

ARTIFICIAL INTELLIGENCE AND ITS APPLICATIONS IN RESTORATIVE  
DENTISTRY- A NARRATIVE REVIEWDr. Pallavi Bhat<sup>\*1</sup>, Dr. Trivikram<sup>2</sup> and Dr. Poornima Bhat<sup>3</sup><sup>1</sup>Department of Conservative Dentistry, A.J. Institute of Dental Sciences, Mangalore, Karnataka, India-575004.<sup>2</sup>Consultant Orthopedic Surgeon, Mangalore, Karnataka, India.<sup>3</sup>Dental Surgeon, Bangalore, Karnataka, India.**\*Corresponding Author: Dr. Pallavi Bhat**

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Article Received on 23/07/2024

Article Revised on 13/08/2024

Article Accepted on 03/09/2024

**ABSTRACT**

Artificial intelligence (AI), has been called the fourth industrial revolution owing to its capacity to mimic human intelligence. Artificial Intelligence (AI) in dentistry is becoming progressively more prevalent within the fields of dental radiography, imaging and pathology, caries detection, electronic record keeping, and robotic support. With its ability to solve several clinical issues and ease the workload of doctors, artificial intelligence (AI), which has been utilized in the healthcare industry for decades, has the potential to completely transform dentistry. The potential applications of artificial intelligence (AI) in restorative dentistry are addressed in this review. The current article emphasizes the significance of artificial intelligence (AI) in maximizing accuracy, efficiency, and its applications in restorative dentistry by delving into the history of AI and its implications in medicine and dentistry. It briefly highlights the classification of artificial intelligence (AI) and the perspectives of patients and dentists on AI. Insights into the shortcomings, ethical dilemmas, and potential developments are included in the review's conclusion, which highlights the necessity for perpetual advancement in AI-driven restorative dentistry.

**KEYWORDS:** artificial intelligence, dentistry, machine learning, restorative dentistry, deep learning.**INTRODUCTION**

Machines capable of executing tasks that usually require human intelligence are regarded as having artificial intelligence (AI). Robotics, automobiles, financial analysis, and many other sectors have embraced AI. It has also been applied to medicine and dentistry, including drug development, hospital monitoring, decision assistance, imaging diagnostics, robotic and virtual assistants, and heart disease prediction.<sup>[1]</sup> AI can perform tasks more accurately and precisely than humans with appropriate training.<sup>[2]</sup> This review briefly explains the history and classification of AI, emphasizing the recent developments of AI in restorative dentistry, patient and doctor perspectives of AI. The Ethical considerations and drawbacks of AI are also analyzed.

**SEARCH STRATEGY**

A search of PubMed indexed database over the last 10 years (custom range: 04-2014 to 04-2024) was conducted using keywords/phrases like "artificial intelligence" and "restorative dentistry". The same search terms were used to search the Google Scholar database. The last search was performed on May 1, 2024. A manual search was also conducted and relevant articles were included. A collection of articles all in the English language conducted in the previous ten years was shortlisted.

Additionally, citation lists of some chosen papers were examined for potential inclusion. All of the chosen papers' titles and abstracts were examined, and after confirmation, the articles' texts were examined for possible inclusion. The articles considered suitable for inclusion were examined and discussed in various sections and subsections of this narrative review. More emphasis was laid on the applications of AI in restorative dentistry.

**HISTORY**

AI was interpreted by Turing as "machine thinking" in his paper.<sup>[3]</sup> He recommended testing if a machine can become as intelligent as a human. We call this the Turing test. A machine is considered to possess "machine intelligence" and passed the Turing Test if a human assessor is unable to discern between a machine and the human examinee. AI expanded rapidly between 1957 and 1974. One example is ELIZA, an operating system that comprehends spoken language and manages issues through text.<sup>[4]</sup> It evolved in two ways in the 1980s: expert systems and machine learning (ML). A deep learning (DL) network with graphics processing unit (GPU) implementation was created in 2012.<sup>[5]</sup> Lately, ChatGPT (Chat Generative Pre-trained Transformer), an AI engine that produces text results that

resemble those of a human being was introduced.<sup>[6]</sup>

## AI IN HEALTHCARE AND DENTISTRY

AI has already been applied to several medical specialties, including robotic surgery and cognitive behavior therapy in psychiatry.<sup>[7,8]</sup> Surgeons only must reorient their eyes to move the camera.<sup>[9]</sup> The smartphone app AiCure helps patients manage their medications.<sup>[10]</sup> Apple and Fitbit can track sleep, activity, and heart rate.<sup>[8]</sup> AI is said to diagnose and treat patients accurately, which benefits patients as well as doctors.<sup>[11]</sup> ANN models were used for decision-making in orthodontic patients for extraction as well as for diagnosis, treatment planning, and implementation in restorative dentistry. This was based on the assumption that taking into consideration all the characteristics and specifics of a case may occasionally be difficult for dentists to analyze and treat due to its complexities and intricacies.<sup>[12–20]</sup>

## CLASSIFICATION

There are two types of AI: weak AI and strong AI. Weak AI employs a program designed to manage a single or narrow set of activities; examples include Amazon chat robot, Google translation, and computer vision (such as Tesla Autopilot and face recognition).<sup>[21]</sup> Strong AI is defined as AI with capabilities and intelligence at the same level as humans.<sup>[22]</sup> Since there are ethical concerns and potential risks associated with strong AI research, no strong AI applications have been developed to date. Expert systems and machine learning are two distinct subsets of weak AI. Machine Learning includes deep learning as a subset. An artificial "neural network" having at least three nodal layers—input, multiple "hidden," and output layers—is referred to be "deep." Artificial neural networks (ANNs), convolution neural networks (CNNs), and generative adversarial networks (GANs) are the three main forms of neural networks (NNs). An ANN is a fundamental version of deep learning that consists of an array of neurons.<sup>[23]</sup> CNN, another deep learning model, is utilized for the creation and identification of images.<sup>[24]</sup> Goodfellow *et al.*<sup>[25]</sup> developed a deep learning algorithm known as GAN to produce new data that is comparable to input data.<sup>[23]</sup>

