ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun1653

From Pulp to Pixels: The Integration of AI in Endodontic Practice

Dr. Mitali Manwar[1]; Dr. Manthan Chavan[2]; Dr. Ashima Mathur[3]; Dr. Yogender Kumar[4*]; Dr. Deepak Sharma[5]; Dr. Azhar Zeya[6]

[1](Post Graduate Student); [2](Post Graduate Student); [3](Post Graduate Student); [4](Professor); [5](Sr. Lecturer); [6](Sr. Lecturer)

[1,2,3,4,5,6]Department of Conservative Dentistry and Endodontics, Darshan Dental College and Hospital, Udaipur (Rajasthan)

Corresponding Author: Dr. Yogender Kumar[4*]

Publication Date: 2025/07/01

Abstract: Artificial intelligence (AI) has emerged as a powerful tool capable of simulating human reasoning to improve prediction and decision-making in healthcare. In dentistry, particularly in endodontics, AI is increasingly being utilized for its high precision in diagnosing and forecasting dental conditions. This technology has the potential to enhance treatment accuracy and improve clinical outcomes. Despite its promise, the routine use of AI in clinical practice still requires validation in terms of its dependability, practical implementation, and cost-efficiency. This review focuses on examining the existing roles of AI in endodontics and considers its future potential in transforming endodontic care.

Keywords: *AI, Machine Learning, Accuracy, Operational, Artificial Models.*

How to Cite: Dr. Mitali Manwar; Dr. Manthan Chavan; Dr. Ashima Mathur; Dr. Yogender Kumar; Dr. Deepak Sharma; Dr. Azhar Zeya (2025) From Pulp to Pixels: The Integration of AI in Endodontic Practice. *International Journal of Innovative Science and Research Technology*, 10(6), 2209-2216. https://doi.org/10.38124/ijisrt/25jun1653

I. INTRODUCTION

Endodontics is a specialized branch of dentistry concerned with the etiology, diagnosis, prevention, and treatment of diseases and injuries involving the dental pulp and periapical tissues. It primarily focuses on root canal therapy, retreatments, endodontic surgeries, and management of dental trauma. Root canal treatments are particularly complex, requiring precise knowledge of root canal anatomy, effective disinfection, and complete obturation to ensure long-term success. Clinical outcomes are heavily dependent on accurate diagnosis, radiographic interpretation, and the clinician's ability to navigate challenging anatomies and pathological conditions.[1]

Despite advances in imaging, materials, and instrumentation, challenges remain in achieving consistently high success rates in endodontic procedures. Diagnostic errors, anatomical variations, missed canals, and treatment planning inconsistencies contribute to failures.[2] These complexities have created an opportunity for advanced technologies, particularly Artificial Intelligence (AI), to support and enhance decision-making in endodontic practice.

Artificial Intelligence (AI) refers to the simulation of human intelligence by machines that are capable of performing tasks such as reasoning, learning, pattern recognition, and problem-solving. Within healthcare, AI encompasses subfields like machine learning (ML), deep learning (DL), natural language processing (NLP), and computer vision, each enabling different levels of data interpretation and automation.[3] These technologies have shown transformative potential in radiology, pathology, and personalized medicine, and are now increasingly being applied across various dental disciplines, including endodontics.[4]

In endodontics, AI is proving to be a powerful tool in diagnostic radiology, predictive modelling, and clinical decision support. One of its most notable applications is in radiographic interpretation, where AI models—particularly Convolutional Neural Networks (CNNs)—have demonstrated high accuracy in detecting periapical lesions, evaluating root canal morphology, and assessing obturation quality in digital periapical and cone-beam computed

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun1653

tomography (CBCT) images.[5] AI-based segmentation tools are also assisting in the automatic detection of root fractures, missed canals, and other critical anatomical features, improving diagnostic efficiency and reducing interobserver variability.[6]

Another growing field is the use of AI in prognostic analysis. By analysing clinical, demographic, and procedural data, machine learning algorithms can predict the likelihood of treatment success or failure, helping clinicians to make more informed treatment choices. This is particularly useful in retreatment cases and for identifying patients at higher risk for complications.[7]

AI is also making strides in endodontic education and training. Intelligent virtual simulation platforms and automated feedback systems are enabling dental students to practice complex procedures in realistic environments while receiving tailored, data-driven feedback on their performance. [8] These tools contribute to the development of clinical competence and improve standardization in dental training. Moreover, AI's potential to streamline workflow and clinical documentation through voice- assisted charting, automatic image annotation, and decision support systems is contributing to greater efficiency in practice management. As AI continues to evolve, its integration with electronic dental records and digital imaging platforms is expected to further enhance clinical productivity and patient outcomes.[9]

This article aims to provide a comprehensive review of the current applications of artificial intelligence in endodontics, including its use in diagnosis, treatment planning and execution, and outcome prediction. It also discusses emerging AI technologies that may enhance future treatment outcomes for patients.

