principles of Artificial Intelligence: Artificial Intelligence is built on computational frameworks that simulate human reasoning and decision-making processes. These systems analyze input data, identify patterns, and generate predictive outputs using structured algorithms¹⁰. Instead of following fixed rule-based programming, AI systems learn from data and improve over time. Core principles include classification, probabilistic reasoning, and adaptive learning models that enhance performance as new data become available¹⁰.

Machine Learning (ML) is a major functional component of AI in dental sciences. It involves training algorithms using labeled datasets to perform prediction and classification tasks. In dental radiography, ML systems are trained to identify anatomical landmarks, detect

pathological lesions, and distinguish between normal and abnormal structures⁸. These models use both supervised and unsupervised learning techniques to improve diagnostic reliability and minimize observer-related variability. Continuous training and validation help improve accuracy across different imaging modalities.

Representation learning is an important advancement within machine learning. It allows systems to automatically extract meaningful features directly from raw data, instead of relying on manually defined diagnostic characteristics⁹. This increases adaptability and reduces dependence on manually engineered features. In dental imaging, representation learning enables automatic recognition of structural variations and radiographic patterns that may be difficult to quantify using traditional methods.

Deep Learning (DL), a specialized area within machine learning, uses multilayer neural network structures to process complex and high-dimensional image data. Convolutional Neural Networks (CNNs) are commonly used in dental radiography because they can extract layered image features effectively⁹. Deep learning models can analyze panoramic radiographs and three-dimensional scans by learning spatial and structural patterns automatically. When combined with probabilistic reasoning models described in AI-based diagnostic systems¹⁰, deep learning provides a strong foundation for advanced image-based diagnosis in Oral Medicine and Radiology.

Applications of Artificial Intelligence in Dentistry: Artificial Intelligence has expanded into many areas of dentistry and has influenced diagnosis, research methods, and clinical decision-making. Structured guidelines have been suggested to improve how AI-based studies are designed, validated, and reported in dentomaxillofacial radiology¹¹. These guidelines stress the importance of transparency, reproducibility, standardized datasets, and clear performance measures to maintain scientific quality in AI research. One major application of AI is in clinical decision-support systems that combine computer-based modeling with clinical reasoning. Bayesian analysis methods have been studied to compare treatment effectiveness and assist in organized treatment planning¹². These systems combine clinical findings, radiographic data, and probability models to help dentists make evidence-based decisions. AI is also used for predictive analysis and risk assessment. By studying structured clinical datasets, AI systems can predict treatment outcomes, estimate disease progression, and help create personalized treatment plans¹². These approaches improve clinical efficiency and support individualized patient care. Research also emphasizes that ethical standards and methodological quality must be maintained when implementing AI in dental practice¹¹. AI is not limited to automation; it is integrated into diagnostic systems and research frameworks. Therefore, AI in dentistry represents a broad advancement that improves analytical accuracy, clinical support, and structured research development.

Techniques of Artificial Intelligence Applied in Oral Medicine and Radiology: Artificial Intelligence in Oral Medicine and Radiology incorporates multiple computational methodologies that enhance diagnostic precision, predictive analytics, and radiographic interpretation. The following twelve techniques play a crucial role in clinical implementation:

1. Clinical Decision Support Systems (CDSS)
2. Artificial Neural Networks (ANN)
3. Principal Component Analysis (PCA)
4. Data Mining Techniques
5. Fuzzy Logic
6. Belief Merging Techniques
7. Genetic Algorithms
8. Probabilistic Neural Networks (PNN)
9. General Regression Neural Networks (GRNN)
10. Dynamic Bayesian Networks
11. Atlas-Based Techniques
12. Machine Learning and Deep Learning

Clinical Decision Support Systems (CDSS): Clinical Decision Support Systems (CDSS) are computer-based tools designed to assist clinicians in diagnostic and therapeutic decision-making. In Oral Medicine and Radiology, CDSS integrate patient history, clinical findings, radiographic features, and laboratory parameters to generate diagnostic suggestions or risk assessments. These systems rely on rule-based algorithms, probabilistic reasoning models, and machine learning frameworks to improve diagnostic consistency^{1,11}. In oral oncology and potentially malignant disorders, CDSS can aid in risk stratification by analyzing lesion characteristics such as size, surface texture, induration, and radiographic bone involvement. By standardizing diagnostic reasoning, CDSS reduce subjective variability and enhance evidence-based decision-making. However, their reliability depends on quality data input and continuous updating of knowledge databases¹³.

Artificial Neural Networks (ANN): Artificial Neural Networks (ANNs) are computational models inspired by biological neural systems¹⁴. They consist of interconnected layers (input, hidden, output) that process complex nonlinear relationships between variables. In Oral Medicine, ANNs are widely used for predicting disease progression, implant success, and endodontic working length determination¹². ANNs are particularly advantageous in multifactorial diseases such as periodontal disease and temporomandibular joint disorders, where multiple clinical and radiographic variables interact simultaneously. Their ability to model nonlinear associations provides improved predictive accuracy compared to traditional statistical methods. However, ANN models require large datasets and careful validation to prevent overfitting¹⁵.

Principal Component Analysis (PCA): Principal Component Analysis (PCA) is a dimensionality reduction technique used to simplify complex datasets while retaining significant variance. In dental radiology, PCA is applied to reduce high-dimensional radiographic features into principal components that represent essential diagnostic patterns¹⁶.

For example, in CBCT-based lesion analysis, PCA can extract dominant structural variations that differentiate cysts from tumors. By minimizing redundant variables, PCA improves computational efficiency and enhances the performance of subsequent machine learning classifiers. However, interpretation of principal components may sometimes lack clinical intuitiveness.

Data Mining Techniques: Data mining involves extracting meaningful patterns and correlations from large datasets¹¹. In Oral Medicine, data mining techniques are used to analyze electronic health records, radiographic databases, and epidemiological data to identify disease trends and risk factors. Association rule mining and clustering algorithms help identify relationships between habits (e.g., tobacco use) and lesion development. These techniques are valuable in public health surveillance and preventive dentistry. However, data mining outcomes depend on data quality, completeness, and ethical data handling protocols¹³.

Fuzzy Logic: Fuzzy logic handles uncertainty by assigning degrees of probability rather than binary classification³. In oral lesion diagnosis, where features overlap between benign and malignant conditions, fuzzy logic provides flexible decision boundaries. This improves classification accuracy in ambiguous radiographic presentations. Fuzzy logic is a reasoning technique that handles uncertainty and imprecision in clinical decision-making. Unlike binary logic (true/false), fuzzy logic operates on degrees of truth, making it highly suitable for oral medicine where lesion characteristics are often subjective. In diagnosing oral potentially malignant disorders, lesion features such as "mild," "moderate," or "severe" dysplasia can be represented using fuzzy membership functions. This allows more realistic modeling of clinical scenarios. Fuzzy systems enhance interpretability but require carefully defined membership criteria to avoid ambiguity.

