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Artificial Intelligence for Precision Dentistry: Advancing Diagnosis and Prognosis

Dr. Anjali Navadiya[1], Dr. Jeeth Rai[2], Dr. Vidhi Kevadiya[3], Dr. Hetvi Parmar[4], Dr. Vivek Kher[5], Dr. Chaitanya Parmar[6]

[1,3]*Tutor at College of Science and Hospital, Amargadh Gujarat, India.*
[2]*Professor, Head of the Department, Department of Periodontics, College of Dental Science and Hospital, Amargadh, Gujarat, India.*
[4.5.6] *Intern at College of Science and Hospital, Amargadh, Gujarat, India.*

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Abstract: Artificial Intelligence (AI) has emerged as a transformative technology in healthcare, with significant applications in dentistry. AI has the ability to help evidence-based clinical decision-making, improve prognostic forecasts, and increase diagnostic accuracy by employing machine learning, deep learning, and complex data analytics. Through the analysis of radiographic, photographic, and clinical data, AI-driven systems are increasingly being used in dentistry to detect and categorize dental caries, periodontal diseases, oral potentially malignant disorders, oral cancers, endodontic pathologies, and orthodontic anomalies. Early illness detection, reduced diagnostic variability, and prompt care are all made feasible by these technologies. Beyond diagnosis, AI aids individualized treatment planning in precision dentistry by forecasting patient-specific risks, treatment results, and disease progression. AI's clinical relevance has been further enhanced by its integration with digital dentistry, including intraoral scanning, cone-beam computed tomography, and electronic medical records. Despite these developments, there are still significant barriers to mainstream adoption, including challenges with data privacy, algorithm transparency, ethics, regulations, and the demand for high-quality datasets. The goal of this paper is to give a thorough overview of the present uses of AI in dentistry diagnosis and prognosis, emphasizing recent advancements in technology, clinical advantages, drawbacks, and potential future advances. It is anticipated that the increasing collaboration between AI and dentistry would transform patient care by facilitating more precise diagnoses, enhanced prognostic evaluations, and individualized treatment plans. AI is set to become a crucial part of precision dentistry, improving clinical outcomes and healthcare efficiency as research and technology innovation continue to advance.

Key Words: "Artificial Intelligence", "Machine Learning", "Deep Learning", "Precision Dentistry", "Dental Diagnosis", "Dental Prognosis".
Time period: e.g., 2018–2026

1. Introduction

The rapid advancement of digital technologies has transformed healthcare delivery, with artificial intelligence (AI) emerging as one of the most influential innovations of the twenty-first century. AI refers to the ability of computer systems to perform tasks that traditionally require human intelligence, including learning, pattern recognition, reasoning, and decision-making. Machine learning (ML) and deep learning (DL), two major branches of AI, have demonstrated remarkable capabilities

in analysing complex healthcare data and assisting clinicians in diagnostic and therapeutic processes. [1,2]

Dentistry has experienced substantial digital transformation over the last decade through the widespread adoption of digital radiography, cone-beam computed tomography (CBCT), intraoral scanners, and electronic health records. These technologies generate vast amounts of clinical and imaging data that can be effectively analysed using AI-driven algorithms. Consequently, AI has emerged as a promising tool for improving diagnostic accuracy, enhancing clinical efficiency, and supporting evidence-based decision-making in dental practice. [1,3]

Among the various applications of AI in dentistry, diagnostic support has received considerable attention. Deep learning models, particularly convolutional neural networks, have demonstrated high accuracy in detecting dental caries, periodontal bone loss, periapical lesions, impacted teeth, orthodontic abnormalities, and oral potentially malignant disorders from radiographic and photographic images. These systems can identify subtle pathological changes that may be overlooked during routine clinical examination, thereby improving diagnostic consistency and facilitating early intervention. [2,4]

Beyond diagnosis, AI is increasingly being utilized for prognostic assessment and personalized treatment planning. Predictive algorithms can analyse patient-specific clinical, radiographic, and behavioural variables to estimate disease progression, treatment outcomes, implant survival, and recurrence risks. Such capabilities align closely with the concept of precision dentistry, which emphasizes individualized care based on each patient's unique characteristics rather than a generalized treatment approach. [3,5]

Recent advancements in computer vision, neural networks, and generative artificial intelligence have further expanded the role of AI in oral healthcare. Modern AI platforms are capable of automated radiographic interpretation, treatment planning assistance, patient communication, clinical documentation, and educational support. Furthermore, large language models and generative AI systems are beginning to influence research, academic writing, and clinical decision-support systems within dentistry. [6,7]