II. KEY ELEMENTS IN ARTIFICIAL INTELLIGENCE

Understanding the fundamental components of modern artificial intelligence (AI) systems is essential for gaining a comprehensive insight into the field.

- *Machine Learning (ML)* is a central component of AI that involves statistical models and algorithms that enable computers to learn from and make predictions on data without being explicitly programmed. It is categorized into:

- Supervised learning: Learning from labelled data to predict outcomes.
- Unsupervised learning: Discovering patterns in unlabelled data.
- Reinforcement learning: Learning through interaction and feedback from the environment.10

- *Deep Learning (DL)* is a subfield of ML that uses neural networks with many layers (deep neural networks). These models are capable of automatically learning high-level features from raw data, making them particularly effective for tasks like speech recognition, image classification, and autonomous driving. Deep learning systems require large amounts of data and computational power, often supported by GPUs and cloud-based platforms. [11,12]

- *Data Science* is the interdisciplinary field that combines computer science, statistics, and domain-specific knowledge to extract insights from data. It plays a critical role in AI development by preparing and analysing data for training machine learning models. Key tasks in data science include data cleaning, exploratory data analysis (EDA), feature engineering, and data visualization.[12]

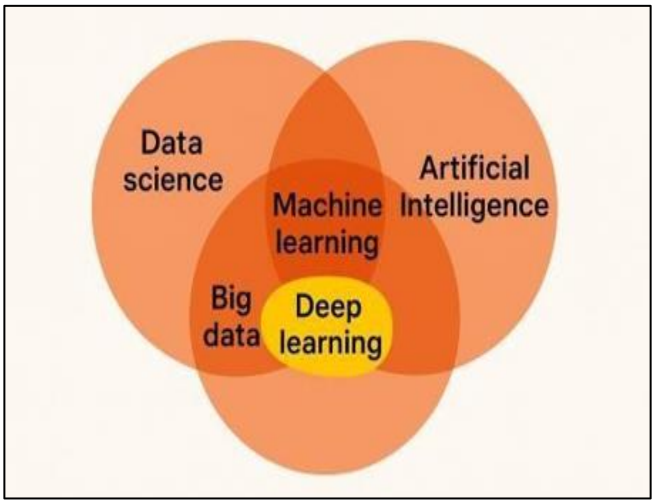

Fig 1 Key Elements in Artificial Intelligence[7]

- *Big Data* refers to data sets that are large, complex, and generated at high speed. The concept is often characterized by the five Vs: Volume, Velocity, Variety, Veracity, and Value. AI systems depend on big data to improve accuracy and make more informed predictions. Technologies such as Hadoop, Spark, and cloud-based analytics platforms are commonly used to handle big data.[14,15]

III. OPERATING MECHANISM OF ARTIFICIAL MODELS

Artificial Intelligence (AI) systems typically function through two key phases: training and testing.

In the training phase, models are built using historical data—such as annotated images or patient records—to learn patterns and adjust internal parameters using optimization algorithms. The aim is to minimize prediction errors and generalize well to unseen inputs. [16] Following this, the testing phase evaluates the model's performance on new data to measure how accurately it can make predictions outside its training set, using metrics like accuracy and F1-score.

Earlier AI systems were often viewed as "black boxes," producing results without insight into how those outcomes were reached (see Figure 2a). This lack of transparency posed risks, especially in critical fields like medicine or

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun1653

finance.[17] However, modern AI models increasingly incorporate interpretability. Tools such as LIME, SHAP, and saliency maps now help visualize which input features contributed to a model's decision. For example, when identifying an image of a cat, the model can generate a heatmap highlighting relevant features like ears or eyes, rather than background elements (see Figure 2[b]).[18] Such interpretability enhances trust and safety, ensuring AI decisions are based on meaningful data features, not irrelevant noise. This is crucial for responsible use in high-stakes environments, where understanding AI reasoning supports transparency, accountability, and user confidence.[19]

