



## Artificial Intelligence In Dentistry: Current Insights

<sup>1</sup>Dr. Pradnya V. Bansode, <sup>2</sup>Dr. M. B. Wavdhane, <sup>3</sup>Dr. Seema D. Pathak, <sup>4</sup>Dr. Shweta Chavan

<sup>1</sup>Professor & Head, <sup>2,3</sup>Associate Professor, <sup>4</sup>Post Graduate Student,  
Dept. Of Conservative Dentistry and Endodontics,  
Government Dental College And Hospital, Chhatrapati Sambhajanagar

**\*Corresponding Author:**

**Dr. Shweta Chavan**

Post Graduate Student, Dept. Of Conservative Dentistry and Endodontics,  
Government Dental College And Hospital, Chhatrapati Sambhajanagar

Type of Publication: Original Research Paper

Conflicts of Interest: Nil

### Abstract

Artificial intelligence (AI) is a rapidly advancing field that spans a broad range of emerging technologies and continues to reshape multiple sectors of daily life. In healthcare, AI plays a crucial role by enabling the processing and analysis of massive datasets, thereby improving the reliability of diagnostic information and facilitating more effective decision-making. Dentistry, as part of this technological revolution, has increasingly embraced AI-driven methods for diagnosis, treatment planning, and outcome prediction. This review article introduces the fundamental principles of AI, its developmental trajectory and its expanding role in modern dentistry. The review explores how AI is utilized in multiple dental specialties. Evidence suggests that AI-powered systems not only enhance diagnostic accuracy but also reduce clinical workload and streamline patient management. In the future, AI integrated dental care is expected to pave the way for high quality personalized treatment while also advancing research and innovation.

**Keywords:** Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Generative Adversarial Network (GAN), Dentistry, Digital Health

### Introduction

Artificial Intelligence (AI) is changing healthcare by helping computers and humans work together more effectively. Since its beginning in the 1950s, AI has grown to play an important role in the medical field. It has the potential to greatly improve how we diagnose diseases, plan treatments, and make clinical decisions. By using AI, healthcare providers can increase accuracy, lower costs and offer better care to patients. One branch of AI, called robotic process automation can handle routine administrative tasks reducing stress and workload for doctors.

AI also helps uncover useful medical information leading to better decisions and more personalized care. Machine learning (ML) is a type of AI that is

especially helpful in analysing medical images, detecting diseases early, and making accurate diagnoses. AI also improves communication between patients and healthcare providers making services more efficient and tailored to individual needs. Overall, AI is driving innovation, economic growth, and a major shift in healthcare leading to better outcomes and improved systems.

The integration of AI into dentistry represents not merely a technological upgrade but a paradigm shift. As the field progresses, AI has the potential to reduce costs, improve efficiency and provide more consistent outcomes while supporting evidence-based decision-making.

## Key Concepts of Artificial Intelligence

AI has two subdomains

### Machine Learning (ML)

Machine learning refers to algorithms that learn patterns from data and subsequently make predictions or decisions without explicit programming. In dentistry, ML has been applied in caries detection, prediction of periodontal disease progression, and orthodontic treatment planning. Its adaptability and ability to improve with increasing data make ML particularly suited for dental diagnostics.

### Deep Learning (DL)

Deep learning is a more advanced subset of ML that uses multi-layered artificial neural networks (ANNs) to process information. Inspired by the architecture of the human brain DL algorithms autonomously learn hierarchical features from raw data. These models are especially powerful in image and speech recognition which are central to radiographic interpretation and diagnostic imaging in dentistry.

- **Artificial Neural Networks (ANNs):** Composed of interconnected nodes (“neurons”). ANNs process data in layers—input, hidden, and output. Each neuron applies transformations that help the system refine and optimize outputs.
- **Convolutional Neural Networks (CNNs):** Specialized for image recognition and classification. CNNs excel in tasks like analysing bitewing radiographs, intraoral scans, and panoramic images for pathologies.
- **Recurrent Neural Networks (RNNs):** Designed for sequential data processing. RNNs are effective in natural language processing and could potentially assist in analysing sequential dental records or time-based treatment outcomes.

While ANNs handle general problem-solving, CNNs are tailored for image-based diagnostics, and RNNs provide insights into temporal data, making the trio complementary in modern dental applications.

### Artificial Intelligence in Dentistry

The application of AI within dentistry has expanded rapidly in recent years. Its uses can be broadly categorized into:

- **Diagnosis** (e.g. caries, lesions, periodontal disease)
- **Decision-making** (e.g. treatment vs. retreatment)
- **Treatment planning** (e.g. orthodontic simulations, prosthodontic restorations)
- **Outcome prediction** (e.g. prognosis after endodontic therapy)

Among these, **diagnosis** is currently the most advanced and widely adopted application. By enabling faster and more precise interpretation of radiographs and clinical images AI reduces dentist’s workload while enhancing diagnostic reliability.

### Role of AI in Conservative Dentistry

#### Caries Detection

Traditional caries diagnosis often involves visual, tactile examination and bitewing radiographs. However, radiographic interpretation can vary significantly between clinicians, leading to false positive or negative results. CNN-based models offer a solution by improving accuracy and consistency.