Belief Merging Techniques: Belief merging techniques combine information from multiple sources to generate a unified diagnostic conclusion. In Oral Radiology, this may involve integrating clinical findings, radiographic interpretation, and histopathological data. These techniques are particularly useful in cases where conflicting information exists, such as differentiating inflammatory from neoplastic lesions. By merging probabilistic beliefs, these systems enhance diagnostic robustness. However, algorithm complexity and computational requirements can be limiting factors.

Genetic Algorithms: Genetic Algorithms (GA) are optimization techniques inspired by natural selection. They iteratively evolve solutions through processes such as selection, crossover, and mutation. In Oral and Maxillofacial Radiology, GA can optimize image segmentation parameters and improve feature selection for lesion detection. They are also used in implant planning to determine optimal implant positioning based on bone density and anatomical constraints². Although powerful, GA may require extensive computational resources and parameter tuning. Genetic algorithms apply evolutionary computation strategies to optimize classification systems¹⁵. These algorithms iteratively refine predictive models by selecting high-performance outputs. In CBCT segmentation and anomaly detection, genetic algorithms improve precision and reduce computational errors.

Probabilistic Neural Networks (PNN): Probabilistic Neural Networks (PNN) are supervised learning models based on Bayesian classification principles. Their advantage lies in fast training speed and strong performance in pattern recognition tasks. In oral radiographic analysis, PNNs assist in lesion classification based on extracted imaging features. However, their performance depends on the quality and representativeness of training datasets. Probabilistic Neural Networks classify data based on statistical probability distributions³. They are effective in oral lesion differentiation and radiographic classification tasks, providing rapid and reliable predictions.

General Regression Neural Networks (GRNN): General Regression Neural Networks (GRNN) are specialized ANN models used for continuous variable prediction. In dentistry, GRNN models are applied to predict treatment outcomes, implant survival rates, and disease progression probabilities¹². GRNNs are advantageous because they require less iterative training compared to traditional ANNs. They provide smooth function approximation and are useful in regression-based predictive modeling. However, they may struggle with very large datasets. GRNN models are used for predictive modeling and outcome estimation¹². In Oral Medicine, they assist in predicting disease progression and evaluating therapeutic effectiveness.

Dynamic Bayesian Networks: Dynamic Bayesian Networks extend traditional Bayesian models by incorporating temporal relationships. In Oral Medicine, DBNs are useful for modeling disease progression over time. For example, in temporomandibular joint disorders or periodontal disease progression, DBNs integrate sequential clinical and radiographic data to predict future disease states¹⁷. These models provide probabilistic reasoning and are clinically interpretable. However, they require accurate prior probabilities and longitudinal datasets. Dynamic Bayesian Networks model temporal relationships and probabilistic dependencies¹². These systems are useful in tracking disease progression and monitoring post-treatment radiographic changes.

Atlas-Based Techniques: Atlas-based techniques involve comparing patient imaging data with a predefined anatomical reference model (atlas). In CBCT imaging, atlas-based segmentation assists in identifying anatomical landmarks such as mandibular canals and sinus boundaries¹⁵. These techniques improve accuracy in implant planning and surgical navigation. However, anatomical variability among populations may limit atlas generalizability, requiring population-specific atlases. Atlas-based techniques compare patient imaging datasets with standardized anatomical templates¹⁵. This

improves segmentation accuracy in CBCT datasets and enhances identification of anatomical landmarks critical for implant planning and surgical navigation.

Machine Learning and Deep Learning: Machine Learning (ML) and Deep Learning (DL) represent the most advanced AI techniques in Oral Medicine and Radiology^{1,16}. ML includes algorithms such as decision trees and support vector machines used for risk prediction and classification². DL, particularly Convolutional Neural Networks (CNNs), automatically extract imaging features and perform lesion detection, segmentation, and classification. Deep learning models have demonstrated high accuracy in detecting periapical lesions, periodontal bone loss, cysts, fractures, and oral malignancies^{10,18}. Despite high performance, these models require large annotated datasets and careful external validation to ensure reliability. Machine Learning and Deep Learning frameworks automate image classification, segmentation, and reconstruction processes^{3,15}. Deep learning models such as convolutional neural networks extract hierarchical features from panoramic and CBCT images, improving detection of cysts, tumors, fractures, and inflammatory conditions.

Artificial Intelligence in Oral Medicine and Radiology: Artificial Intelligence has emerged as a transformative tool in Oral Medicine and Radiology due to its ability to process large volumes of digital imaging data with high precision. AI systems, particularly Convolutional Neural Networks (CNN), Deep Neural Networks (DNN), and Artificial Neural Networks (ANN), are capable of analysing intraoral periapical radiographs, panoramic radiographs, and CBCT images for detection of caries, periapical pathology, cystic lesions, tumours, and periodontal bone loss¹⁶. These models operate by extracting multiple layers of image features, beginning from basic pixel intensity patterns to complex structural representations, enabling automated classification and segmentation. Deep learning-based radiographic analysis has demonstrated diagnostic performance comparable to experienced clinicians in detecting periapical radiolucencies on panoramic radiographs¹⁸. This is particularly significant in reducing inter-observer variability and improving consistency in diagnostic reporting. AI algorithms also assist in automated tooth numbering, anatomical landmark identification, and lesion boundary delineation, thereby enhancing workflow efficiency in radiology departments¹⁶. In CBCT imaging, AI-driven segmentation models enable three-dimensional reconstruction of anatomical structures, facilitating more precise localisation of impacted teeth, cysts, and bone defects. These systems reduce interpretation time and improve reproducibility of measurements. However, variability in image acquisition protocols and dataset heterogeneity may influence algorithm performance, necessitating external validation across diverse populations¹⁵. Although AI demonstrates high sensitivity and specificity in image-based detection tasks, it remains a decision-support tool rather than a substitute for clinical judgment. Ethical concerns, data privacy issues, and medico-legal accountability must be carefully addressed prior to routine integration into clinical practice¹³. Future directions involve multimodal AI systems integrating radiographic findings with electronic health records to enhance predictive modelling and personalised treatment planning¹⁴.

Oral Medicine and Radiology are particularly suitable for AI integration because they depend heavily on image-based diagnosis. AI-driven segmentation models such as U-Net and CNN architectures allow automated identification of radiolucent and radiopaque lesions on panoramic radiographs and CBCT scans^{18,15}. The precision of such systems is enhanced by advanced feature extraction and contrast optimization techniques¹⁶. Studies show that AI can match or exceed junior clinicians in detecting caries and periapical pathologies¹⁰. Endres et al. reported that their deep learning model outperformed 14 out of 24 oral surgeons in detecting periapical lesions¹⁸. This demonstrates AI's potential as a training adjunct in academic settings. Furthermore, AI enhances three-dimensional CBCT analysis. Automated detection of anatomical landmarks and lesion boundaries improves surgical planning and risk assessment¹⁵. Bayesian belief network analysis has also been applied to temporomandibular joint

evaluation using MRI data¹⁷, demonstrating AI's adaptability across imaging modalities. However, heterogeneity in imaging protocols and limited multicenter validation remain challenges¹⁵. Standardized reporting frameworks and transparent algorithm training are essential for reliable clinical integration¹¹.