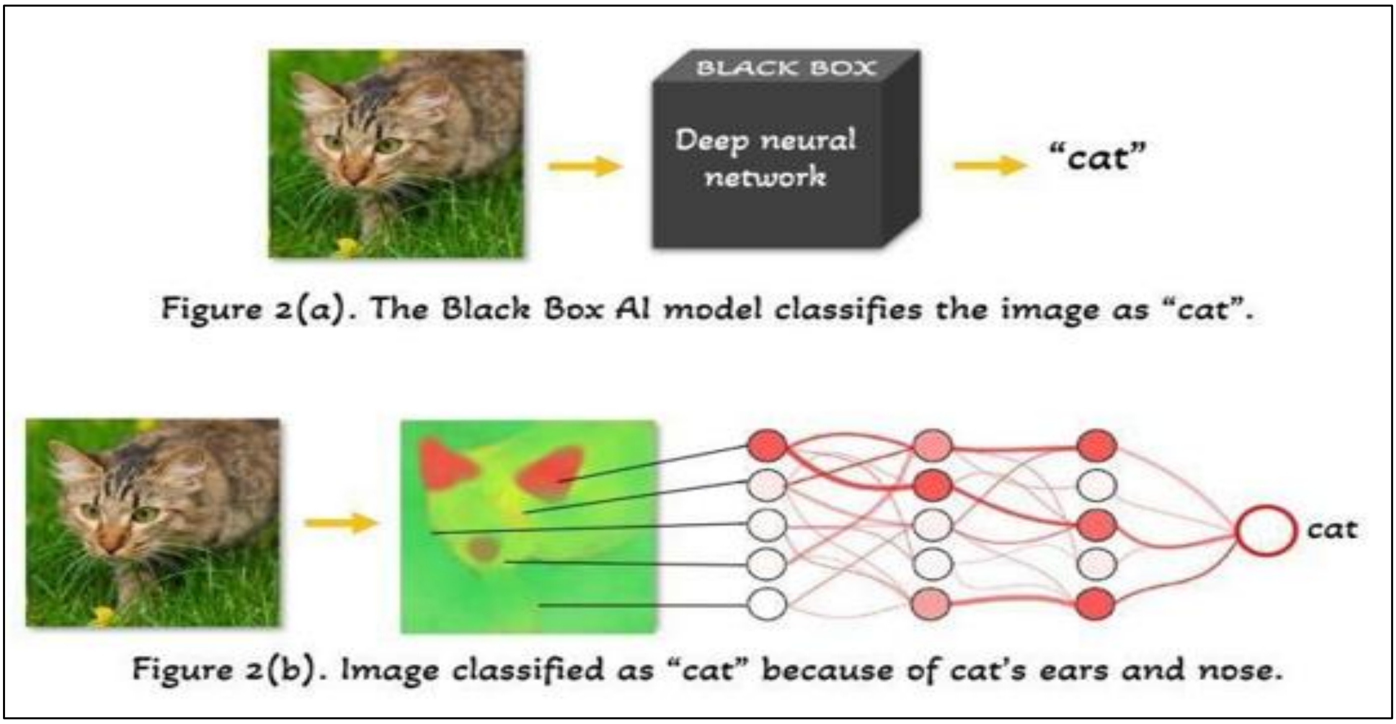

Fig 2 Mechanism of Artificial Models (a) Black Box Identifies Image as "cat''
(b)Image Classified as Cat because of Cat's Ear & Nose.

IV. WORKING PRINCIPLE OF AI IN ENDODONTICS

In the field of endodontics, artificial intelligence functions by evaluating extensive collections of dental images and clinical data to improve diagnostic accuracy and treatment planning. Using machine learning techniques, AI can interpret X-rays and cone-beam computed tomography (CBCT) scans to detect patterns and abnormalities related to pulp disorders or root canal conditions. [20]

Neural networks further assist by identifying subtle details such as fractures or lesions that might escape human detection. In addition to diagnosis, AI tools can forecast treatment results and offer customized therapeutic suggestions. As these systems are exposed to more data over time, their predictive accuracy increases, empowering endodontists to make better-informed decisions and deliver more targeted, effective care. [21]

V. VARIOUS APPLICATION OF AI IN ENDODONTICS

In dentistry, and more specifically endodontics, AI applications are rapidly expanding. It significantly enhances clinical precision and efficiency. Deep learning algorithms have demonstrated superior performance in detecting apical lesions, root fractures, and complex canal morphologies from radiographs and CBCT scans improving diagnostic accuracy beyond what may be visible to the human eye.[22] AI tools can estimate working length and identify canal curvature, assisting practitioners in performing safer and more effective root canal procedures. Additionally, machine learning systems are capable of evaluating pre- and post-operative radiographs to assess healing and detect potential failures. In treatment planning, AI applications can integrate clinical data and imaging findings to suggest optimal intervention strategies, reducing uncertainty and increasing procedural confidence. [23,24]

Beyond clinical functions, AI-driven platforms streamline the administrative side of endodontic practice, from generating personalized patient reports to managing treatment schedules and insurance claims. Patient-facing technologies, such as AI chatbots, offer instant responses to common questions, provide aftercare instructions, and schedule follow-ups contributing to better patient education and adherence.[25]

