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CONTENTS

FROM EDITORS DESK

Dear Readers,

It gives us immense pleasure to release this special issue, featuring a compelling collection of manuscripts that explore the evolving role of Artificial Intelligence (AI) across various disciplines in dentistry.

From diagnostics and treatment planning to predictive modelling and patient management, AI is steadily transforming the landscape of dental practice and research. The articles presented in this issue reflect the diversity, depth, and interdisciplinary potential of AI applications in dentistry, offering valuable insights for clinicians, researchers, and academicians alike.

We extend our heartfelt appreciation to the authors and reviewers for their contributions, and we hope this issue serves as a meaningful step forward in embracing innovation and technology in dental sciences.

Dr. Mohan Kumar K. P
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PRESIDENT'S MESSAGE

Dr. Shivasharan Shetty

President

Dear Colleagues,

It gives me immense pleasure to pen this message for the Karnataka State Dental Journal, a platform that continues to reflect the academic excellence and evolving clinical innovations within our fraternity.

As we stand at the crossroads of tradition and transformation, dentistry is witnessing a paradigm shift — and at the heart of this evolution lies Artificial Intelligence (AI). AI is no longer a futuristic concept; it is here, now, actively shaping how we diagnose, treat, and manage dental conditions.

From AI-powered radiographic interpretation in oral medicine to predictive analytics in orthodontics, and from automated charting systems in dental practice management to virtual treatment planning in prosthodontics and implantology, AI is revolutionizing every specialty. Tools like CBCT image segmentation, digital smile design, and AI-enhanced oral cancer detection are not only improving diagnostic precision but also saving time and enhancing patient trust.

For our community in Karnataka, this is a pivotal moment. As dental professionals, it is imperative that we stay abreast of these advancements and thoughtfully integrate them into our daily practice. AI is not here to replace the clinician but to augment our clinical judgement and enhance patient outcomes.

I urge all members — clinicians, educators, researchers, and students alike — to embrace this technological shift with open minds. Let us encourage academic exploration, hands-on training, and ethical deployment of AI-based systems to ensure that Karnataka remains at the forefront of digital dental excellence in India.

The future of dentistry is intelligent — and it starts with us.

Warm regards,
Dr. Shivasharan Shetty
President, Indian Dental Association Karnataka state

SECRETARY MESSAGE

It is with great pride, enthusiasm, and anticipation that I invite you to read the special issue of the IDA KARNATAKA STATE BRANCH Journal, a new kind of topic Artificial Intelligence. An enormous amount of work has gone into the development of this edition of journal, and I believe you will see that effort reflected in this journal and in the impact, it will have on the association. We want it to look different, to be different, to be one Journal that, with its related website, will be as dynamic as the work going on in our disciplines, a rarity in dental practice.

Dr. Mahesh Chandra K
Secretary

Second, we want it to be a vehicle for a new type of conversation about dental practice and its place in the continuing dental education, tenure, promotion, and reward process. That's a tall order, but with your help we will make it happen. Over the past three years, having acquired considerable new experience in Indian Dental Association with such experienced and well-informed colleagues from all the Dental Colleges and various local branches, I believe this is the proper time to initiate some new activities.

Setting a Journal is such an activity; I believe quite an important activity, which will add to the association's wider recognition and, consequently, better and more efficient communication and exchange of scientific ideas. Warm regards,

Dr. Mahesh Chandra K

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Artificial Intelligence in Periodontology: A Paradigm Shift in Diagnosis and Care

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Abstract:

The integration of artificial intelligence (AI) in periodontics is reshaping the landscape of periodontal diagnosis, risk assessment, and treatment planning. This review explores the transformative potential of AI technologies—including machine learning (ML), deep learning (DL), and natural language processing (NLP)in periodontal care. AI applications, particularly convolutional neural networks (CNNs), have demonstrated high accuracy in identifying and classifying periodontal disease, evaluating risk factors, detecting bone loss, and aiding implant planning. These tools enhance diagnostic consistency and accessibility, enabling non-invasive and data-driven decision-making. Despite promising results, challenges remain concerning ethical issues, model generalizability, and clinical validation. This review outlines current applications, limitations, and future directions of AI in periodontology, aiming to support clinicians and researchers in navigating this emerging field.

Keywords: artificial intelligence, deep learning, diagnostic imaging, implant planning, machine learning, periodontics, risk assessment.