- Studies using CNNs trained on intraoral photographs achieved detection accuracies exceeding 90%.
- When applied to bitewing radiographs, AI systems increased detection sensitivity from 44% to 75% significantly outperforming unaided dentists.
- Software such as *dentalXrai* demonstrated higher accuracy in identifying enamel caries compared with conventional diagnosis, though caution remains necessary to avoid overtreatment.

Overall, AI shows remarkable potential in early caries detection particularly for non-cavitated lesions where human judgment may be limited.

#### Detection of Tooth Preparation Margins

Determining precise tooth preparation margins is critical for ensuring proper fit and longevity of dental restorations. Manual delineation is often time-consuming and error prone.

In digital dentistry, margin line determination may be performed through three methods –

**a) Manual-** The manual method is simple for the operator to manually choose feature points on the tooth preparation model while it can be less efficient.

**b) Semiautomatic-** In semiautomatic method, the operator chooses multiple feature points sequentially on the path of the tooth feature line while employing a search algorithm to instinctively extract the margin line between the feature points. This technique is simple but inefficient.

**c) Automatic-** In the automatic method the feature line is automatically extracted based on the curvature and topological relationship by using differential geometry. This method is more automated and efficient while minimizing manual interventions.

CNN-based models have demonstrated over 97% accuracy in automatically mapping finish lines, significantly reducing the need for manual intervention.

### **Tooth Restoration Design**

Computer-aided design and Computer-aided manufacturing (CAD/CAM) has already revolutionized restorative dentistry. Integrating AI into CAD workflows further enhances precision by automating crown and bridge design. Systematic reviews showed that AI generated reconstructed designs more closely resembled natural teeth and offered improved efficiency as compared to traditional crowns.

### **Tooth Shade Determination**

Achieving natural shade matching remains one of the most challenging aspects of restorative dentistry. CNNs combined with spectrophotometry and digital photography allow for objective color analysis and improved reproducibility. Back-propagation neural networks and fuzzy logic models contribute to adaptability across diverse datasets, capturing and accounting for variability in tooth shades. AI integration further improves precision by recognizing subtle variations in teeth color, providing more consistent aesthetic outcomes.

### **Smile Designing**

AI powered smile design platforms can simulate post-treatment results using patient specific facial and dental data. This not only aids personalized treatment planning but also enhances communication by

allowing patients to visualize expected outcomes before committing to procedures.

### **Role of AI in Endodontics**

#### **Detection of Periapical Lesions**

Apical periodontitis is a prevalent condition. It accounts for approximately 75% of cases involving radiolucent jaw lesions. Timely detection of periapical lesions becomes paramount in enhancing treatment efficacy, preventing the spread to adjacent tissues and mitigating potential complications.

Common radiographic techniques to diagnose pulp and periapical diseases are intraoral periapical radiographs (IOPA), orthopantomograms, and cone-beam computed tomography (CBCT) imaging.

In a meta-analysis, CBCT imaging demonstrated superior accuracy scores for identifying periapical lesions compared with traditional IOPA radiographs and digital radiographs. Notably, the accuracy of CBCT imaging diminishes in diagnosing apical periodontitis in teeth with filled roots, limiting its use to specific clinical scenarios due to its high cost and radiation exposure. The distinctive features of periapical radiolucency and alveolar bone resorption provide valuable foundations for developing AI models aimed at detecting periapical pathology and apical periodontitis. Deep learning algorithms trained on panoramic and periapical radiographs have demonstrated diagnostic accuracies above 90% rivalling the performance of experienced clinicians. AI-based tools such as *Diagnocat* have shown sensitivity and specificity exceeding 90% in identifying apical pathosis.

#### **Vertical Root Fracture Diagnosis**

Vertical root fractures (VRFs) are notoriously difficult to identify. AI models applied to CBCT images have demonstrated superior diagnostic accuracy compared with conventional radiographs. Advanced techniques such as wavelet analysis further enhance detection by filtering noise in imaging data.

#### **Predicting Postoperative Pain**

Artificial neural networks can predict post-treatment pain by analysing multiple clinical variables. Studies suggest ANN-based models can provide accurate prognosis, assisting clinicians in preparing patients for post-endodontic discomfort and selecting appropriate pain management strategies.

## Root and Root Canal Morphology

CBCT imaging combined with AI has proven valuable in detecting missed canals and complex root anatomies, such as C-shaped canals. For example, AI algorithms achieved diagnostic accuracies exceeding 85% in identifying extra roots or accessory canals.

## Determination of Working Length

Accurate working length measurement is crucial for successful root canal therapy. ANN-based systems have outperformed clinicians in identifying apical constrictions on radiographs achieving up to 96% accuracy compared with 76% for endodontists.

## Decision-Making in Retreatment

Endodontic retreatments carry a risk of failure. AI decision-support systems using case-based reasoning have achieved over 80% accuracy in predicting retreatment outcomes, helping clinicians decide between retreatment and extraction more reliably.