AI also plays a growing role in dental education and training, where virtual simulations and diagnostic challenges supported by AI can help dental students and professionals refine their skills. Overall, the integration of AI into

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun1653

endodontics and broader dental practice fosters a more accurate, efficient, and patient-centered approach to care.[26] As these technologies continue to evolve, AI is expected to support even more sophisticated diagnostics, predictive analytics, and personalized treatments redefining the standards of dental care and transforming both patient and provider experiences.[27]

➢ *AI in Diagnosis*

AI-driven diagnostic systems, particularly those leveraging deep learning and convolutional neural networks (CNNs), can process and interpret complex imaging data such as periapical radiographs, panoramic X-rays, and cone-beam computed tomography (CBCT) scans. These tools are trained on vast datasets containing thousands of labelled images, which allows them to learn patterns associated with a wide range of dental pathologies. As a result, AI systems are capable of identifying early signs of conditions such as pulpitis, dental caries, apical periodontitis, vertical root fractures, bone loss, and other periapical or periodontal lesions—sometimes even before they become clinically or radiographically obvious to human observers.[28]

One of the key advantages of AI in diagnosis is its ability to minimize inter-observer variability and reduce diagnostic errors due to fatigue, oversight, or inexperience. By functioning as a decision- support system, AI enhances clinicians' diagnostic confidence and helps ensure that subtle or rare anomalies are not overlooked.[29] For example, in a landmark study by Lee et al., a deep learning- based CNN model was developed and tested using 4,129 annotated periapical radiographs. The AI system demonstrated high accuracy in detecting dental caries and periapical inflammation, performing comparably to experienced human examiners. This study exemplifies how AI is not only augmenting diagnostic capability but also standardizing evaluation criteria across clinical settings.[30]

Furthermore, AI models integrated into diagnostic platforms can provide real-time analysis, highlighting suspect regions on dental images and offering preliminary assessments that assist clinicians in making faster, more informed decisions. Some AI tools also employ heatmaps or saliency maps to visually indicate areas of concern, thus improving transparency and interpretability—a critical factor in earning practitioner trust. [31,32]

As research progresses, AI diagnostic systems are expected to evolve from simple binary classifiers to multi-class, multi-label models capable of simultaneously identifying multiple conditions with high specificity and sensitivity. In the near future, such systems may also integrate clinical data, patient history, and genetic markers, enabling a more comprehensive, holistic approach to diagnosis.[33]

➢ *Assessment of Root Canal Morphology*

A thorough understanding of root canal morphology is essential for the success of non-surgical root canal treatments. Failure to detect and treat all canals, especially accessory or aberrant canals, is a common cause of endodontic failure. Artificial Intelligence (AI), particularly through deep learning algorithms applied to cone-beam computed tomography (CBCT) scans, has shown considerable promise in aiding clinicians in the accurate identification of complex root canal systems.[34]

AI-assisted analysis of dental imaging can detect subtle anatomical variations and enhance the visibility of elusive structures, such as secondary canals. A critical example of this is the mesiobuccal-2 (MB2) canal in maxillary molars, which is frequently missed during conventional treatment due to its small size or atypical positioning. In a study by Albitar et al., 57 anonymized CBCT scans of previously treated maxillary molars were analyzed using AI-driven tools to identify the presence of unobturated MB2 canals. [35] The system demonstrated a high level of accuracy in detecting both filled and unfilled MB2 canals, underscoring the potential of AI in enhancing diagnostic reliability in endodontics. [34,35]

Despite its advantages, AI in root canal morphology assessment still faces technical challenges. Artifacts from metallic restorations or endodontic materials, canal calcification**,** and highly complex canal anatomies can obscure radiographic features, thereby affecting the performance of AI models. These factors introduce noise and ambiguity that may lead to false positives or missed detections. [36]

Moreover, variation in image quality and resolution across different CBCT machines can impact the generalizability of AI systems, requiring robust training datasets and algorithmic adaptability. Nevertheless, ongoing advancements in imaging technology and algorithm development—such as artifact reduction techniques, multi-view data fusion, and 3D convolutional neural networks—are expected to enhance the accuracy and clinical utility of AI in this domain.[37] With further refinement and integration into diagnostic workflows, AI could play a pivotal role in improving root canal detection rates, thereby supporting more predictable and successful endodontic outcomes.