Despite these promising developments, challenges remain regarding data quality, algorithm transparency, ethical concerns, patient privacy, and regulatory approval. The successful integration of AI into routine dental practice requires robust validation studies, standardized datasets, and appropriate clinician oversight to ensure patient safety and reliability of outcomes. [1,2]

Therefore, understanding the current applications, strengths, and limitations of AI is essential for clinicians, researchers, and policymakers. This review aims to provide a comprehensive overview of artificial intelligence in precision dentistry, with particular emphasis on its applications in diagnosis and prognosis, contemporary AI tools, existing challenges, and future directions that may shape the next generation of oral healthcare.

2. Evolution of Artificial Intelligence In Dentistry

The concept of artificial intelligence was first introduced in the mid-twentieth century, when researchers began exploring the possibility of developing computer systems capable of simulating human cognitive functions. Initially, AI applications in healthcare were limited by insufficient computational power, restricted data availability, and the complexity of clinical decision-making. However, advances in computing technology, data storage, and algorithm development have significantly accelerated the adoption of AI across medical and dental disciplines.[8,9]

The incorporation of artificial intelligence into dentistry began with expert systems designed to assist clinicians in diagnosis and treatment planning. These early systems relied on predefined rules and knowledge-based algorithms to support decision-making. Although useful in specific situations, the performance was limited by the inability to learn from new data and adapt to complex clinical scenarios. As a result, application in routine dental practice remained restricted. [10]

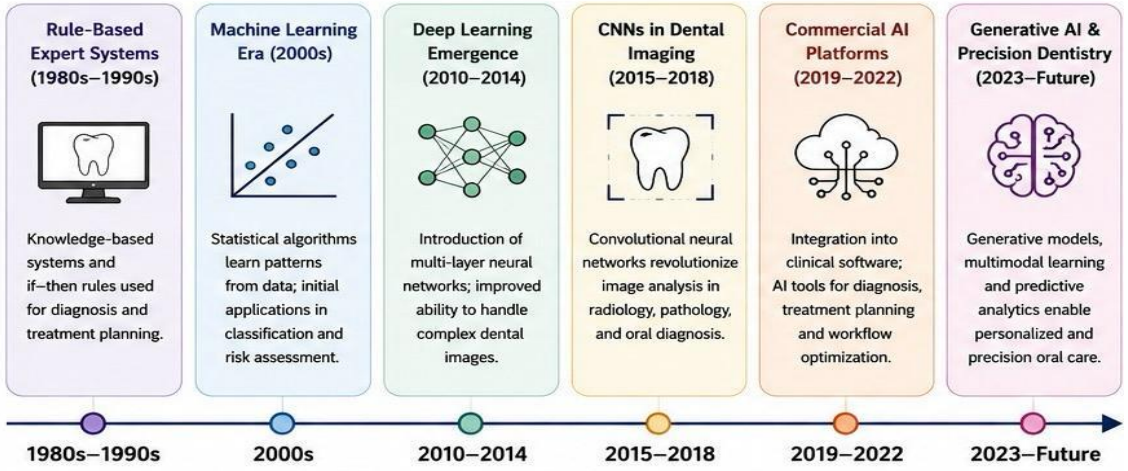
A major breakthrough occurred with the development of machine learning techniques, which enabled computer systems to learn patterns directly from data rather than relying solely on programmed rules. The increasing availability of digital dental records and imaging modalities provided the necessary foundation for training these algorithms. During this period, AI applications expanded to include caries risk assessment, interpretation of radiographic findings, and prediction of treatment outcomes. [11] Figure1. Shows evolution of artificial intelligence in dentistry.

The introduction of deep learning further revolutionized dental AI. Deep learning models, particularly convolutional neural networks (CNNs), demonstrated exceptional performance in image analysis tasks. These algorithms became capable of detecting dental caries, periodontal bone loss, periapical lesions, impacted teeth, and other oral pathologies with accuracy comparable to experienced clinicians. The widespread adoption of digital radiography and cone-beam computed tomography (CBCT) substantially contributed to the growth of AI-driven diagnostic systems by providing large datasets for algorithm training and validation. [12,13

Over the past decade, AI has evolved from a primarily research-based concept into a practical clinical tool. Modern AI systems are increasingly integrated into dental software platforms, enabling automated image interpretation, treatment planning assistance, and risk assessment. Commercially available platforms such as Diagnocat, Pearl AI, Overjet, and Videa AI have demonstrated the feasibility of incorporating AI into everyday dental workflows. These systems assist clinicians by identifying radiographic abnormalities, quantifying periodontal bone loss, and generating diagnostic reports, thereby enhancing efficiency and consistency in patient care. [3,7]