## Virtual Dental Assistants for Patient Management

AI-driven assistants now manage scheduling, insurance processing, and preliminary diagnosis, freeing up human resources. These systems can access patient history, habits, emergency needs, providing continuity of care even in the absence of the primary dentist.

## AI in Periodontics

Periodontal disease remains a global health burden. Early detection is critical for preventing tooth loss, yet conventional clinical indices such as the Periodontal Screening Index have limitations.

CNN-based models have been used to detect periodontal bone loss on panoramic radiographs with promising accuracy. Similarly, algorithms analysing systemic health data have shown potential in predicting periodontal conditions, underscoring AI's utility in both diagnosis and risk assessment.

## AI in Orthodontics

Orthodontic diagnosis and treatment planning are highly individualized, requiring analysis of numerous variables. AI applications in this field include:

- Automating cephalometric landmark identification for skeletal analysis.

- Predicting treatment outcomes and simulating facial changes pre and post treatment.
- Enhancing patient communication by visualizing results in a clear and personalized manner.

By integrating patient specific data, AI significantly reduces the subjectivity and time required in orthodontic planning.

## AI in Oral and Maxillofacial Pathology

Pathological conditions in the oral cavity particularly oral cancer require accurate and timely diagnosis. AI has been applied to radiographic, histopathological and ultrasonographic images for tumor detection, achieving high diagnostic accuracy. Additionally, AI contributes to cleft lip and palate management by aiding in diagnosis, surgical planning and speech assessment.

## AI in Prosthodontics

Prosthodontics has embraced AI in restoration design, shade matching and workflow optimization. Generative Adversarial Network (GAN) based models have successfully generated realistic crown morphologies, while AI-assisted CAD/CAM systems streamline the design and fabrication process. AI has also been utilized in predicting debonding risks of CAD/CAM restorations and in classifying dental arches for removable denture design.

## Limitations and Future Applications

Despite encouraging results, several limitations hinder the widespread adoption of AI in dentistry:

- Dataset Limitations:** Many models are trained on limited datasets from single institutions, so it can't be generalized to all applications.
- Human Bias:** Operator-labelled training data may introduce subjectivity.
- Technical Variability:** Differences in imaging devices and protocols may reduce model reliability across clinics.

Future research must prioritize large, diverse, multi-centre datasets and explore automated labelling to minimize bias. Moreover, integrating AI into real-world dental workflows will require clinician training, ethical considerations, and regulatory approval.

## Conclusion

Artificial intelligence is emerging as a transformative force in dentistry. From caries detection to complex orthodontic planning, AI enhances diagnostic precision, streamlines workflows, and improves patient outcomes. While current applications are promising, the future lies in addressing dataset limitations, reducing bias and strengthening interdisciplinary collaboration. With careful implementation, AI has the potential to become an indispensable tool for clinicians, ensuring more efficient, accurate and patient centred dental care.

#### References:

1. Ahmed ZH, Almuharib AM, Abdulkarim AA, et al. Artificial Intelligence and Its Application in Endodontics: A Review. *J Contemp Dent Pract* 2023;24(11):912–917.
2. Najeeb, M., Islam, S. Artificial intelligence (AI) in restorative dentistry: current trends and future prospects. *BMC Oral Health* 25, 592 (2025). <https://doi.org/10.1186/s12903-025-05989-1>
3. Arjumand B. The application of artificial intelligence in restorative dentistry: A narrative review of current research. *Saudi Dent J*. 2024;36(6):835–40.
4. Veseli E. Revolutionizing dentistry: the integration of artificial intelligence and robotics. *KHYBER Med Univ J*. 2024;16(4).
5. Umer F, Habib S. Critical analysis of artificial intelligence in endodontics: A scoping review. *J Endod* 2022;48(2):152–160.
6. Tabatabaian F, Vora SR, Mirabbasi S. Applications, functions, and accuracy of artificial intelligence in restorative dentistry: A literature review. *J Esthet Restor Dent*. 2023 Sep;35(6):842-859. doi: 10.1111/jerd.13079. Epub 2023 Jul 31. PMID: 37522291.
7. Shan T, Tay FR, Gu L. Application of artificial intelligence in dentistry. *J Dent Res*. 2021;100:232-244.
8. Binhuraib H, Aloqayli S, Alkhalifah S, Aljohani A, Alotaibi R, Almalki R, et al. Digital shade matching techniques in fixed prosthodontics. *J Healthc Sci*. 2024;04(01):34–40.
9. Albalawi F, Alamoud KA. Trends and application of artificial intelligence technology in orthodontic diagnosis and treatment planning—A review. *Appl Sci* 2022;12(22):11864. DOI: 10.3390/app122211864.
10. Hung K, Montalvao C, Tanaka R, Kawai T, Bornstein MM. The use and performance of artificial intelligence applications in dental and maxillofacial radiology: a systematic review. *Dentomaxillofac Radiol*. 2020;49:20190107.
11. Bernauer SA, Zitzmann NU, Joda T. The use and performance of artificial intelligence in prosthodontics: a systematic review. *Sensors (Basel)*. 2021;21:6628.