➢ *Caries Detection*

Visual examination remains the most employed method for detecting dental caries. It is widely preferred due to its simplicity and reasonable diagnostic accuracy. However, despite its popularity, this method is prone to subjective variability clinicians often arrive at different diagnoses under similar conditions, highlighting a key limitation in consistency and reliability.[38]

To address this challenge, Artificial Intelligence (AI) has emerged as a promising tool in caries detection. Currently, three primary AI-based techniques have been proposed:

- **Image-Based Caries Detection Using AI:** Utilizes deep learning and image processing algorithms to identify carious lesions from intraoral photographs, radiographs, or other imaging modalities with enhanced precision.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun1653

- **AI-Assisted Caries Risk Assessment:** Involves predictive modeling using patient data (e.g., diet, oral hygiene habits, socioeconomic factors) to estimate the likelihood of caries development.
- **Integration of AI with Computer-Aided Diagnosis (CAD) Systems:** Combines AI algorithms with CAD technologies to provide real-time diagnostic support and reduce human error. [38]

➢ *Working Length Determination*

Accurate determination of working length (WL) is a key factor in ensuring the success of root canal therapy. Errors in estimating WL may result in over-instrumentation past the apical foramen, which can cause postoperative flare-ups, foreign body reactions in the periapical tissues, and incomplete removal of microorganisms from the canal system.[39]

Traditional techniques for determining WL such as radiographic analysis, tactile sensation, and patient feedback using paper points or endodontic files are commonly used, though they are not always precise. Although digital systems, including apex locators and enhanced radiographic imaging, have improved the detection of the apical foramen, these methods can still be prone to human error or image interpretation limitations.[40]

As a result, researchers have begun exploring the role of Artificial Neural Networks (ANN) in enhancing WL accuracy. In a study by Saghiri et al. ANNs demonstrated a high level of precision in identifying the apical foramen on radiographs, thereby supporting more consistent and reliable WL determinations.[41] Furthermore, integrating AI with real-time imaging tools and electronic apex locators could potentially automate the WL measurement process, reduce operator variability, and improve the predictability of endodontic outcomes. As AI systems continue to evolve through machine learning, their diagnostic and predictive performance in endodontics is expected to further enhance clinical efficiency and treatment success. [40,41]

VI. ADVANTAGES OF ARTIFICIAL INTELLIGENCE IN ENDODONTICS

Artificial intelligence brings transformative benefits to the field of endodontics, chiefly by boosting the precision of diagnoses and enhancing the overall efficiency of treatment procedures. By employing AI to meticulously analyses radiographs and CBCT scans, endodontists can significantly reduce human errors and minimize the chances of misdiagnosis. This reliable accuracy not only accelerates the diagnostic process but also shortens the time needed for treatment planning, ultimately decreasing patient wait times and improving workflow in busy clinical settings.[40] Moreover, AI's ability to process and learn from vast amounts of clinical data enables the generation of personalized treatment plans that are informed by historical case outcomes. This data- driven approach helps clinicians select the most effective intervention strategies, thereby increasing the likelihood of treatment success and patient satisfaction.[42] Beyond clinical practice, AI also plays a crucial role in dental education and professional development. It assists students and practitioners in interpreting a wide variety of dental pathologies, offering valuable insights that enhance diagnostic skills and deepen understanding. Interactive AI-based learning tools and simulations allow learners to experience diverse clinical scenarios, accelerating their proficiency and confidence. [43]

➢ *Additional Benefits Include:*

- Consistency and Objectivity: AI provides standardized assessments that are not influenced by fatigue or subjective judgment, ensuring consistent quality of care.
- Early Disease Detection: AI algorithms can identify subtle signs of disease progression earlier than conventional methods, allowing timely intervention.
- Resource Optimization: By automating routine diagnostic tasks, AI frees up clinicians to focus on complex decision-making and patient interaction.
- Continuous Improvement: AI systems adapt and improve over time as they incorporate new data, enhance diagnostic accuracy and treatment recommendations with ongoing use.

Overall, AI's integration into endodontics heralds a new era of precision, efficiency, and personalized care, benefiting both practitioners and patients alike. [44]

VII. IMPACT OF AI

Artificial intelligence is profoundly transforming the role of endodontists by boosting the accuracy of diagnoses and optimizing treatment strategies. By automating routine and repetitive tasks such as image analysis and record keeping AI frees endodontists to concentrate on more complex clinical decisions and patient care.[45]

The reduction of human error through AI-assisted evaluation improves the reliability of diagnoses and treatment outcomes. Furthermore, AI acts as an intelligent decision-support system by analyzing extensive clinical data, thereby enabling more evidence- based and personalized care. Overall, AI enhances clinical efficiency, elevates treatment quality, and supports endodontists in delivering superior patient care. [44,45]