Applications of Artificial Intelligence in Diagnosing Oral

Conditions: Artificial Intelligence in oral diagnosis is mainly based on machine learning algorithms that identify complex patterns in radiographic and clinical data. Since the early concepts of AI were introduced and machine learning developed further¹¹, these systems have moved from theoretical models to practical clinical tools. In dentistry, AI models are trained using large, labeled datasets from panoramic radiographs, CBCT scans, and intraoral images to detect caries, periapical lesions, cysts, and bone changes^{1,19}. Convolutional Neural Networks (CNNs) are especially useful because they automatically extract layered image features without requiring manual feature selection¹⁶. AI-based diagnosis usually involves two main stages: training and validation¹⁶. During training, the algorithm learns from labeled examples and adjusts its internal parameters to reduce classification errors. During validation, the trained model is tested on new images to measure sensitivity, specificity, F1-score, and overall accuracy. Endres et al. showed that deep learning models had strong agreement with experienced clinicians in detecting periapical lesions¹⁸. Similarly, Lee et al. demonstrated that CNN models could predict periodontal prognosis accurately from radiographs¹⁰. These findings support AI's role in improving diagnostic structure. AI also reduces variation between observers, which is a common issue in radiographic interpretation. Different clinicians may interpret images differently, leading to inconsistent diagnoses. AI provides standardized outputs, improving consistency and reproducibility¹⁵. However, proper external validation and transparency in methodology are essential before routine implementation¹⁵. Beyond detection, AI also supports predictive modeling. Decision trees², Bayesian networks¹⁷, and artificial neural networks¹² combine imaging findings with patient risk factors to predict disease progression. For example, implant success prediction models using W-J48 decision trees showed high specificity and accuracy². Thus, AI moves from passive detection toward proactive risk prediction. Despite these benefits, ethical issues, dataset bias, and validation limitations must be addressed before widespread adoption^{13,15}. AI should be viewed as a decision-support tool rather than a replacement for clinician expertise.

Oral Malignancies and Cervical Lymph Node Metastasis: AI applications in oral oncology focus on early detection, classification, and prognostic prediction of malignant lesions. Machine learning frameworks analyse radiographic patterns such as cortical bone destruction, irregular tumour margins, and radiographic heterogeneity to distinguish malignant from benign lesions¹⁶. These systems are trained using labelled datasets, allowing them to recognise subtle morphological differences associated with malignant transformation. Predictive modelling techniques described in AI frameworks enable probabilistic classification and risk estimation¹¹. Such models can be applied to evaluate the likelihood of cervical lymph node metastasis by integrating radiographic nodal characteristics with clinical parameters. Automated segmentation of lymph nodes on advanced imaging improves staging accuracy and supports therapeutic planning. AI also enhances histopathological analysis by identifying cellular atypia, abnormal mitotic activity, and dysplastic features in digitised slides¹⁶. Neural network-based evaluation reduces subjectivity and enhances reproducibility in grading epithelial dysplasia. The integration of clinical risk factors such as tobacco exposure into AI-based predictive algorithms further strengthens malignancy risk stratification¹⁴. Despite promising results, implementation in oncology requires rigorous validation, as false positives or negatives may have serious clinical consequences. Concerns regarding algorithm bias, transparency, and ethical accountability are highlighted as critical barriers in high-stakes diagnostic applications¹³. Continuous refinement and large-scale validation studies are necessary before AI systems can be fully integrated into oncologic practice¹⁵.

AI enhances early detection of oral malignancies through automated lesion segmentation and pattern recognition^{19,16}. Deep learning algorithms identify cortical bone destruction and irregular tumor margins on radiographs¹⁵. Predictive modeling assists in evaluating cervical lymph node metastasis using radiographic and clinical features¹⁷. Early identification significantly improves staging accuracy and prognosis. However, ethical and medico-legal concerns regarding cancer diagnosis require stringent validation¹³. AI systems have demonstrated significant potential in early detection and classification of oral malignancies. Structured diagnostic models emphasize lesion pattern recognition and standardized reporting in oncologic imaging¹¹. Advanced imaging analytics have been applied for evaluating tumor margins and cervical lymph node involvement¹⁵. AI-driven analytical tools further support pathological interpretation and predictive modeling in malignant lesions²². These systems enhance early detection strategies and assist in staging and treatment planning.

Red, White, and Vesiculobullous lesions of the oral cavity: Artificial Intelligence has been explored as a diagnostic support tool in chronic inflammatory and autoimmune oral mucosal disorders, particularly those characterized by recurrent ulceration, mucosal erosions, and vesiculobullous presentations⁵. These conditions—including recurrent aphthous stomatitis, oral lichen planus, pemphigus vulgaris, and bullous pemphigoid—often present with overlapping clinical manifestations, making differential diagnosis challenging. AI-based computational models assist in pattern recognition by analyzing lesion morphology, distribution, recurrence patterns, and associated clinical parameters⁵. Through structured data integration, these systems aim to improve diagnostic consistency and reduce misclassification. In recurrent aphthous stomatitis, AI models assist in identifying clinical patterns based on ulcer size, location, recurrence frequency, and associated systemic factors⁵. Automated classification systems enhance differentiation between minor, major, and herpetiform variants by evaluating morphological characteristics. By incorporating patient history and lesion parameters, AI-driven diagnostic support systems improve early recognition and guide therapeutic planning. For Oral Lichen Planus (OLP), AI-based analytical systems focus on recognizing reticular, erosive, atrophic, and plaque-like variants through structured image analysis and clinical data modeling⁵. These computational systems assist in identifying potentially malignant transformation risk indicators by evaluating lesion persistence, surface changes, and clinical progression. Such applications enhance monitoring protocols and support early biopsy decision-making. In autoimmune blistering diseases such as pemphigus vulgaris and bullous pemphigoid, AI frameworks analyze vesiculobullous patterns, mucosal fragility, and lesion distribution to assist in diagnostic differentiation⁵. By integrating clinical presentation with structured pattern recognition models, AI reduces diagnostic ambiguity between immune-mediated blistering conditions and other ulcerative disorders. Similarly, in psoriasis with oral manifestations, AI systems support identification of characteristic mucosal involvement patterns and correlate them with systemic disease features⁵. These developments indicate that AI has potential not only in image-based detection but also in structured clinical reasoning within oral medicine.

