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Artificial Intelligence in Dentistry: Clinical Applications, Public Health Impact, and Ethical Challenges

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Abstract: ***Artificial Intelligence (AI) is transforming healthcare through machine learning, deep learning, robotics, and computer vision, improving diagnosis, clinical workflows, and population health monitoring. In dentistry, AI-assisted tools now support radiographic interpretation, caries detection, periodontal assessment, endodontic diagnosis, orthodontic planning, and prosthodontic design. Despite these gains, major concerns persist around data privacy, algorithmic bias, informed consent, and regulatory gaps of many AI systems.***

Keywords: Artificial intelligence, Healthcare technology, Dental diagnosis, Clinical decision support, Data privacy

1. Introduction

Artificial Intelligence (AI) is a branch of computer science focused on building machines and software that perform tasks requiring human intelligence. Coined by John McCarthy in 1956, AI has progressed from theory to a transformative force, reshaping industries such as finance, transportation, and healthcare.[1] **AI in medicine** applies algorithms and computational systems to help clinicians and researchers make faster, more accurate decisions. Enabled by advances in computing power, digital datasets, and cloud infrastructure, its adoption is now feasible at scale.[2]

Healthcare systems face escalating pressures from rising disease burden, workforce shortages, and the demand for precision medicine.[2] Conventional workflows depend on manual interpretation and clinician experience, leading to delays, variability, and cost overruns. AI addresses these by processing vast structured and unstructured datasets faster and more consistently than traditional methods.[3]

Dentistry was among the earliest adopters of Artificial Intelligence, owing to its reliance on imaging, pattern recognition, and digital records. AI-driven tools now detect caries, bone loss, and periapical lesions with accuracy that rivals or even surpasses human experts. Beyond the clinical setting, AI extends its utility to healthcare administration, epidemiological modelling, and community-level preventive care. Yet, alongside these advances, complex challenges emerge particularly around privacy, informed consent, and professional accountability indicating the need for careful, evidence-based integration of AI into healthcare and dentistry.

In this context, exploring the role of Artificial Intelligence in healthcare and dentistry is not merely an academic exercise but a pressing necessity. As disease burdens rise, workforce shortages intensify, and the demand for precision medicine grows, AI offers both opportunities and challenges. This narrative review, seeks to critically examine its clinical applications, public health impact, and ethical dimensions, highlighting the need for evidence-based integration to ensure that technological innovation translates into meaningful improvements in patient care and population health.

2. Methodology

Literature for this review was collected using MEDLINE via PubMed and EBSCO which include Health care dentistry, population health impact, tele-dentistry and ethical challenges. In this, only peer-reviewed articles published between 2020 and 2025 were included. 25 relevant studies were selected after screening. Studies that focusses on applications of AI in healthcare dentistry, population health impact, tele-dentistry, diagnosis, treatment planning, patient management, and ethical challenges were included.

Overview of Artificial Intelligence in Healthcare

Artificial intelligence is rapidly reshaping the way healthcare is delivered. Rather than being just a futuristic concept, AI has become a practical tool that supports doctors, dentists, and other healthcare professionals in making better decisions, diagnosing conditions more accurately, and tailoring treatments to individual patients. By processing vast amounts of medical data, AI can uncover hidden patterns, predict outcomes, and help optimize care in ways that were once unimaginable.

Its influence now stretches across multiple areas—dentistry, telehealth, population health management, and even disease surveillance- making healthcare more efficient, accessible, and patient-centered. In short, AI is no longer just an add-on; it's becoming an integral part of modern healthcare systems.

AI Technologies in Healthcare

Artificial Intelligence in healthcare encompasses a range of computational approaches that are transforming clinical practice and research. The most prominent technologies include **Machine Learning (ML), Deep Learning (DL), Convolutional Neural Networks (CNNs), and Natural Language Processing (NLP)**, each contributing uniquely to healthcare innovation.