More recently, the emergence of generative artificial intelligence and large language models has expanded the scope of AI beyond image analysis. These technologies have shown potential in-patient communication, clinical documentation, educational content generation, research assistance, and decision-support systems. Additionally, advances in multimodal AI models that combine imaging, clinical, and textual data are expected to further improve diagnostic precision and prognostic prediction in dentistry. [6,14]

Figure 1. Evolution of Artificial Intelligence in Dentistry



Despite these advancements, the evolution of AI in dentistry remains ongoing. Continued improvements in algorithm transparency, data quality, regulatory frameworks, and ethical governance are necessary to ensure safe and effective clinical implementation. Nevertheless, the progression from rule-based expert systems to sophisticated deep learning and generative AI models highlights the transformative impact of artificial intelligence on modern dental practice and its growing role in precision dentistry. [9,14]

3. Fundamentals of Artificial Intelligence

Artificial intelligence (AI) encompasses a group of computational technologies designed to perform tasks that typically require human intelligence, such as learning, reasoning, pattern recognition, and decision-making. In dentistry, AI serves as the foundation for numerous applications ranging from disease detection and treatment planning to outcome prediction and patient management. Understanding the fundamental components of AI is essential for appreciating its role in precision dentistry. [15,1]

❖Artificial Intelligence

Artificial intelligence refers to the development of computer systems capable of mimicking cognitive processes traditionally associated with human intelligence. These systems can analyse large volumes of data, identify patterns, and generate predictions or recommendations with minimal human intervention. In healthcare, AI facilitates evidence-based decision-making by integrating clinical, radiographic, and demographic information to support diagnosis and treatment planning. Within dentistry, AI is increasingly being employed for radiographic interpretation, disease screening, patient risk assessment, and workflow optimization. [15,3]

❖Machine Learning

Machine learning (ML) is a subset of AI that enables computers to learn from data without being explicitly programmed for every task. Instead of relying on predefined rules, ML algorithms identify relationships and patterns within datasets and use this information to make predictions or classifications. Machine learning approaches are commonly categorized as supervised learning, unsupervised learning, and reinforcement learning.

Supervised learning utilizes labelled datasets to train algorithms for specific tasks, such as identifying carious lesions or classifying periodontal disease severity. Unsupervised learning explores unlabelled datasets to identify hidden patterns or groupings, while reinforcement learning improves performance through interactive feedback mechanisms. In dentistry, machine learning has been applied to caries risk assessment, orthodontic treatment planning, implant prognosis prediction, and patient stratification according to disease risk. [1,11]

❖ Deep Learning

Deep learning (DL) is an advanced branch of machine learning that employs artificial neural networks containing multiple interconnected layers. These networks automatically extract relevant features from large datasets, eliminating the need for manual feature selection. Deep learning has become particularly valuable in image-based diagnostics because of its ability to recognize complex visual patterns with high accuracy.

The widespread availability of digital radiographs, CBCT scans, and intraoral photographs has accelerated the adoption of deep learning in dentistry. Deep learning algorithms have demonstrated impressive performance in detecting dental caries, identifying periapical lesions, measuring periodontal bone loss, and diagnosing oral potentially malignant disorders. Numerous

studies have reported diagnostic accuracies comparable to those achieved by experienced dental professionals, highlighting the potential of deep learning as a clinical decision-support tool. [12,13]

❖ **Artificial Neural Networks and Large Language Models**

Artificial neural networks (ANNs) are computational models inspired by the structure and function of the human brain. These networks consist of interconnected nodes, or neurons, organized into input, hidden, and output layers. ANNs form the basis of many machine learning and deep learning systems used in dentistry. They are capable of processing complex datasets and generating predictive models for diagnosis, prognosis, and treatment planning. Applications include predicting implant success, assessing orthodontic treatment outcomes, and estimating the progression of periodontal disease. [4]

More recently, large language models (LLMs) have emerged as a novel category of AI capable of understanding and generating human language. These models are trained on extensive text datasets and can assist with information retrieval, clinical documentation, patient communication, educational content creation, and research support. Although LLMs offer significant potential, concerns regarding accuracy, transparency, and ethical use necessitate careful human oversight when applied in clinical settings. [6,16]

Collectively, artificial intelligence, machine learning, deep learning, neural networks, and large language models form the technological framework underpinning modern precision dentistry. As these technologies continue to evolve, they are expected to further enhance diagnostic accuracy, prognostic assessment, and personalized patient care.