Red and white lesions of the oral cavity present diagnostic complexity due to overlapping clinical appearances and variable malignant potential. AI-based image recognition systems utilise deep learning architectures to evaluate lesion colour distribution, surface texture, border irregularity, and internal structural variation¹⁶. Through layered convolutional processing, these systems extract discriminative features that assist in classification into benign, inflammatory, or potentially malignant categories. Machine learning algorithms trained on large datasets improve classification accuracy by identifying patterns not readily perceptible to the human eye¹⁴. Integration of clinical variables such as habit history and systemic conditions enhances predictive modelling and supports risk-based stratification. AI-driven diagnostic support may assist in early biopsy decision-making, particularly in screening settings. Automated analysis reduces diagnostic delay and minimises subjective variability between

clinicians¹⁶. However, performance depends heavily on dataset quality and image standardisation. Variability in lighting conditions, image resolution, and clinical presentation may affect reliability¹⁵. Furthermore, as emphasised in AI ethical discussions, over-reliance on automated outputs without adequate clinical correlation may lead to diagnostic errors¹³. Therefore, AI systems should function as adjunctive tools under professional supervision. Future developments may include portable AI-based screening platforms capable of analysing intraoral images in real-time, thereby improving early detection rates in high-risk populations¹⁴.

Periodontal Disease: AI-based diagnostic systems in periodontics focus on radiographic bone level assessment and disease progression analysis. Structured evaluation frameworks emphasize reproducibility and diagnostic accuracy in periodontal image analysis¹¹. Computational models assist in identifying bone loss patterns and classifying periodontal severity¹⁶. Periodontal disease diagnosis relies heavily on radiographic bone level analysis. CNN models can quantify alveolar bone loss patterns with high reproducibility¹⁰. This enhances early detection of periodontitis. Bayesian network models evaluate multifactorial risk factors such as smoking and diabetes¹⁷. AI thus supports personalized periodontal management. Longitudinal radiographic comparison allows AI to monitor disease progression objectively¹⁵. However, algorithm generalizability across diverse populations must be validated. Probabilistic reasoning approaches further enhance clinical decision-making in periodontal management¹⁰. Radiographic analytical systems have also been explored for quantifying alveolar bone changes and predicting disease outcomes¹³.

Maxillary Sinus Conditions: Artificial Intelligence (AI) has demonstrated promising applications in the detection and evaluation of maxillary sinus pathologies on panoramic radiographs and CBCT imaging. Deep learning algorithms, particularly Convolutional Neural Networks (CNNs), are capable of identifying mucosal thickening, sinusitis, retention cysts, and opacification patterns with high diagnostic sensitivity^{15,16}. Because maxillary sinus abnormalities are often detected incidentally during routine dental imaging, automated AI-based screening systems enhance early identification and reduce oversight errors. Studies in dentomaxillofacial radiology emphasize that AI-based segmentation improves delineation of sinus boundaries and pathological changes, particularly in CBCT datasets where volumetric analysis is required¹⁵. In addition to detection, AI assists in quantitative assessment of sinus pathology. Algorithms can measure mucosal thickness and volumetric changes, which are clinically relevant in implant planning and sinus lift procedures. Machine learning frameworks trained on large radiographic datasets improve diagnostic consistency and reduce subjectivity among clinicians^{11,16}. This is particularly important because interpretation of sinus pathology may vary depending on radiographic quality and examiner experience. However, limitations include variability in CBCT imaging protocols and insufficient multicenter validation studies¹⁵. AI models must be trained on diverse datasets to ensure generalizability. With further refinement, AI has the potential to become a standardized adjunct tool in sinus pathology evaluation.

Salivary Gland Diseases: AI applications in salivary gland disease primarily focus on differentiating inflammatory conditions from benign and malignant neoplasms using imaging analysis. Convolutional neural networks can analyze radiographic and CBCT features such as gland enlargement, calcifications, and architectural distortion¹⁶. By extracting high-dimensional imaging features, AI enhances diagnostic precision and reduces subjective variability. Machine learning models also integrate clinical variables such as age, symptom duration, and xerostomia to improve differential diagnosis¹². For example, predictive models may assist in distinguishing sialolithiasis from neoplastic lesions based on radiographic density patterns and gland morphology. However, limited large-scale datasets specific to salivary gland pathology restrict algorithm training and validation¹⁵. Ethical considerations and biopsy confirmation remain essential before clinical decision-making. With expanded datasets, AI may significantly improve non-invasive salivary gland diagnostics.

Temporomandibular Joint Disorders: AI has been applied to MRI and CBCT evaluation of temporomandibular joint disorders (TMD). Bayesian belief networks and deep learning systems demonstrate high accuracy in detecting condylar displacement, disc dislocation, and degenerative joint changes¹⁷. Automated segmentation algorithms quantify joint space alterations and morphological variations in the condyle. Moayeri et al. reported that Bayesian network models achieved high diagnostic accuracy in detecting TMJ bone displacement, supporting AI's role in complex joint evaluation¹⁷. AI improves consistency in MRI interpretation, which is often examiner-dependent. Nevertheless, AI-based TMJ evaluation requires standardized imaging protocols and robust validation studies¹⁵. AI serves as a supportive adjunct to clinical examination and functional assessment rather than replacing clinical judgment.

Application of Artificial Intelligence in Dental Radiology: Artificial Intelligence has emerged as a pivotal advancement in dental radiology by improving image interpretation, lesion detection, and workflow optimization. Dental radiology relies heavily on subjective visual assessment, which may lead to diagnostic inconsistencies. AI-based radiographic systems utilize deep learning architectures—particularly CNNs and U-Net models—to automatically detect and classify pathologies such as dental caries, periapical lesions, periodontal bone defects, cysts, tumors, and fractures^{10,16}. These models are trained on annotated datasets and validated using performance metrics such as sensitivity, specificity, and F1-score. One of the major contributions of AI in dental radiology is automated lesion segmentation. AI algorithms can outline lesion boundaries and quantify radiolucent or radiopaque areas, improving objectivity in diagnosis¹⁵. Lee et al. reported that CNN-based models demonstrated strong performance in periodontal bone loss assessment¹⁰. Similarly, deep learning systems have shown high agreement with clinicians in detecting apical periodontitis¹⁸. This reduces diagnostic variability and enhances reproducibility across practitioners. AI also improves efficiency within radiology workflows. Automated preprocessing techniques enhance image contrast, reduce artifacts, and assist in anatomical landmark detection¹⁶. In CBCT imaging, AI facilitates three-dimensional reconstruction and identification of anatomical risk structures, thereby supporting surgical and implant planning¹⁵. Bayesian belief networks have also been applied in TMJ imaging analysis, demonstrating AI's versatility in advanced radiographic modalities¹⁷. However, despite significant advancements, challenges remain in algorithm generalizability, dataset bias, and ethical validation^{13,15}. Multicenter studies and standardized reporting guidelines are required to ensure reliable clinical implementation. Importantly, AI does not replace the radiologist but serves as an adjunct tool that enhances diagnostic confidence and decision-making accuracy. In conclusion, AI in dental radiology represents a paradigm shift from subjective image interpretation to data-driven, standardized, and predictive diagnostic systems, improving both clinical outcomes and workflow efficiency. The following shows role of AI in Dental radiology.