Introduction:

Periodontitis is a chronic inflammatory condition initiated by multifactorial host–microbial interactions and is a major contributor to adult tooth loss worldwide. It has also been linked to systemic illnesses such as diabetes and cardiovascular disease [(1)]. The field of periodontics focuses on the prevention, diagnosis, and management of diseases impacting periodontal tissues. Despite technological progress, identifying and managing periodontal conditions early remains complex [(2)].

The digitization of healthcare has accelerated the adoption of artificial intelligence (AI) in dental practice. AI, which is described as the science of constructing systems capable of simulating intelligent human behavior [(3)], is increasingly applied in healthcare for diagnostics, treatment planning, and personalized care [(4,5)]. In dentistry, AI is being explored for applications like analyzing radiographs, predicting orthodontic outcomes, identifying caries, and forecasting endodontic success.

One notable benefit of AI in periodontics is enhanced diagnostic precision. Traditional diagnostic tools, such as probing depths and radiographic evaluations, often vary among clinicians. AI can reduce such discrepancies through data-centric analysis and standardized image interpretation [(2)].

The evolution of deep learning (DL) and machine learning (ML), particularly the application of convolutional neural networks (CNNs), has made it possible to automate and refine medical image interpretation [(6)]. CNNs are now frequently utilized to detect bone loss, determine disease stage, evaluate risk factors, and recognize microbial patterns from radiographic data [(7)]. Classifiers like Support Vector Machines (SVMs) and Decision Trees (DTs) have shown strong results in distinguishing health from diseased tissue using radiological features [(8)]. Hybrid frameworks combining CNNs with SVM or DT have improved accuracy, while sequence-based models such as Faster-RNN are emerging tools for longitudinal monitoring of periodontal progression [(9)]. These AI applications often rival or surpass expert performance.

AI has also shown utility beyond imaging—predictive models have been trained on microbiological datasets to discern health from disease [(10)]. Moreover, Natural Language Processing (NLP) techniques are being used to extract relevant diagnostic data from free-text clinical notes in electronic dental records, facilitating efficient data retrieval and retrospective evaluations [(11)].

Despite these advancements, the clinical adoption of AI in periodontics faces several challenges, including data standardization, model generalizability, ethical concerns, and the need for rigorous validation in real-world settings. Nevertheless, the integration of AI holds transformative potential to enhance the accuracy, speed, and personalization of periodontal care.

This review aims to explore the current landscape of AI in periodontics, emphasizing original research studies that showcase diagnostic innovations, clinical applications, and future directions. By understanding the scope and limitations of existing AI technologies, clinicians and researchers can better navigate the evolving interface between artificial intelligence and periodontal health care.

Fundamentals of Artificial Intelligence

Artificial Intelligence(AI) encompasses a broad spectrum of computational methodologies designed to simulate human cognitive capabilities, such as learning, decision-making, and problem-solving [12,13]. Within the context of healthcare, AI is revolutionizing data interpretation and clinical workflows, driven by the rapid expansion of accessible health data and sophisticated analytical techniques [14].

AI is categorized into several key subfields, notably machine learning (ML), deep learning (DL), and artificial neural networks (ANNs).

Machine Learning (ML) ML, a foundational element of AI, refers to a set of algorithms that allow systems to identify patterns and improve performance based on experience, without being explicitly programmed [15]. It is especially beneficial in healthcare for enhancing the efficiency and accuracy of diagnostics and treatment decisions. Among the ML techniques, neural networks (NNs) have demonstrated particular efficacy in processing complex datasets, such as medical images and natural language [4].

Deep Learning (DL) DL is a specialized branch of ML utilizing multi-layered neural networks to model intricate data representations. This technique is particularly effective for analyzing visual data, making it well-suited for medical imaging tasks. Through hierarchical learning, DL models extract increasingly abstract features from raw input, enabling robust recognition of clinical patterns [4].

Artificial Neural Networks (ANNs) Inspired by biological neural systems, ANNs consist of interconnected artificial neurons capable of modeling non-linear relationships. These models have been applied in diverse medical scenarios including disease prediction, classification, and pattern recognition, proving to be valuable tools in clinical decision support [16].

Convolutional Neural Networks (CNNs) CNNs represent advanced ANN architecture that is especially proficient in image processing tasks. Modeled after the visual cortex, CNNs have significantly advanced the field of computer vision, including its applications in radiology and pathology. Their capacity for automated image analysis offers substantial advantages in diagnostic speed and accuracy, particularly in the context of digital medical imaging [17].

Natural Language Processing (NLP) NLP bridges the gap between human language and computer understanding. In dentistry, NLP techniques are being utilized to transform narrative clinical notes into structured, analyzable data. This facilitates automated extraction of diagnostic insights and enhances the efficiency of electronic health record systems [11].