4. Precision Dentistry: Concept And Clinical Relevance

Precision dentistry is an emerging approach that aims to provide individualized dental care by integrating patient-specific biological, clinical, behavioural, and environmental factors into diagnosis, treatment planning, and disease prevention. Unlike the traditional "one-size-fits-all" model, precision dentistry focuses on tailoring interventions according to the unique characteristics and risk profile of each patient. [9,17]

The concept is closely aligned with precision medicine, which emphasizes the use of advanced technologies and data-driven strategies to optimize healthcare outcomes. In dentistry, the increasing availability of digital records, radiographic imaging, genomic information, and clinical datasets has facilitated the implementation of personalized treatment approaches. Artificial intelligence plays a pivotal role in this transition by enabling the analysis of large and complex datasets that would be difficult to interpret using conventional methods. [17,3]

AI-driven systems can identify disease patterns, predict treatment outcomes, estimate individual risk factors, and support clinical decision-making. These capabilities are particularly valuable in managing dental caries, periodontal diseases, implant therapy, orthodontic treatment, and oral cancer screening, where patient-specific variations significantly influence prognosis and treatment success. [3,7]

Furthermore, precision dentistry promotes preventive and predictive healthcare by identifying high-risk individuals before the onset of advanced disease. Such an approach allows clinicians to implement targeted preventive strategies, monitor disease progression more effectively, and improve long-term treatment outcomes. The integration of AI with precision dentistry has the potential to enhance diagnostic accuracy, reduce treatment variability, and support the delivery of patient-centred oral healthcare. [7,9]

As digital technologies continue to evolve, precision dentistry is expected to become a fundamental component of modern dental practice, transforming oral healthcare from a reactive model to a predictive, preventive, and personalized approach. [4,17]

5. Data Sources Enabling AI in Dentistry

The effectiveness of artificial intelligence systems largely depends on the quality and diversity of the data used for training and validation. In dentistry, AI algorithms utilize information obtained from various digital sources to assist in diagnosis, prognosis, and clinical decision-making. [3,7]

➢ **Digital Radiography**

Digital radiographs, including periapical, bitewing, and panoramic images, represent the most widely used data source for dental AI applications. These images provide valuable information for the detection of dental caries, periapical lesions, periodontal bone loss, and other oral pathologies. Deep learning algorithms can analyse radiographic features with high accuracy and consistency. [12]

➢ **Cone-Beam Computed Tomography**

Cone-beam computed tomography (CBCT) provides three-dimensional visualization of dental and maxillofacial structures. AI-assisted analysis of CBCT images has been employed for implant planning, identification of anatomical landmarks, assessment of impacted teeth, and evaluation of pathological lesions. [5]

➢ **Intraoral Scanners and Digital Impressions**

The growing adoption of intraoral scanners has generated detailed three-dimensional datasets of dental arches and occlusion. These digital records support AI applications in orthodontics, prosthodontics, and restorative dentistry by enabling accurate assessment of tooth morphology and treatment outcomes. [7]