VIII. FUTURE ASPECT OF AI

Looking ahead, AI is poised to revolutionize endodontic practice by increasing both precision and personalization in patient management. Its advanced algorithms can detect subtle dental anomalies often missed by human observation, leading to earlier diagnosis and better prognosis.[46]

By integrating patient-specific information such as genetic factors, medical history, and lifestyle habits.AI can recommend customized treatment plans that improve therapeutic success and patient satisfaction. In education, AI-powered simulations and virtual training modules offer valuable opportunities for dental students and

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun1653

practitioners to refine their skills in a risk-free environment. Emerging technologies like augmented reality (AR) and 3D printing combined with AI have the potential to enable minimally invasive and highly precise endodontic procedures.[47] Moreover, AI streamlines clinical workflows by automating administrative duties and enhancing patient communication through intelligent assistants. However, the widespread adoption of AI also calls for rigorous attention to ethical considerations, especially data privacy, informed consent, and algorithmic transparency, to build and maintain patient trust and comply with healthcare regulations. [48]

IX. CONCLUSION

AI is transforming endodontics by enhancing diagnostic accuracy, personalizing treatment approaches, and improving clinical workflows. Its ability to analyze vast and complex data sets leads to more precise diagnoses and tailored therapies, ultimately elevating patient outcomes. Additionally, AI facilitates more efficient practice management and offers innovative educational tools. Despite these advantages, addressing ethical challenges such as patient data protection and maintaining transparency in AI decision-making is vital. Balancing technological innovation with ethical responsibility, AI can be safely integrated into endodontic practice, heralding a new era of advanced, patient-centered dental care.

Nevertheless, the integration of AI into endodontics is not without limitations. Challenges related to data quality, algorithm transparency, ethical considerations, and clinical validation remain. For AI to be reliably used in practice, robust datasets, interdisciplinary collaboration, and regulatory oversight are essential to mitigate risks and ensure safe deployment.

REFERENCES

[1]. Siqueira Jr JF, Rôças IN. Clinical implications and microbiology of bacterial persistence after treatment procedures. Journal of Endodontics. 2008 Nov 1;34(11):1291-1301.
[2]. Ng YL, Mann V, Gulabivala K. A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health. International Endodontic Journal. 2011 Jul;44(7):583-609.
[3]. Ndiaye AD, Gasqui MA, Millioz F, Perard M, Leye Benoist F, Grosgogeat B. Exploring the Methodological Approaches of Studies on Radiographic Databases Used in Cariology to Feed Artificial Intelligence: A Systematic Review. Caries Research. 2024 Jul 18;58(3):117-140.
[4]. Orhan KA, Bayrakdar IS, Ezhov M, Kravtsov A, Özyürek TA. Evaluation of artificial intelligence for detecting periapical pathosis on cone-beam computed tomography scans. International Endodontic Journal. 2020 May;53(5):680-689.
[5]. Nagendrababu V, Vinothkumar TS, El-Karim I, Rossi-Fedele G, Doğramaci EJ, Dummer PM, Duncan HF. Dental patient-reported outcomes in endodontics-a narrative review. Journal of Evidence-Based Dental Practice. 2023 Mar 1;23(1):101805.
[6]. Setzer FC, Hinckley N, Kohli MR, Karabucak B. A survey of cone-beam computed tomographic use among endodontic practitioners in the United States. Journal of endodontics. 2017 May 1;43(5):699-704.
[7]. Dennis D, Suebnukarn S, Heo MS, Abidin T, Nurliza C, Yanti N, Farahanny W, Prasetia W, Batubara FY. Artificial intelligence application in endodontics: A narrative review. Imaging Science in Dentistry. 2024 Aug 25;54(4):305-310.
[8]. Aminoshariae A, Kulild J, Nagendrababu V. Artificial intelligence in endodontics: current applications and future directions. Journal of Endodontics. 2021 Sep 1;47(9):1352-1357.
[9]. Goncharuk-Khomyn M, Noenko I, Cavalcanti AL, Adigüzel Ö, Dubnov A. Artificial intelligence in endodontics: relevant trends and practical perspectives. Ukrainian Dental Journal. 2023 Mar 5;2(1):96-101.
[10]. Khanagar SB, Al-Ehaideb A, Maganur PC, Vishwanathaiah S, Patil S, Baeshen HA, Sarode SC, Bhandi S. Developments, application, and performance of artificial intelligence in dentistry–A systematic review. Journal of Dental Sciences. 2021 Jan 1;16(1):508-522.
[11]. Umer F, Habib S. Critical analysis of artificial intelligence in endodontics: a scoping review. Journal of Endodontics. 2022 Feb 1;48(2):152-160.
[12]. Ahmed ZH, Almuharib AM, Abdulkarim AA, Alhassoon AH, Alanazi AF, Alhaqbani MA, Alshalawi MS, Almuqayrin AK, Almahmoud MI. Artificial intelligence and its application in endodontics: a review. The Journal of Contemporary Dental Practice. 2024 Jan 11;24(11):912-917.
[13]. Sudeep P, Gehlot PM, Murali B, Mariswamy AB. Artificial intelligence in endodontics: a narrative review. Journal of International Oral Health. 2023 Mar 1;15(2):134-41.
[14]. Shan T, Tay FR, Gu L. Application of artificial intelligence in dentistry. Journal of Dental Research. 2021 Mar;100(3):232-244.
[15]. Lee SJ, Chung D, Asano A, Sasaki D, Maeno M, Ishida Y, Kobayashi T, Kuwajima Y, Da Silva JD, Nagai S. Diagnosis of tooth prognosis using artificial intelligence. Diagnostics. 2022 Jun 9;12(6):1422-1433.
[16]. Albitar L, Zhao T, Huang C, Mahdian M. Artificial intelligence (AI) for detection and localization of unobturated second mesial buccal (MB2) canals in cone-beam computed tomography (CBCT). Diagnostics. 2022 Dec 18;12(12):3214-3229.
[17]. Johari M, Esmaeili F, Andalib A, Garjani S, Saberkari H. Detection of vertical root fractures in intact and endodontically treated premolar teeth by designing a probabilistic neural network: an ex vivo study. Dentomaxillofacial Radiology. 2017 Feb 1;46(2):1-12.
[18]. Lai G, Dunlap C, Gluskin A, Nehme WB, Azim AA. Artificial intelligence in endodontics. Journal of the California Dental Association. 2023 Dec 31;51(1):1-