Chat Generative Pretrained Transformer (ChatGPT) ChatGPT exemplifies the convergence of NLP and ML in a conversational AI model. As a chatbot, it can simulate human dialogue, supporting roles in clinical education, patient interaction, and research dissemination. While its utility in healthcare is still being evaluated, its potential for streamlining communication and information retrieval is significant [18].

Advantages of AI in Periodontics

- Enhances diagnostic precision and reduces subjectivity.
- Increases accessibility to care, especially in remote or underserved areas.
- Facilitates personalized treatment planning based on predictive analytics.
- Enables early detection and risk stratification of periodontal diseases.
- Automates data analysis from clinical records, images, and microbial profiles.

Limitations and Challenges

- Variability in data sources may affect model generalizability.
- Ethical concerns regarding patient privacy, data ownership, and bias.
- Regulatory approval and integration into standard clinical workflows are still evolving.
- Requirement for continuous training, validation, and clinician oversight.
- Dependence on high-quality annotated data for accurate training of AI systems.

Conclusion:

Artificial intelligence steadily transforming the landscape of periodontics by enhancing diagnostic capabilities, streamlining clinical workflows, and supporting evidence-based decision-making. From image analysis to risk assessment and implant planning, AI tools are contributing to more precise, accessible, and effective periodontal care. However, the integration of AI into everyday clinical practice requires careful attention to ethical standards, regulatory compliance, and clinical validation. As the field advances, collaboration between clinicians, researchers, and technologists will be key to unlocking AI's full potential in improving periodontal health outcomes.

References:

1. Tonetti MS, Jepsen S, Jin L, Otomo-Corgel J. Impact of the global burden of periodontal diseases on health, nutrition and wellbeing of mankind: A call for global action. Journal of clinical periodontology. 2017 May;44(5):456-62.
2. Vinayaka AM, Laxmi, Kohalli S. Artificial intelligence in periodontics: Transforming the future of periodontal care. IP Int J Maxillofac Imaging. 2024;10(3):129–31. Shapiro SC. Encyclopaedia of artificial intelligence second edition. New Jersey: A Wiley Interscience Publication. 1992:25.
3. Schwendicke FA, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. Journal of dental research. 2020 Jul;99(7):769-74.
4. Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJ. Artificial intelligence in radiology. Nature Reviews Cancer. 2018 Aug;18(8):500-10.
5. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nature medicine. 2019 Jan;25(1):44-56.
6. Kong L, Zhang Y, Liu J, Wang H, Li Z, Zhao Q, et al. Deep learning model for detecting periodontal disease using panoramic radiographs. In: Bartlett JE, editor. AI in Medical Imaging. Berlin: Springer; 2021. p. 112–20.
7. Zhang D, Liu J, Zhang L, Yang GZ. Hamlyn CRM: A compact master manipulator for surgical robot remote control. International journal of computer assisted radiology and surgery. 2020 Mar; 15:503-14.
8. Li Z, Zhang Y, Wang X, Liu L, Chen H, Li J, et al. Faster RNN-based sequence learning for periodontal disease progression. J Biol Phys. 2021;47(4):305–12.
9. Sánchez-Lopera M, Mira A, Simón-Soro Á. Machine learning identification of periodontitis patients and their subgingival microbial features. J Int AcadPeriodontol. 2022;24(1):2–8.
10. Iroju OG, Olaleke JO. A systematic review of natural language processing in healthcare. International Journal of Information Technology and Computer Science. 2015 Jul 8;8(8):44-50.
11. Tagliaferri SD, Angelova M, Zhao X, Owen PJ, Miller CT, Wilkin T, Belavy DL. Artificial intelligence to improve back pain outcomes and lessons learnt from clinical classification approaches: three systematic reviews. NPJ digital medicine. 2020 Jul 9;3(1):93.
12. Tran BX, Vu GT, Ha GH, Vuong QH, Ho MT, Vuong TT, La VP, Ho MT, Nghiem KC, Nguyen HL, Latkin CA. Global evolution of research in artificial intelligence in health and medicine: a bibliometric study. Journal of clinical medicine. 2019 Mar 14;8(3):360.
13. Jiang F, Jiang Y, Zhi H, Dong Y, Li H, Ma S, Wang Y, Dong Q, Shen H, Wang Y. Artificial intelligence in healthcare: past, present and future. Stroke and vascular neurology. 2017 Dec 1;2(4).