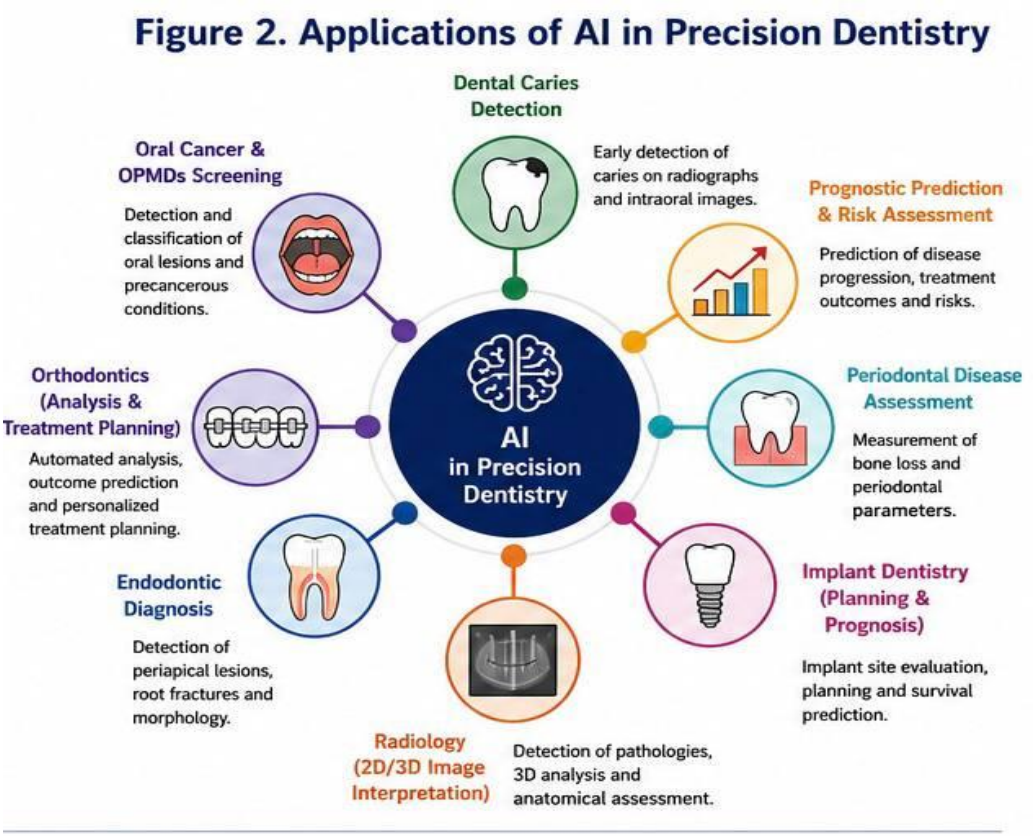
➢ **Clinical Photographs**

Clinical and intraoral photographs are increasingly used for the detection and monitoring of oral lesions, dental anomalies, and aesthetic conditions. AI-based image analysis can facilitate screening and improve diagnostic consistency in routine clinical practice. [17]

➢ **Electronic Health Records**

Electronic health records (EHRs) contain demographic, clinical, behavioral, and treatment-related information. When integrated with imaging data, these records enable AI systems to generate personalized risk assessments, predict treatment outcomes, and support precision dentistry initiatives. [1,3]

The integration of multiple data sources allows AI systems to develop a comprehensive understanding of patient health, thereby improving diagnostic accuracy and enabling more personalized approaches to oral healthcare. [1]



6. Artificial Intelligence in Dental Diagnosis

Artificial intelligence has significantly enhanced diagnostic capabilities in dentistry by enabling rapid analysis of complex clinical and imaging data. Through machine learning and deep learning algorithms, AI systems can identify pathological changes, support clinical decision-making, and improve diagnostic consistency. These technologies have found applications across multiple dental specialties, contributing to earlier disease detection and more accurate treatment planning. [1,3] Figure 2. Shows application of AI in precision dentistry

A. Dental Caries Detection

Dental caries remains one of the most prevalent oral diseases worldwide. Early detection is essential for preventing disease progression and preserving tooth structure. AI-based systems, particularly convolutional neural networks (CNNs), have demonstrated high accuracy in identifying carious lesions on bitewing, periapical, and panoramic radiographs. These systems can recognize subtle radiographic changes that may be difficult to detect during routine examination, thereby improving diagnostic sensitivity and reducing observer variability. [12,18]

Several studies have reported diagnostic performances comparable to experienced clinicians, highlighting the potential of AI as an adjunctive tool for caries screening and risk assessment. [12]

B. Periodontal Disease Assessment

Periodontal diseases are characterized by the progressive destruction of tooth-supporting tissues and remain a major cause of tooth loss globally. Accurate evaluation of periodontal bone loss is critical for diagnosis and treatment planning. AI algorithms have been developed to automatically quantify alveolar bone levels and identify radiographic signs of periodontal disease from panoramic and periapical radiographs. [19]

These systems provide objective measurements, minimize inter-examiner variability, and facilitate disease monitoring over time. AI-assisted periodontal assessment may also contribute to personalized treatment planning by identifying patients at increased risk of disease progression. [3,19]

C. Endodontic Diagnosis

The diagnosis of pulpal and periapical diseases often relies on radiographic interpretation, which can be challenging in complex cases. AI-based image analysis has demonstrated promising results in detecting periapical lesions, root fractures, root canal morphology, and apical pathologies using both conventional radiographs and CBCT images. [20]

Automated detection systems can assist clinicians in identifying lesions that may be overlooked during routine evaluation and improve diagnostic accuracy, particularly in early-stage disease. Additionally, AI has been explored for predicting endodontic treatment outcomes and supporting treatment planning decisions. [4,20]