11.
[19]. Ourang SA, Sohrabniya F, Mohammad-Rahimi H, Dianat O, Aminoshariae A, Nagendrababu V, Dummer PM, Duncan HF, Nosrat A. Artificial intelligence in endodontics: Fundamental principles, workflow, and tasks. International Endodontic Journal. 2024 Nov;57(11):1546-1565.
[20]. Asgary S. Artificial intelligence in endodontics: a scoping review. Iranian Endodontic Journal. 2024;19(2):75-85.
[21]. Karobari MI, Adil AH, Basheer SN, Murugesan S, Savadamoorthi KS, Mustafa M, Abdulwahed A, Almokhatieb AA. Evaluation of the diagnostic and prognostic accuracy of artificial intelligence in endodontic dentistry: a comprehensive review of literature. Computational and Mathematical Methods in Medicine. 2023(1):1-12.
[22]. Winterhalter L, Kofler F, Ströbele DA, Othman A, von See C. AI-assisted diagnostics in dentistry: An eye-tracking study on user behavior. Journal of Clinical and Experimental Dentistry. 2024 May 1;16(5):547-560.
[23]. Agrawal P, Nikhade P, Nikhade PP. Artificial intelligence in dentistry: past, present, and future. Cureus. 2022 Jul 28;14(7)1-10.
[24]. Slim MS, Kandel M, Yacovone A, Snedeker J. Webcams as windows to the mind? A direct comparison between in-lab and web-based eye-tracking methods. Open Mind. 2024 Nov 22;8: 1369-1379.
[25]. Habibzadeh S, Ghoncheh Z, Kabiri P, Mosaddad SA. Diagnostic efficacy of cone-beam computed tomography for detection of vertical root fractures in endodontically treated teeth: a systematic review. BMC Medical Imaging. 2023 Jun 1;23(1):1-9.
[26]. Boreak N. Effectiveness of artificial intelligence applications designed for endodontic diagnosis, decision-making, and prediction of prognosis: a systematic review. Journal of Contemporary Dental Practice. 2020 Aug 1;21(8):926-934.
[27]. Iniesta M, Pérez-Higueras JJ. Global Trends in the Use of Artificial Intelligence in Dental Education: A Bibliometric Analysis. European Journal of Dental Education. 2025 Jun 2;(3): 1-10.
[28]. Arsiwala-Scheppach LT, Castner NJ, Rohrer C, Mertens S, Kasneci E, de Oro JE, Schwendicke F. Impact of artificial intelligence on dentists' gaze during caries detection: A randomized controlled trial. Journal of Dentistry. 2024 Jan 1;(8):1-10.
[29]. Abdulrab S, Abada H, Mashyakhy M, Mostafa N, Alhadainy H, Halboub E. Performance of 4 Artificial Intelligence Chatbots in Answering Endodontic Questions. Journal of Endodontics. 2025 Jan 13;(24):1-10.
[30]. Devlin H, Williams T, Graham J, Ashley M. The ADEPT study: a comparative study of dentists' ability to detect enamel-only proximal caries in bitewing radiographs with and without the use of AssistDent artificial intelligence software. British Dental Journal. 2021 Oct 22;231(8):481-495.
[31]. Çakmakoğlu EE, Günay A. Dental Students' Opinions on Use of Artificial Intelligence: A Survey Study. Medical Science Monitor: International Medical Journal of Experimental and Clinical Research. 2025 Apr 30;31: 947-958.
[32]. Boreak N. Effectiveness of artificial intelligence applications designed for endodontic diagnosis, decision-making, and prediction of prognosis: a systematic review. Journal of Contemporary Dental Practice 2020 Aug 1;21(8):926-934.