Image Analysis and Processing: AI-based image analysis involves automated enhancement, filtering, and feature extraction from dental radiographs^{2,17}. Machine learning and deep learning models process high-dimensional image data to identify anatomical landmarks and pathological variations⁹. Computational frameworks improve diagnostic reliability by reducing noise and enhancing image clarity¹².

Automated Detection of Dental Anomalies: AI algorithms are designed to automatically detect anomalies such as caries, periapical lesions, impacted teeth, and bone defects^{17,12}. These systems analyze radiographic patterns and classify abnormalities with high sensitivity. Automated detection reduces clinician workload and enhances early intervention strategies².

Diagnosis and Classification of Dental Conditions: Deep learning models enable classification of dental conditions through hierarchical feature extraction⁹. Bayesian and probabilistic models support structured diagnostic reasoning and comparative effectiveness

analysis. AI-based classification improves differentiation between normal anatomical variations and pathological findings².

Image Segmentation and Reconstruction: Segmentation techniques allow precise delineation of anatomical structures within radiographic datasets⁹. AI-driven reconstruction methods enhance three-dimensional imaging interpretation, particularly in CBCT datasets¹⁷. These systems assist in treatment planning by accurately identifying lesion boundaries and anatomical landmarks².

Radiation and Dose Reduction: AI contributes to radiation dose optimization by enhancing image quality even with reduced exposure parameters¹⁷. Computational enhancement algorithms compensate for lower radiation intensity, maintaining diagnostic clarity⁹. Such advancements align with radiation safety principles while preserving image accuracy^{2,12}.

Artificial intelligence in Imaging Modalities of Dental Disease Diagnosis: Artificial Intelligence (AI) has significantly transformed imaging-based dental diagnostics by enhancing the interpretation of two-dimensional and three-dimensional imaging modalities. Modern dental imaging—including intraoral periapical radiographs (IOPA), bitewing radiographs, panoramic radiographs (OPG), cone-beam computed tomography (CBCT), and magnetic resonance imaging (MRI)—generates large volumes of data that require precise interpretation. AI systems, particularly machine learning (ML) and deep learning (DL) models, are capable of analyzing these complex datasets with high sensitivity and reproducibility^{1,16}. Convolutional Neural Networks (CNNs) extract hierarchical spatial features from radiographic images, allowing automated detection of caries, periapical lesions, periodontal bone loss, cysts, tumors, and anatomical variations^(10,18).

In two-dimensional imaging modalities such as periapical and bitewing radiographs, AI enhances early detection of proximal caries, root fractures, and apical pathologies. Deep learning models improve diagnostic sensitivity by identifying subtle grayscale variations that may be overlooked by human observers¹⁶. Endres et al. demonstrated that AI-based systems achieved diagnostic performance comparable to experienced oral surgeons in detecting periapical radiolucencies¹⁸. Such systems reduce inter-observer variability and improve standardization in radiographic interpretation¹¹.

Three-dimensional imaging modalities, particularly CBCT, have further expanded AI applications. AI-driven segmentation algorithms enable automated identification of anatomical structures such as the mandibular canal, maxillary sinus, and impacted teeth¹⁵. Volumetric analysis allows accurate assessment of lesion size, bone density, and spatial relationships—critical in implant planning and surgical decision-making. Deep learning models also enhance image preprocessing by reducing noise and improving contrast, thereby increasing diagnostic clarity¹⁶. Overall, AI in imaging modalities enhances diagnostic accuracy, efficiency, and reproducibility, functioning as a clinical decision-support system that complements professional expertise rather than replacing it.

X-ray Imaging System: X-ray imaging systems form the cornerstone of dental disease diagnosis by enabling visualization of hard tissue structures and pathological changes¹⁹. Conventional radiography operates through ionizing radiation to produce two-dimensional representations of dental and maxillofacial structures. AI integration enhances interpretation accuracy by facilitating automated detection of radiolucent and radiopaque lesions. Digital advancements in X-ray systems allow improved image acquisition, contrast enhancement, and data storage, forming the basis for AI-assisted analysis.

Intraoral Imaging: Intraoral imaging systems include periapical and bitewing radiographs, which provide high-resolution visualization of tooth structures and supporting bone¹⁹. These modalities are essential for detecting caries, periapical pathology, and periodontal bone loss. AI-assisted intraoral image processing enhances feature extraction

and lesion identification by analyzing grayscale variations and structural boundaries.

Extraoral Imaging: Extraoral imaging includes panoramic radiography and cone-beam computed tomography (CBCT), which provide comprehensive visualization of maxillofacial anatomy¹⁹. These systems allow three-dimensional assessment of impacted teeth, cysts, tumors, and sinus conditions. AI algorithms enhance segmentation, structural identification, and pathological detection in complex imaging datasets.

Non-Infrared Imaging System: Non-infrared imaging systems encompass advanced diagnostic technologies that operate beyond traditional X-ray modalities¹⁹. These include optical and light-based imaging approaches that assist in soft tissue evaluation and early lesion detection. AI-based analytical systems enhance signal interpretation and improve sensitivity in detecting subtle mucosal changes.

Spectral Ranges: Spectral range-based imaging utilizes varying wavelengths to enhance tissue contrast and diagnostic visibility¹⁹. By analyzing spectral responses, these systems differentiate healthy from diseased tissue. AI integration facilitates automated interpretation of spectral variations, improving early disease detection and diagnostic precision.

Artificial Intelligence in Cone Beam Computed Tomography (CBCT): Artificial Intelligence integration in Cone Beam Computed Tomography has significantly transformed three-dimensional diagnostic interpretation in Oral and Maxillofacial Radiology. CBCT produces volumetric datasets that allow multiplanar visualization of craniofacial structures, and AI algorithms are trained to analyze voxel-based imaging data to enhance diagnostic accuracy²⁰. These systems process grayscale density distribution, cortical bone continuity, trabecular architecture, and anatomical boundaries to support automated identification of pathological changes. AI applications in CBCT include automated detection and classification of cystic lesions, periapical pathologies, impacted teeth, and osseous abnormalities¹⁸. Through pattern recognition and feature extraction mechanisms, AI models identify subtle radiographic variations that may not be immediately evident during manual interpretation. These models are trained using annotated CBCT datasets and continuously improve performance through supervised learning processes²⁰. Automated segmentation techniques allow precise delineation of lesion margins, facilitating accurate volumetric measurement and treatment planning.