D. Orthodontic Diagnosis and Treatment Planning

Orthodontics has emerged as one of the most active areas of AI application in dentistry. Machine learning algorithms can perform automated cephalometric landmark identification, skeletal classification, growth prediction, and treatment planning. These systems substantially reduce the time required for cephalometric analysis while maintaining high levels of accuracy. [21]

AI has also been utilized for predicting treatment outcomes, assessing facial profiles, and monitoring tooth movement during orthodontic therapy. Such applications contribute to improved treatment efficiency and individualized patient management. [22]

E. Oral Cancer and Oral Potentially Malignant Disorders

Early detection of oral cancer remains a major challenge in oral healthcare. Delayed diagnosis is frequently associated with poorer prognosis and reduced survival rates. AI-based diagnostic systems have shown encouraging results in identifying oral squamous cell carcinoma and oral potentially malignant disorders through the analysis of clinical photographs, histopathological images, and cytological data. [4]

Deep learning models can identify subtle morphological patterns associated with malignant transformation, supporting early diagnosis and timely intervention. Although these technologies are not intended to replace clinical expertise, they may serve as valuable screening and decision-support tools in oral medicine and pathology. [4,17]

F. Implant Dentistry

Artificial intelligence has increasingly been integrated into implant dentistry for diagnostic assessment and treatment planning. AI algorithms can analyse CBCT scans to identify anatomical landmarks, evaluate bone quality and quantity, and assist in optimal implant positioning. Such systems enhance treatment precision and reduce the risk of complications involving adjacent anatomical structures. [23]

In addition, AI-assisted diagnostic tools contribute to patient-specific treatment planning by evaluating multiple clinical variables simultaneously, thereby supporting more predictable implant therapy. [23,24]

G. Oral and Maxillofacial Radiology

The field of oral and maxillofacial radiology has benefited substantially from advances in artificial intelligence. Deep learning models are capable of detecting impacted teeth, cysts, tumours, maxillary sinus abnormalities, temporomandibular joint disorders, and other maxillofacial pathologies from panoramic radiographs and CBCT images. [13]

AI-assisted image interpretation improves efficiency by reducing the time required for image analysis and highlighting areas of potential concern for clinician review. As image datasets continue to expand, AI is expected to play an increasingly important role in radiological diagnosis and clinical decision support. [1,13]

Overall, AI has demonstrated significant potential in enhancing diagnostic accuracy, improving efficiency, and reducing variability across multiple dental specialties. While these technologies are intended to complement rather than replace clinical judgment, their continued development is expected to strengthen diagnostic workflows and contribute substantially to precision dentistry. [3,7]

7. Artificial Intelligence in Dental Prognosis

While artificial intelligence has gained widespread recognition for its diagnostic capabilities, its role in prognostic assessment is equally significant. Prognosis involves predicting the likely course of a disease and estimating treatment outcomes based on patient-specific factors. By analysing large datasets comprising clinical, radiographic, demographic, and behavioural variables, AI systems can generate predictive models that support personalized treatment planning and long-term patient management. [3,9] Figure 3. shows the workflow of AI in precision dentistry.

- **Prediction of Disease Progression**

Accurate prediction of disease progression is fundamental to preventive and personalized dentistry. Machine learning algorithms can identify patterns associated with the advancement of dental caries, periodontal disease, and other oral conditions by analysing multiple risk factors simultaneously. Such predictive models enable clinicians to identify high-risk individuals and implement preventive interventions before significant disease progression occurs. [11]

AI-based risk prediction models may also facilitate more effective recall scheduling and monitoring strategies, thereby improving overall treatment outcomes and resource utilization. [3]

- **Prognosis of Periodontal Therapy**

Periodontal disease progression is influenced by numerous factors, including oral hygiene practices, smoking status, systemic health conditions, and genetic predisposition. Conventional prognostic assessment often relies on clinician experience and individual risk factors. AI algorithms can integrate these variables to provide more comprehensive and objective prognostic evaluations. [25]

Machine learning models have demonstrated the ability to predict attachment loss, tooth survival, and response to periodontal therapy with promising accuracy. Such predictions may assist clinicians in selecting appropriate treatment strategies and establishing realistic expectations for patients. [26]

- **Implant Survival Prediction**

Predicting the long-term success of dental implants remains an important aspect of implant therapy. AI systems can evaluate multiple clinical and radiographic variables, including bone quality, implant characteristics, systemic health factors, and patient habits, to estimate implant survival rates and identify potential complications. [24]

By providing individualized risk assessments, AI may help clinicians optimize treatment planning, reduce implant failure rates, and improve long-term clinical outcomes. Furthermore, predictive models can support evidence-based decision-making in complex implant cases. [23,24]