## APPLICATIONS OF AI IN RESTORATIVE DENTISTRY

### 1. Detection of carious lesions

AI can help with caries detection on bitewings and improve caries diagnosis.<sup>[26–28]</sup> This could be cost-effective, due to its increased sensitivity in the diagnosis and arrest of initial caries lesions.<sup>[29,30]</sup> A recent study published in Feb. 2024 by Das *et al.*<sup>[31]</sup> showed that AI-based software was 89% accurate when detecting dental caries from intraoral radiographs while human interpretation was 86% accurate. Based on a systematic review the accuracy of AI models in predicting caries ranges from 83.6% to 97.1% across various studies.<sup>[32]</sup> Tooth Surface Loss can be fairly accurately predicted using ANN.<sup>[33]</sup>

### 2. Tooth preparation margins

According to a recent study published in January 2024, AI design enhances productivity, accuracy, execution time, and marginal adaptation when compared to traditional techniques.<sup>[34]</sup> A systematic review in November 2022 found that the accuracy of AI models used to locate the finish line following tooth preparation ranged from 90.6% to 97.4%.<sup>[32]</sup>

### 3. Restoration Detection

One of the most recent advances in AI is no-code computer vision, used in a study where dental restorations on panoramic radiographs were identified appropriately.<sup>[35]</sup> Deep learning was employed by Takahashi *et al.*<sup>[36]</sup> to identify 11 different kinds of restorations and prostheses using 36 YOLOv3 AI systems which improves the identification of color restorations. AI models are also utilized through images to anticipate restoration failures and to extend the life of composite restorations by predicting the debonding of the resins.<sup>[37]</sup>

### 4. Design of Tooth Restoration

AI models can be implemented for both the occlusal surface design and the automated manufacturing of dental restorations through customized reconstruction.<sup>[38]</sup> A 3DDCGAN network, which used 3D data effectively in the crown manufacturing process, was described by Ding *et al.*<sup>[39]</sup> and the anatomy of the developed crowns was comparable to that of natural teeth. The recommended restorative material for a specific tooth preparation can also be determined by the CBR (Case-Based Reasoning) AI model.<sup>[37]</sup>

### 5. Smile Design & Tooth Shade

Bellus 3D Dental Pro Integration software links the treatment plan, patient's face, and 3D visualization of the result improving the patient's satisfaction and simplifying the process.<sup>[40]</sup> Digital Smile Design (DSD) combines PowerPoint and Keynote with digital images of the patient's smile aiding to create personalized treatment plans. Intraoral scans and computed tomography scans can all be utilized in the 3-D version.<sup>[41]</sup> DentShadeAI estimates the closest VITA shade guide and helps take pictures with a smartphone camera without the need for a controlled light source.<sup>[42]</sup> A systematic review published in November 2023 found that the decision tree regression model had the highest accuracy (99.7%) in predicting dental hues followed by the fuzzy decision (99.62%), and support vector machine using cross-validation (97%).<sup>[43]</sup>

### 6. Cracked Tooth

According to Juncheng Guo *et al.*, a CNN model was employed to aid in the diagnosis of cracked teeth; however, this was done on simulated cracked teeth, and its accuracy in the clinical identification of cracked teeth has to be tested.<sup>[44]</sup>

## PATIENT PERSPECTIVES

A third of the participants in a study said that by using AI and involving patients in the diagnosis and treatment process, AI in the dental field might enhance professional relationships and improve its prominence. Furthermore, the fact that 330 patients participated in the survey and that only 18 patients chose not to, reflects the level of interest dental patients have in AI. Nevertheless, a third of the patients were worried about potential price hikes.<sup>[45]</sup>

## DOCTORS PERSPECTIVES

In a study using questionnaires, 460 dental professionals and students participated; 94.13% had a fair notion about AI and how it functions (73.30%). The majority (92.39%) said AI should be included in dental academic programs, whereas a significant percentage (35.87%) opposed the idea, fearing that AI would eventually replace clinicians (76.52%).<sup>[46]</sup> According to a different study, dental students understand AI rather well, but they know less about its implications in dentistry. As a result, continuing education (CE) for practitioners and lectures for students must be implemented by dental schools and organizations.<sup>[47]</sup>

## ETHICS

For implementing AI ethically in dentistry, patients should be informed about the use of their data and AI-based decision-making, particularly if there is no legal framework in place, also if AI is used to save costs rather than enhance patient health.<sup>[48]</sup> Rokhshad *et al.* listed eleven aspects in a checklist: accountability and responsibility, respect for autonomy, decision-making, diversity, openness, wellness, privacy protection, solidarity, equity, prudence, law and governance, and sustainable development. When creating, implementing, or accepting AI applications in dentistry, these guidelines must be taken into account.<sup>[49]</sup>

## LIMITATIONS

Even while AI seems extremely remarkable and promising, there are drawbacks, like security vulnerabilities and the need for regular human supervision and its lack of empathy for patients. Concerns have been raised about the quality, ethical issues, and the likelihood that students would become unduly dependent on AI at the expense of their capacity to think analytically.<sup>[50]</sup>

## CONCLUSION

When compared to traditional approaches, AI models have demonstrated promising performance in the mentioned aspects of restorative dentistry, according to the current literature. However, since these models are still in development, more research is needed to confirm their efficacy and implement them in routine clinical practice.

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