Deep learning-based CBCT analysis enhances three-dimensional reconstruction accuracy and anatomical landmark identification¹⁵. AI-driven segmentation systems assist in mapping critical anatomical structures such as the inferior alveolar nerve canal, maxillary sinus boundaries, cortical plates, and temporomandibular joint components. This is particularly important in surgical planning, implant site assessment, and orthodontic evaluation, where spatial accuracy is essential¹⁵. Volumetric analysis algorithms provide quantitative measurements of lesion size, bone density variations, and cortical integrity. Furthermore, AI systems applied to CBCT imaging improve diagnostic reproducibility and reduce observer variability²⁰. Automated classification models assist in differentiating inflammatory, cystic, and neoplastic conditions based on structural and density-related features¹⁸. In implantology and maxillofacial surgery, AI-supported CBCT evaluation enhances preoperative planning by identifying anatomical constraints and risk factors¹⁵. Collectively, these advancements position CBCT as a critical imaging modality for AI-assisted diagnosis and precision-based treatment planning in Oral Medicine and Radiology.

Deep Learning Techniques in Dental Radiology: Deep learning has emerged as a dominant computational approach in dental radiology due to its ability to automatically learn hierarchical image representations from large radiographic datasets. Convolutional Neural Networks (CNN) are specifically designed for image-based

pattern recognition and are widely applied in panoramic radiographs, intraoral radiographs, and CBCT imaging⁹. CNN architectures perform convolutional filtering operations that extract spatial features such as edges, density gradients, structural discontinuities, and anatomical contours. These extracted features are then passed through multiple hidden layers, enabling accurate classification of dental anomalies, periapical lesions, impacted teeth, and osseous defects. Recurrent Neural Networks (RNN) are particularly suited for analyzing sequential or time-dependent radiographic data. In longitudinal dental imaging studies, RNN models evaluate progressive disease changes, treatment responses, and lesion evolution across serial radiographs. This technique allows temporal correlation of radiographic findings, supporting monitoring of periodontal bone loss progression or post-treatment healing patterns. RNN-based analysis improves predictive modeling where disease progression is dynamic rather than static. Transfer Learning (TL) enables adaptation of pre-trained deep learning models to dental radiology datasets². Instead of training models from scratch, existing neural networks trained on large imaging databases are fine-tuned using dental radiographic images. This significantly reduces the requirement for extensive annotated dental datasets while maintaining diagnostic performance. Transfer learning accelerates implementation of AI systems in clinical radiology and enhances computational efficiency in diagnostic workflows.

Artificial Intelligence in Other Dental Departments

Artificial Intelligence in Pediatric Dentistry: Artificial Intelligence has increasingly been integrated into paediatric dentistry, particularly in early diagnosis, risk assessment, and preventive treatment planning. AI-driven systems based on Convolutional Neural Networks (CNN) and Artificial Neural Networks (ANN) are capable of detecting early childhood caries from intraoral periapical and panoramic radiographs with high sensitivity and specificity¹⁶. These models analyse radiographic density changes, enamel demineralisation patterns, and proximal surface alterations that may not be easily detectable during routine visual examination. AI applications also extend to growth and developmental assessment. Automated analysis of panoramic and cephalometric radiographs enables evaluation of skeletal maturation and eruption timing. These systems reduce observer variability and enhance reproducibility in developmental assessments¹⁶. Early identification of growth discrepancies supports timely orthodontic referral and interceptive management. In pediatric dentistry, early detection of dental caries is critical. Deep learning systems have demonstrated high diagnostic performance in detecting occlusal and proximal caries in children¹⁶. AI also supports growth and development assessment. Automated cephalometric landmark detection improves accuracy in skeletal analysis and orthodontic growth prediction³. By eliminating manual tracing variability, AI enhances diagnostic consistency. Ethical safeguards are particularly important in pediatric AI applications to ensure data protection and avoid over-dependence on automation¹³.

Artificial Intelligence in Orthodontics: Orthodontics represents one of the most advanced areas of AI integration in dentistry due to its reliance on cephalometric analysis and treatment simulation. AI-driven deep learning models are capable of automated cephalometric landmark detection with high reproducibility, significantly reducing manual tracing errors¹⁶. These systems analyse craniofacial anatomical structures using multi-layered convolutional filters to identify skeletal relationships and dental discrepancies. Machine learning algorithms have demonstrated strong predictive capability in determining extraction versus non-extraction treatment planning, achieving high diagnostic accuracy in clinical datasets³. Such systems assist clinicians by analysing occlusal relationships, crowding severity, skeletal patterns, and soft tissue profiles to generate data-driven treatment suggestions. AI is also widely utilised in digital orthodontics, particularly in aligner therapy. Integration with CAD/CAM systems allows simulation of tooth movement and prediction of treatment duration¹⁴. Future developments may include fully integrated AI platforms combining facial analysis, 3D imaging,

and growth prediction to deliver personalised orthodontic treatment planning with enhanced accuracy¹⁴.

Artificial Intelligence in Prosthodontics: AI applications in prosthodontics focus on predictive modeling, prosthetic design optimization, and material longevity assessment. Case-based reasoning systems analyze patient-specific variables to recommend appropriate restorative strategies²¹. Machine learning models predict prosthesis survival rates by evaluating occlusal load, material properties, and oral hygiene status. Integration with CAD/CAM systems enhances precision in crown and denture fabrication¹⁶. AI-driven digital workflows reduce manual errors and improve marginal fit accuracy. While promising, long-term clinical validation of AI-based predictive models remains limited¹⁵. Ethical implementation requires clinician supervision and patient-specific customization.

Artificial Intelligence in Oral and Maxillofacial Surgery: AI supports fracture detection, lesion segmentation, and surgical planning in oral and maxillofacial surgery. Deep learning models identify mandibular fractures and pathological lesions with high precision on CBCT imaging¹⁵. Automated 3D reconstruction assists in preoperative assessment and implant placement planning. AI enhances risk prediction and complication assessment through predictive modeling frameworks². Integration with navigation systems improves surgical accuracy and minimizes intraoperative errors. Despite technological advancements, surgical decision-making must remain clinician-driven, with AI serving as a supportive planning tool¹³.

Artificial Intelligence in Endodontics: AI has significantly contributed to improving diagnostic accuracy and procedural precision in endodontics. Deep learning algorithms are capable of detecting periapical radiolucencies on panoramic radiographs with performance comparable to experienced clinicians¹⁸. These systems evaluate radiographic density variations and periapical structural changes to support early diagnosis of apical periodontitis. Artificial Neural Networks have also been applied in determining working length and locating the minor apical foramen with high precision¹². Accurate working length determination is critical to endodontic success, and AI-assisted measurement reduces the risk of over-instrumentation or under-preparation. AI-driven CBCT analysis assists in identifying additional root canals, canal morphology variations, root resorption, and vertical root fractures. Automated segmentation enhances three-dimensional visualisation, improving treatment planning in complex cases¹⁶. These systems reduce diagnostic errors associated with superimposition in two-dimensional radiographs. AI reduces procedural errors by providing objective measurements and automated interpretation of radiographic findings. This improves treatment precision and long-term prognosis.