- **Orthodontic Treatment Outcome Prediction**

Artificial intelligence has demonstrated considerable potential in forecasting orthodontic treatment outcomes. Machine learning algorithms can analyse craniofacial morphology, growth patterns, cephalometric measurements, and treatment variables to predict treatment duration, tooth movement, and post-treatment stability. [22]

Such predictive capabilities facilitate personalized treatment planning and improve communication between clinicians and patients regarding anticipated treatment outcomes. AI-assisted prognosis may also contribute to more efficient resource allocation and enhanced treatment effectiveness. [22,27]

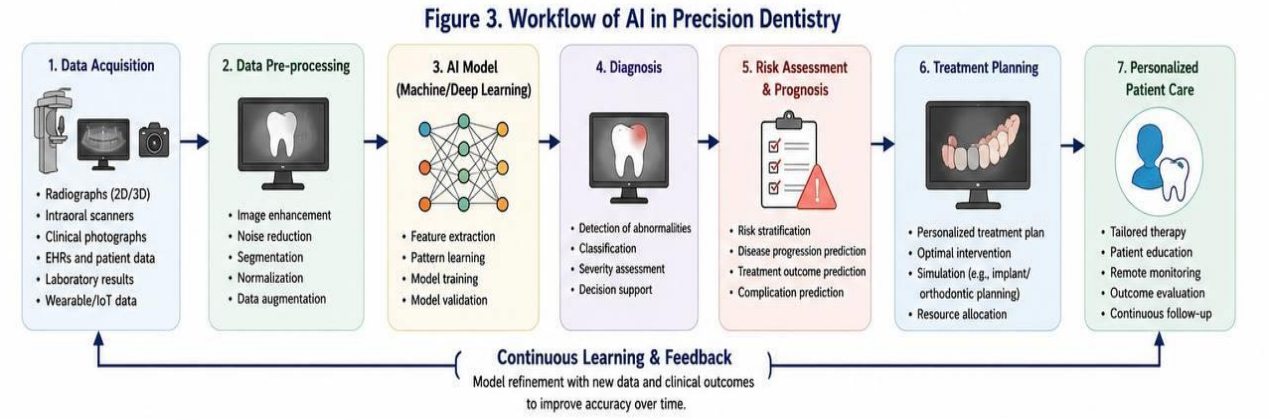
- **Personalized Risk Assessment and Precision Care**

One of the most promising applications of AI in prognosis is the development of personalized risk assessment models. By integrating clinical findings, radiographic information, behavioural factors, and patient history, AI systems can generate individualized risk profiles for various oral diseases. [9]

These models support the principles of precision dentistry by enabling clinicians to tailor preventive and therapeutic interventions according to each patient's specific needs. Personalized prognostic assessment may improve treatment predictability, enhance patient engagement, and contribute to better long-term oral health outcomes. [3,7]

Although AI-based prognostic systems continue to evolve, current evidence suggests substantial potential for improving predictive accuracy and supporting individualized patient care. As larger datasets and more sophisticated algorithms become available, AI is expected to play an increasingly important role in forecasting disease outcomes, optimizing treatment strategies, and advancing precision dentistry. [7,27]

8. Contemporary And Advanced AI Tools In Dentistry [Table]



The transition of artificial intelligence from research settings to clinical practice has led to the development of several commercial AI platforms designed to support diagnosis, treatment planning, patient monitoring, and clinical decision-making. These tools utilize machine learning, deep learning, and computer vision technologies to enhance efficiency and accuracy in dental care. [3,7]

A. Diagnocat

Diagnocat is an AI-powered platform that assists in the analysis of two-dimensional and three-dimensional dental images. It is commonly used for CBCT interpretation, implant planning, airway assessment, and automated radiology reporting. [28]

B. Pearl AI and Overjet

Pearl AI and Overjet are among the most widely adopted dental AI systems for radiographic analysis. These platforms assist in detecting dental caries, assessing periodontal bone loss, identifying restorations, and improving patient communication through visual diagnostic aids. [29,30]

C. VideaHealth and DEXIS AI

VideaHealth and DEXIS AI employ deep learning algorithms to support radiographic interpretation and clinical decision-making. Their applications include detection of carious lesions, calculus deposits, periapical abnormalities, and other common dental conditions. [13,32,33]

D. Dental Monitoring

Dental Monitoring is primarily used in orthodontics and enables remote monitoring of treatment progress through smartphone-based image analysis. The platform facilitates virtual follow-up, improves patient compliance, and reduces the need for frequent clinical visits. [31]