- **Machine Learning (ML):** ML algorithms analyze large datasets such as electronic health records, imaging results, and laboratory data to detect patterns and trends without explicit programming. This capability underpins disease prediction models, clinical decision support systems, and drug discovery pipelines, enabling healthcare providers to anticipate risks and personalize interventions.

- **Deep Learning (DL):** DL, built on layered neural network architectures, excels in complex tasks like medical image analysis. By mimicking human cognitive processes, DL systems can identify subtle abnormalities in radiographs, CT scans, and MRIs, often achieving diagnostic accuracy comparable to experienced specialists.
- **Convolutional Neural Networks (CNNs):** CNNs are particularly effective in extracting features from medical images. Unlike traditional methods that require manual preprocessing, CNNs automatically learn to recognize clinically relevant structures. They have demonstrated success in detecting pathologies across radiology, dermatology, and dentistry. However, their "black-box" nature poses a limitation—when a CNN flags a potential disease, the reasoning behind its decision is often opaque, raising concerns about interpretability and trust.
- **Natural Language Processing (NLP):** NLP converts unstructured clinical text—such as physician notes, discharge summaries, and research articles—into structured, analysable data. This enables automated medical coding, the development of intelligent chatbots for patient interaction, and large-scale literature synthesis to support evidence-based practice.
- **Computer Vision:** Computer vision applies AI to interpret medical images and videos in real time. It supports applications ranging from radiographic analysis to surgical guidance, enhancing precision and reducing human error.
- **Robotics:** Robotics integrates AI into physical systems, including surgical robots, rehabilitation devices, and pharmacy automation. These systems respond dynamically to real-time data, improving surgical outcomes, patient recovery, and medication dispensing efficiency.

Clinical Applications of AI in Dentistry

Dentistry's dependence on imaging and pattern recognition. Conventional diagnosis is subject to inter-observer variability and clinician fatigue but AI offers greater consistency.[5]

In dental radiology, CNN an AI models automatically number teeth, detect caries, apical lesions, and screen for osteoporosis from panoramic images, with accuracies of 85-95%.[6,7] Endodontics benefits include automated periapical lesion detection, 3D CBCT segmentation, vertical root fracture identification, and working length estimation.[7,8]

In Periodontology, ML uses to integrate clinical, radiographic, and microbial data for disease progression prediction, enabling proactive risk-based management rather than static diagnosis.[9] It may recommend restorative materials based on patient-specific factors.[7,18]

In Orthodontics, AI use for cephalometric analysis, and growth prediction. CNN and ANN models identify landmarks and assess cervical vertebral maturation with sensitivity and specificity exceeding 90%.[18] Clinical Decision Support Systems (CDSS) now unite findings from multiple specialties to guide treatment planning, recall scheduling, and preventive recommendations, steering dentistry toward genuinely personalized care.[8,9]

3. Results

The principal of AI applications recognized across dental and healthcare areas, composed with the AI technologies employed and reported performance are summarised in the Table 1 respectively.

Table 1: Summary of AI Technology, Applications, and performance in Dentistry and Healthcare

Area	AI Technology Used	Applications	Reported Performance
Dental Radiology	CNN (Convolutional neural networks)	Caries detection, tooth numbering, apical lesion identification, osteoporosis screening from OPGs	Enhanced diagnostic accuracy and faster interpretation with 85–95% accuracy
Endodontics	Deep Learning / CBCT AI	Periapical lesion detection, root fracture identification, working length estimation, segmentation	High sensitivity, better precision and early diagnosis
Periodontology	ML (multi-input)	Disease progression prediction integrating clinical, radiographic, Bone loss assessment and microbial data	Improved risk based periodontal management
Prosthodontics	ML / Intraoral Scanners	Impression accuracy enhancement, material recommendation	Enhanced Patient-specific outcomes planning
Orthodontics	CNN / ANN	Cephalometric landmark detection, cervical vertebral maturation assessment	>90% sensitivity and reduced manual errors with faster analysis
Healthcare Administration	ML	Patient flow forecasting, EHR automation, inventory management	Reduced over-population and cost
Public Health / Tele-dentistry	AI screening platforms	Remote oral lesion detection, community caries risk assessment	Improved access in underserved regions