14. Khan SF, Siddique A, Khan AM, Shetty B, Fazal I. Artificial intelligence in periodontology and implantology—A narrative review. Journal of Medical Artificial Intelligence. 2024 Mar 30;7.
15. Ozden FO, Ozgonenel O, Ozden B, Aydogdu AH. Diagnosis of periodontal diseases using different classification algorithms: a preliminary study. Nigerian journal of clinical practice. 2015;18(3):416-21.
16. Lee JH, Kim DH, Jeong SN, Choi SH. Diagnosis and prediction of periodontally compromised teeth using a deep learning-based convolutional neural network algorithm. Journal of periodontal & implant science. 2018 Apr 30;48(2):114.
17. Al Kuwaiti A, Nazer K, Al-Reedy A, Al-Shehri S, Al-Muhanna A, Subbarayalu AV, Al Muhanna D, Al-Muhanna FA. A review of the role of artificial intelligence in healthcare. Journal of personalized medicine. 2023 Jun 5;13(6):951.
18. Khan A, Khan KJ, Ghaza MA, Dave T, Shahnoor S, Khan AM, Oduoye MO, Nafula WP, Ubechu SC. Celebrating breakthrough in dental diagnostics: FDA approval of an AI model for diagnosis of periodontal diseases: Some correspondence. Health Science Reports. 2023 Sep;6(9): e1573.
19. Aberin ST, de Goma JC. Detecting periodontal disease using convolutional neural networks. In2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM) 2018 Nov 29 (pp. 1-6). IEEE.
20. Balaei AT, de Chazal P, Eberhard J, Domnisch H, Spahr A, Ruiz K. Automatic detection of periodontitis using intra-oral images. In2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) 2017 Jul 11 (pp. 3906-3909). IEEE.
21. Feres M, Louzoun Y, Haber S, Faveri M, Figueiredo LC, Levin L. Support vector machine-based differentiation between aggressive and chronic periodontitis using microbial profiles. International dental journal. 2018 Feb 1;68(1):39-46.
22. Rana A, Yauney G, Wong LC, Gupta O, Muftu A, Shah P. Automated segmentation of gingival diseases from oral images. In2017 IEEE healthcare innovations and point of care technologies (HI-POCT) 2017 Nov 6 (pp. 144-147). IEEE.
23. Moosa Y, Bacha SH, Raza SA, Zia MH, Fatima A, Shaikh AA. Role of Artificial Intelligence in Periodontology. Pakistan Journal of Medical & Health Sciences. 2023 Jul 11;17(05):363-.
24. Patel JS, Patel K, Vo H, Jiannan L, Tellez MM, Albandar J, Wu H. Enhancing an AI-Empowered Periodontal CDSS and comparing with traditional perio-risk assessment tools. InAMIA Annual Symposium Proceedings 2023 Apr 29 (Vol. 2022, p. 846).
25. Yauney G, Rana A, Wong LC, Javia P, Muftu A, Shah P. Automated process incorporating machine learning segmentation and correlation of oral diseases with systemic health. In2019 41st annual international conference of the IEEE engineering in medicine and biology society (EMBC) 2019 Jul 23 (pp. 3387-3393). IEEE.
26. Shankarapillai R, Mathur LK, Nair MA, Rai N, Mathur A. Periodontitis risk assessment using two artificial neural networks-a pilot study. International Journal of Dental Clinics. 2010 Oct 1;2(4):36-40.
27. Alotaibi G, Awawdeh M, Farook FF, Aljohani M, Aldhafiri RM, Aldhoayan M. Artificial intelligence (AI) diagnostic

tools: Utilizing a convolutional neural network (CNN) to assess periodontal bone level radiographically—A retrospective study. BMC Oral Health. 2022 Sep 13;22(1):399.

28. Chang HJ, Lee SJ, Yong TH, Shin NY, Jang BG, Kim JE, Huh KH, Lee SS, Heo MS, Choi SC, Kim TI. Deep learning hybrid method to automatically diagnose periodontal bone loss and stage periodontitis. Scientific reports. 2020 May 5;10(1):7531.
29. Nakhleh MK, Amal H, Jeries R, Broza YY, Aboud M, Gharra A, Ivgi H, Khatib S, Badarneh S, Har-Shai L, Glass-Marmor L. Diagnosis and classification of 17 diseases from 1404 subjects via pattern analysis of exhaled molecules. ACS nano. 2017 Jan 24;11(1):112-25.
30. Moufti MA, Trabulsi N, Ghousheh M, Fattal T, Ashira A, Danishvar S. Developing an artificial intelligence solution to autosegment the edentulous mandibular bone for implant planning. European Journal of Dentistry. 2023 Oct;17(04):1330-7.