[33]. Kula B, Kula A, Bagcier F, Alyanak B. Artificial intelligence solutions for temporomandibular joint disorders: Contributions and future potential of ChatGPT. Korean Journal of Orthodontics. 2025 Mar 25;55(2):131-141.
[34]. Durmazpinar PM, Ekmekci E. Comparing diagnostic skills in endodontic cases: dental students versus ChatGPT-4o. BioMed Central Oral Health. 2025 Dec;25(1):1-8.
[35]. Fattah FH, Salih AM, Salih AM, Asaad SK, Ghafour AK, Bapir R, Abdalla BA, Othman S, Ahmed SM, Hasan SJ, Mahmood YM. Comparative analysis of ChatGPT and Gemini (Bard) in medical inquiry: a scoping review. Frontiers in Digital Health. 2025 Feb 3;7: 148-160.
[36]. Ayad N, Schwendicke F, Krois J, van den Bosch S, Bergé S, Bohner L, Hanisch M, Vinayahalingam S. Patients' perspectives on the use of artificial intelligence in dentistry: a regional survey. Head & face medicine. 2023 Jun 22;19(1):23-34.
[37]. Reader A, Drum M. A Review of ChatGPT as a Reliable Source of Scientific Information Regarding Endodontic Local Anesthesia. Journal of Endodontics. 2025 Feb 12;1-10.
[38]. Ekmekci E, Durmazpinar PM. Evaluation of different artificial intelligence applications in responding to regenerative endodontic procedures. BioMed Central Oral Health. 2025 Dec;25(1):1-7.
[39]. Kılıc MC, Bayrakdar IS, Çelik Ö, Bilgir E, Orhan K, Aydın OB, Kaplan FA, Sağlam H, Odabaş A, Aslan AF, Yılmaz AB. Artificial intelligence system for automatic deciduous tooth detection and numbering in panoramic radiographs. Dentomaxillofacial Radiology. 2021 Sep 1;50(6):202- 211.
[40]. Saghiri MA, Asgar K, Boukani KK, Lotfi M, Aghili H, Delvarani A, Karamifar K, Saghiri AM, Mehrvarzfar P, Garcia-Godoy F. A new approach for locating the minor apical foramen using an artificial neural network. International Endodontic Journal. 2012 Mar;45(3):257-265.
[41]. Dhopte A, Bagde H. Smart smile: revolutionizing dentistry with artificial intelligence. Cureus. 2023 Jun 30;15(6):1-11.
[42]. Endres MG, Hillen F, Salloumis M, Sedaghat AR, Niehues SM, Quatela O, Hanken H, Smeets R, Beck-Broichsitter B, Rendenbach C, Lakhani K. Development of a deep learning algorithm for periapical disease detection in dental radiographs. Diagnostics. 2020 Jun 24;10(6):430-436.
[43]. Nguyen TT, Larrivée N, Lee A, Bilaniuk O, Durand R. Use of artificial intelligence in dentistry: current clinical trends and research advances. Journal of the

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun1653

Canadian Dental Association 2021;87(l7):1488-2159.
[44]. Friedman S, Mor C. The success of endodontic therapy—healing and functionality. Journal of the California Dental Association. 2004 Jun 1;32(6):493-503.
[45]. Sjögren UL, Hägglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. Journal of Endodontics. 1990 Oct 1;16(10):498-504.
[46]. Fransson H, Dawson V. Tooth survival after endodontic treatment. International Endodontic Journal. 2023 Mar;56:140-153.
[47]. Wong R. Conventional endodontic failure and retreatment. Dental Clinics. 2004 Jan 1;48(1):265-289.
[48]. Bender IB, Seltzer S, Soltanoff W. Endodontic success—A reappraisal of criteria: Part II. Oral Surgery, Oral Medicine, Oral Pathology. 1966 Dec 1;22(6):790-802.