Artificial Intelligence in Forensic Odontology: AI models contribute to dental identification and pattern analysis in forensic investigations¹⁰. Radiographic comparison and structural analysis techniques assist in age estimation and identification processes¹⁵. AI improves age estimation and human identification through dental morphology analysis²³. Machine learning models analyze radiographic features, tooth eruption stages, and pulp-to-tooth ratios to estimate chronological age. In mass disaster scenarios, AI enhances efficiency by automating dental record comparison. This reduces human error and increases objectivity. Ethical and legal validation are essential before routine forensic implementation¹³.

Artificial Intelligence in Implantology: AI-based decision tree models predict implant success by analyzing bone density, systemic conditions, and occlusal load². Radiographic assessment using deep learning enhances evaluation of bone quality and optimal implant positioning¹⁵. Predictive analytics reduce implant failure rates and support personalized treatment planning. AI also assists in guided implant surgery through digital workflow integration. Nevertheless, long-term multicenter validation studies are required before universal adoption¹⁵. AI-driven imaging analytics support implant site assessment and bone quality evaluation¹⁵. Computational models

assist in planning implant positioning and predicting osseointegration outcomes.

Applications of Artificial Intelligence in Pathology: AI-driven digital pathology enhances microscopic evaluation of oral tissues. Deep learning algorithms analyze cellular morphology, nuclear atypia, and architectural distortion to detect dysplasia and malignancy¹⁶. Pattern recognition systems improve diagnostic consistency among pathologists. AI assists in grading lesions and predicting malignant transformation risk. However, ethical implementation requires expert supervision and histopathological confirmation¹³. With further refinement, AI may significantly standardize oral pathology diagnostics while maintaining clinician oversight. AI systems have been explored for digital histopathological analysis and lesion classification²². Pattern recognition algorithms assist in identifying cellular abnormalities and enhancing diagnostic accuracy in oral pathology.

Advantages of Artificial Intelligence

- Improves diagnostic accuracy in detecting caries, periapical lesions, cysts, tumors, and fractures.
- Enhances early detection of oral cancer and potentially malignant disorders.
- Reduces inter-observer and intra-observer variability in radiographic interpretation.
- Provides standardized and reproducible diagnostic outputs.
- Enables automated segmentation of lesions in panoramic radiographs and CBCT scans.
- Allows precise volumetric measurement of pathological lesions.
- Improves three-dimensional analysis in CBCT imaging.
- Assists in accurate identification of anatomical landmarks such as the mandibular canal and maxillary sinus.
- Supports predictive modeling for implant success and periodontal progression.
- Enhances orthodontic treatment planning and extraction prediction.
- Improves assessment of temporomandibular joint disorders using MRI and CBCT.
- Aids in screening for systemic osteoporosis using mandibular cortical analysis.
- Increases efficiency by reducing radiographic interpretation time.
- Automates repetitive diagnostic tasks and workflow processes.
- Supports digital integration with CAD/CAM systems in prosthodontics.
- Assists in surgical planning and risk assessment in oral and maxillofacial surgery.
- Enhances forensic age estimation and dental identification.
- Improves educational training in radiographic interpretation.
- Supports tele-dentistry and remote screening applications.
- Helps optimize radiation dose while maintaining diagnostic quality.

Disadvantages of Artificial Intelligence

- Requires large, well-annotated datasets for accurate training.
- Limited multicenter validation reduces generalizability.
- Performance depends heavily on image quality and standardized imaging protocols.
- High computational and infrastructure costs limit accessibility.
- Risk of algorithm bias due to non-diverse training datasets.
- Possibility of overfitting in small or single-center datasets.
- Deep learning models often lack transparency (black-box problem).

- Ethical concerns related to patient data privacy and security.
- Medico-legal uncertainty regarding accountability in misdiagnosis.
- Requires continuous validation and periodic updating of models.
- Cannot fully interpret clinical context or patient history.
- Cannot replace biopsy or histopathological confirmation.
- Most studies are retrospective with limited long-term outcome data.
- Over-reliance on AI may reduce clinician analytical skills.
- Regulatory guidelines for clinical implementation are still evolving.

Challenges in Automated Dental Disease Diagnosis: Despite the rapid advancement of Artificial Intelligence (AI) in oral medicine and radiology, several challenges hinder its seamless clinical integration. One of the primary challenges is the availability of high-quality, well-annotated datasets for training deep learning models. AI algorithms require large, diverse, and standardized radiographic datasets to achieve optimal performance^{11,15}. However, dental imaging datasets are often limited to single-center studies, leading to reduced generalizability across populations with varying demographic and anatomical characteristics.

- Another significant challenge is variability in imaging protocols. Differences in exposure settings, CBCT machines, image resolution, and patient positioning can influence algorithm performance^{15,16}. Models trained on specific datasets may not perform equally well on images obtained from different equipment or institutions. This heterogeneity creates difficulties in achieving standardized implementation across dental practices.
- Interpretability and transparency of AI systems also remain major concerns. Deep learning models, particularly convolutional neural networks, often function as “black box” systems where the reasoning behind a decision is not easily explainable^{1,13}. In oral oncology and potentially malignant disorders, where diagnostic decisions carry serious medico-legal implications, lack of explainability may limit clinician trust and adoption.
- Ethical and legal considerations present further challenges. Issues related to patient data privacy, informed consent, algorithm bias, and accountability in case of misdiagnosis must be clearly addressed before AI can be widely implemented in routine practice¹³. Regulatory approval and standardization frameworks are still evolving in many regions.

Future Perspective

- The future of AI in oral medicine and radiology is promising, with potential expansion toward fully integrated diagnostic ecosystems. Development of large, multicenter, annotated datasets will enhance algorithm generalizability and robustness^{11,15}. Collaborative international databases may significantly improve AI training diversity and reliability.
- Explainable AI (XAI) represents a major future direction. Improving model transparency through visualization tools such as heat maps and attention maps will increase clinician trust and acceptance¹³. Such systems can highlight specific regions of interest in radiographs, allowing clinicians to verify algorithmic decisions.
- Integration of AI with advanced imaging modalities such as CBCT, MRI, and digital pathology platforms may enable multimodal diagnostic systems. Combining radiographic, clinical, and histopathological data could allow comprehensive disease prediction models, particularly in oral cancer risk stratification and autoimmune mucosal disorders^{12,16}.

- Furthermore, AI-assisted chairside applications may enhance real-time screening, early detection of potentially malignant disorders, and predictive modeling for implant success or periodontal progression^{2,17}. With regulatory refinement, ethical governance, and clinician training, AI has the potential to transition from supportive analytics to an indispensable component of precision dentistry.