AI in Healthcare Management and Dental Public Health

Administrative inefficiency in healthcare is costly. ML algorithms forecast patient flow, helping hospitals optimize staffing and reduce overcrowding. AI-driven inventory systems maintain supply continuity, while automated scheduling and EHR management free clinicians for direct patient care.[2,]

In public health, AI surveillance systems detect disease clusters earlier than conventional reporting by aggregating pharmacy data, emergency visit patterns, and search trends.[2] Tele-dentistry platforms with AI support provide preliminary screening, risk assessment, and referral guidance in areas lacking specialist access a meaningful change for underserved communities where oral healthcare has historically been inadequate.[9,10]

4. Ethical and Practical Challenges

The growing use of artificial intelligence in dentistry has several ethical and practical challenges that must be addressed for its safe and effective implementation. One of the major

ethical concerns is patient data privacy and security, as AI systems depend on large amounts of clinical and radiographic data. [3,4] Protecting sensitive patient information and obtaining informed consent are essential to maintain trust and confidentiality. Another important issue is algorithmic bias[5], where AI systems trained on limited or non-diverse datasets may produce inaccurate or unequal results for certain populations, potentially increasing healthcare disparities. [6,11]

Legal accountability is also an important concern. In cases of incorrect diagnosis or treatment recommendations generated by AI, it may become difficult to determine responsibility between the clinician, software developer, or healthcare institution.[4,12] Additionally, excessive dependence on AI could reduce the role of clinical judgment and human interaction, both of which are important in patient dental care.

From a practical perspective, the implementation of AI in dentistry faces challenges such as high installation and maintenance costs, lack of advanced infrastructure, and limited technical expertise among dental professionals. Many clinics, especially in developing regions, may not have access to the necessary digital systems required for AI integration. Furthermore, continuous training and education are necessary to help dentists understand and effectively use AI-based technologies.[13,14]

Therefore, while AI offers promising advancements in dentistry, its adoption must be guided by ethical principles, proper regulations, professional training, and a balanced approach that combines technological innovation with human clinical expertise.[15,16]

5. Future Perspectives

The future of dentistry with AI is highly promising, with technology expected to make dental care more accurate, efficient, and personalized. AI may help dentists detect oral diseases at earlier stages, improve treatment planning, and provide faster clinical decisions through advanced imaging and predictive analysis. [17,18]

It will combine genomic data, biomarkers, lifestyle patterns, and real-time sensor readings to generate individualized treatment plans.[11,12] Tele-dentistry with AI image screening can enable early oral lesion detection and community caries risk assessment without requiring in-person visits.[9,11] After sometime, smart dental systems, robotic assistance, and tele-dentistry could further improve patient care and accessibility, especially in remote areas.

However, the future success of AI in dentistry will depend on ethical implementation, proper training, reliable regulations, and maintaining the essential role of human judgment, empathy, and communication in dental practice.[4,19]

6. Conclusion

AI has become an important part of modern healthcare and dentistry, offering key improvements in diagnosis, and treatment planning. In dental specialties such as radiology, orthodontics, endodontics, prosthodontics, and periodontology, AI helps to achieve greater diagnostic accuracy, consistency, and faster administrative. It also supports healthcare management by improving administrative processes and enabling earlier detection and monitoring of diseases.

Despite these advantages, the integration of AI into dentistry also increases several significant concerns which include data privacy, patient consent, algorithmic bias, unequal access to technology, and unclear legal responsibility.

The effective and ethical use of AI in dentistry involves careful planning and responsible implementation. The development of transparent and explainable AI systems, strong regulatory guidelines, secure data handling practices, and continuous education for dental professionals are essential for building trust and ensuring patient safety. Furthermore, AI is a supportive tool that improves the skills and decision of dental professionals rather than replacing the human expertise, and clinical decision-making that remain fundamental to quality patient care.

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