E. Generative AI and Large Language Models

Recent advances in generative AI, including large language models such as ChatGPT, have expanded AI applications beyond image analysis. These tools can assist with clinical documentation, patient education, literature review, research support, and academic writing. Although promising, their outputs require professional verification to ensure clinical accuracy and reliability. [6,26,34]

As AI technologies continue to evolve, the integration of advanced diagnostic platforms and generative AI systems is expected to further enhance precision dentistry by supporting efficient, data-driven, and personalized patient care. [7,26]

AI Tool	Primary Application	Specialty
Diagnocat	CBCT Analysis	Radiology
Pearl AI	Caries Detection	General Dentistry
Overjet	Bone Loss Assessment	Periodontology
Videa AI	Radiographic Analysis	General Dentistry
DEXIS AI	Image Interpretation	Radiology
Dental Monitoring	Remote Monitoring	Orthodontics
ChatGPT	Documentation & Education	Multi-specialty

TABLE -1. Shows the AI tools and their application.

9. Advantages of Artificial Intelligence in Precision Dentistry

Artificial intelligence offers several advantages that contribute to the advancement of precision dentistry. By rapidly processing large volumes of clinical and imaging data, AI systems can improve diagnostic accuracy and reduce variability associated with human interpretation. These technologies facilitate early disease detection, enabling timely intervention and potentially improving treatment outcomes. [1,3]

AI also enhances clinical efficiency by automating repetitive tasks such as image analysis, record evaluation, and treatment planning. Furthermore, predictive algorithms support personalized patient care through risk assessment and prognosis estimation, allowing clinicians to develop individualized treatment strategies. [3,7]

Another important benefit is the integration of multiple data sources, including radiographs, CBCT scans, intraoral images, and electronic health records, to support comprehensive clinical decision-making. Consequently, AI has the potential to improve treatment predictability, optimize resource utilization, and promote evidence-based dental practice. [1,2]

10. Challenges, Ethical Considerations and Limitations

Despite its considerable potential, the implementation of artificial intelligence in dentistry is associated with several challenges. The performance of AI models largely depends on the quality, quantity, and diversity of training datasets. Incomplete, biased, or poorly annotated data may compromise model accuracy and limit generalizability across different populations. [1,3]

Ethical concerns regarding patient privacy, data security, and informed consent remain significant barriers to widespread adoption. Additionally, many AI algorithms function as “black-box” systems, making it difficult for clinicians to fully understand how decisions are generated. This lack of transparency may affect trust and clinical acceptance. [27]

Regulatory issues, legal liability, and the need for extensive clinical validation further complicate integration into routine practice. Importantly, AI should be regarded as a supportive tool rather than a replacement for professional judgment. Human oversight remains essential to ensure accurate interpretation and appropriate clinical decision-making. [3,6]

11. Future Directions

The future of artificial intelligence in dentistry is expected to be driven by advances in explainable AI, multimodal learning, generative AI, and precision healthcare. Emerging systems are increasingly capable of integrating radiographic, clinical, genomic, and behavioural data to provide comprehensive patient assessments and personalized treatment recommendations. [3,7]

Generative AI and large language models may further support clinical documentation, patient education, research activities, and decision-support systems. Additionally, the development of digital twins and predictive healthcare models has the potential to transform dentistry from a reactive discipline into a predictive and preventive healthcare model. [6,14]

As technology continues to evolve, collaboration among clinicians, researchers, data scientists, and regulatory bodies will be essential to ensure the safe, ethical, and effective integration of AI into routine dental practice. [3]

12. Conclusion

Artificial intelligence has emerged as a transformative technology with the potential to redefine modern dental practice. Through applications in diagnosis, prognosis, treatment planning, and patient management, AI contributes significantly to the realization of precision dentistry. Machine learning and deep learning algorithms have demonstrated promising performance in detecting oral diseases, predicting treatment outcomes, and supporting personalized care.

Recent advancements in commercial AI platforms and generative AI technologies have further expanded the scope of clinical and academic applications. However, challenges related to data quality, ethical considerations, transparency, and regulatory compliance must be addressed before widespread implementation can be achieved.

Despite these limitations, current evidence suggests that AI will play an increasingly important role in enhancing diagnostic accuracy, improving prognostic assessment, and supporting evidence-based clinical decision-making. With continued technological advancement and responsible integration, artificial intelligence is poised to become an indispensable component of future dental healthcare, ultimately improving patient outcomes and advancing the principles of precision dentistry. [3,7,13]

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