Limitations

- One of the key limitations of AI in oral medicine and radiology is overfitting. Many studies report high accuracy within training datasets but fail to demonstrate similar performance in external validation cohorts¹⁵. This reduces the reliability of results and highlights the need for multicenter validation studies.
- Another limitation is the dependence on image quality. AI systems are highly sensitive to poor contrast, motion artifacts, and improper exposure settings¹⁶. In clinical scenarios where radiographs are suboptimal, algorithm performance may decline significantly. Unlike experienced radiologists who can compensate for minor image distortions, AI systems may misclassify such cases.
- AI also lacks comprehensive clinical context integration. Although machine learning models can incorporate structured clinical variables, they cannot fully replicate clinical judgment, patient history interpretation, or tactile examination findings. For example, differentiation between inflammatory and neoplastic lesions often requires histopathological confirmation, which AI cannot independently replace.
- Additionally, most AI studies in dental radiology remain cross-sectional and retrospective¹⁵. There is limited long-term prospective data evaluating clinical outcomes, cost-effectiveness, and patient-centered benefits. Without strong longitudinal evidence, AI remains an adjunctive rather than definitive diagnostic tool.

CONCLUSION

Artificial Intelligence has emerged as a transformative adjunct in Oral Medicine and Radiology, reshaping the landscape of diagnostic precision, disease prediction, and clinical decision-making¹⁴. Through the integration of machine learning, deep learning, and advanced neural network architectures, AI systems have demonstrated significant potential in detecting dental caries, periapical lesions, periodontal bone loss, maxillofacial fractures, salivary gland disorders, temporomandibular joint abnormalities, and oral malignancies. By reducing inter- and intra-observer variability and enhancing radiographic interpretation, AI contributes to improved diagnostic consistency and early disease identification. Looking forward, the future of AI in Oral Medicine and Radiology lies in multimodal data integration, combining radiographic, clinical, and histopathological information to create comprehensive diagnostic ecosystems¹⁹. With continued research, ethical governance, and clinician training, AI has the potential to enhance early detection of oral diseases, improve patient outcomes, and contribute significantly to the evolution of evidence-based, precision dentistry²⁴.

REFERENCES

Advancements and applications of artificial intelligence and machine learning. *Int J Creat Res Thoughts*. 2023; 11(11).
 Ali M, Irfan M, Ali T, Wei CR, Alkimali A. Artificial intelligence in dental radiology: A narrative review. *Ann Med Surg*. 2025;87:2212–2217.
 Applications of artificial intelligence in machine learning: Review and prospect. *Int J Comput Appl*. 2015; 115(9).

Ayinampudi BK, Tanveer A, Bhagirath PV, Gannepalli A. Role of artificial intelligence in diagnostic oral pathology: A modern approach. PanineeyaMahavidyalaya Institute of Dental Sciences, Hyderabad, Telangana, India.
 Heo MS, Kim JE, Hwang JJ, Han SS, Kim JS, Yi WJ, et al. Artificial intelligence in oral and maxillofacial radiology: What is currently possible?
 Hung K, Yeung AWK, Tanaka R, Bornstein MM. Current applications, opportunities, and limitations of AI for 3D imaging in dental research and practice.
 Ilhan B, Lin K, Guneri P, Wilder-Smith P. Improving oral cancer outcomes with imaging and artificial intelligence.
 Kale IP, Mhapuskar AA, Jhavar M, Hiremutt DRP. Artificial intelligence in oral medicine and oral radiology. *SRM J Res Dent Sci*. 2023;14(4):199–205.
 Khanna SS, Dhaimade PA. Artificial intelligence: Transforming dentistry today. *Indian J Basic Appl Med Res*. 2017;6(3):161–167.
 Kim K, Lim CY, Shin J, Chung MJ, Jung YG. Enhanced artificial intelligence-based diagnosis using CBCT with internal denoising: Clinical validation for discrimination of fungal ball, sinusitis, and normal cases in the maxillary sinus. *arXiv [Preprint]*. 2022.
 Krishna AB, Tanveer A, Bhagirath PV, Gannepalli A. Role of artificial intelligence in diagnostic oral pathology—A modern approach.
 Madhivanan K, Dhandapani P, Thirugnanamurthy S, Krishnan S, Balasubramanian N, Jayachandran V. Artificial intelligence in oral medicine and radiology—An overview. *J Chem Health Risks*. 2024;14(5):590–596.
 Mallineni SK, Sethi M, Punugoti D, Kotha SB, Alkhayal Z, Mubarak S, et al. Artificial intelligence in dentistry: A descriptive review. *Bioengineering*. 2024;11:1267.
 Negrete D, Lopes SLPC, Barreto MDA, Moura NB, Nahas ACR, Costa ALF. Artificial intelligence and dentomaxillofacial radiology education: Innovations and perspectives. *Dentistry Journal*. 2025;13:245.
 Patil S, Albogami S, Hosmani J, Mujoo S, Kamil MA, Almansour M, et al. Artificial intelligence in the diagnosis of oral diseases: Applications and pitfalls. *Diagnostics*. 2022;12:1029.
 Sarwar S, Jabin S. AI techniques for cone beam computed tomography in dentistry: Trends and practices. *J Multimed Inf Syst*. 2023;10(4):xx–xx.
 Semerci ZM, Yardımcı S. Empowering modern dentistry: The impact of artificial intelligence on patient care and clinical decision making. *Diagnostics*. 2024;14(12):1260.
 Shafi I, Fatima A, Afzal A, de la Torre Diez I, Lipari V, Berenos J, et al. A comprehensive review of recent advances in artificial intelligence for dentistry e-health. *Diagnostics*. 2023;13:2196.
 Silva Filho WJE, Santana Lima BN, De Souza LLT, Silva TP, Takeshita WM. Artificial intelligence in oral radiology: A checklist proposal. *J Oral Maxillofac Radiol*. 2022;10(3):63–66.
 Srivastava B, Chandra S, Singh SK, Srivastava T. Artificial intelligence in dentistry: Its applications, impact and challenges. *Asian J Oral Health Allied Sci*. 2023;3(1):1–7.
 Suganya B, David MP. Artificial intelligence in oral medicine and radiology—Heralding a new era. *Int J Contemp Med Res*. 2020;7(12):L7–L11.
 Surdu A, Budala AG, Lucian I, Foia LG, Botnariu GI, Scutariu AMM. Using AI in optimizing oral and dental diagnoses—A narrative review. *Diagnostics*. 2024;14:2804.
 Tiwari A, Gupta N, Singla D, Soni IR, Gupta R, Mehta D, et al. Artificial intelligence's use in the diagnosis of mouth ulcers: A systematic review. *Cureus*. 2023;15(9):e45187.
 Tosun ZT, Kumbasar N, Sumbullu MA, Miloglu O. Evaluation of the effectiveness of artificial intelligence models in radiopaque and radiolucent lesions of the maxillofacial region on panoramic radiographs. *Oral Radiol*. 2025.
 Zabrowicz K, Zabrowicz M, Cielinska K, Dakiera-Nicker A, Finkel M, Blazik B. Artificial intelligence methods in the detection of oral diseases on pantographic images—A systematic narrative review. *J Clin Med*. 2025;14:3262.