The Uses of Artificial Intelligence in Oral and Maxillofacial Surgery

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Abstract:

Artificial intelligence (AI) is revolutionizing the field of oral and maxillofacial surgery by improving surgical precision, treatment planning, and diagnostic accuracy. AI-driven technologies, including deep learning models and machine learning algorithms, are being incorporated into imaging analysis to enhance the accuracy of early pathology detection, such as tumors, fractures, and disorders of the temporomandibular joint. AI-powered virtual surgical planning reduces operating time and improves outcomes by enabling more accurate preoperative simulations and personalized prosthetic designs. Robotics and AI-assisted navigation systems are facilitating increased surgical precision and less invasive procedures. Furthermore, AI applications in patient data management and outcome prediction enable evidence-based practices and individualized care. Despite its potential, challenges such as data security, ethical issues, and the need for clinical validation remain.

Keywords: Artificial intelligence, oral & maxillofacial surgery, treatment planning, surgical navigation

Introduction:

Artificial Intelligence (AI) is revolutionizing healthcare, particularly in the field of oral and maxillofacial surgery. This surgical specialization involves the diagnosis, operative management, and rehabilitation of illnesses and issues concerning the mouth, jaws, face, and neck. AI algorithms, robotics, and various machine learning schemes are being integrated across multiple disciplines within oral and maxillofacial surgery. These technologies enhance diagnostic precision, improve surgical accuracy, tailor treatment plans, and optimize postoperative management. This article discusses how AI is utilized in these areas, highlighting major advantages, challenges, and ethical implications.

1. AI in Preoperative Planning and Diagnosis

a. Image Analysis and Interpretation

AI's role in image analysis is one of its most important contributions to oral and maxillofacial surgery. Traditionally, oral surgeons rely on X-rays, CT scans, and MRIs to diagnose and plan surgeries. AI-based tools, particularly deep learning algorithms, can analyse these images quickly and with high accuracy. Machine learning models are trained on large collections of medical images, allowing them to identify features like fractures, tumours, cysts, and other abnormalities that may have been overlooked (Sayed et al., 2020).

For instance, an AI system trained to interpret dental radiographs would be able to diagnose early-periodontitis or jaw malignancies, enabling intervention at an earlier stage and improved outcomes for the patient. When it comes to head and neck cancers, AI systems have proven to be more accurate than human radiologists in detecting tumors or lymph node metastasis (Shao et al., 2020). This has a considerable decrease in diagnostic mistakes and improved treatment accuracy.

b. 3D Imaging and Virtual Surgical Planning

AI's use in 3D imaging has revolutionized surgical planning, especially for complicated surgeries such as orthognathic surgery (jaw surgery) and reconstructive surgeries. AI software works with 3D CT scans to develop precise models of the patient's facial anatomy, enabling surgeons to view the outcome of surgery without any incisions.

With the assistance of AI, surgeons can virtually plan various approaches to surgery and forecast the outcomes, thereby reducing risk. Virtual planning of surgeries reduces the risk of errors and increases accuracy during the operation itself (Gonzalez et al., 2018). In addition, AI-based systems can assist in predicting post-operative results such as facial aesthetics and function, thereby helping patients make well-informed choices.

c. Temporomandibular Joint Disorders (TMD) Diagnosis

Another life-changing use of AI in oral surgery is in the diagnosis of Temporomandibular Joint (TMJ) disease. TMJ disease can result in debilitating pain and discomfort, necessitating surgical correction. AI can help by scanning images of the TMJ based on CT and MRI to detect joint pathologies such as disc displacement, osteoarthritis, or inflammation (Yoo et al., 2020).

Machine learning algorithms can identify small changes in the structure of the joint, which gives an accurate and early diagnosis and enables intervention at the right time. Based on imaging information and patient symptoms, AI is also capable of suggesting proper treatment options specific to each patient.

2. AI-Assisted Robotic Surgery and Surgical Navigation

a. Robotic-Assisted Surgery in Maxillofacial Procedures

AI has also opened the gates for robotic surgeries. Robotic surgery allows precision, flexibility, and control of a higher magnitude, especially during intricate oral and maxillofacial surgeries such as tumour resection, mandibular relining, and reconstructive operations. AI may combine preoperative imaging data along with real-time feedback to manoeuvre robotic systems for precise incision and adjustments.

Artificial intelligence-supported robot-assisted surgery provides a great degree of repeatability and accuracy, with less chance of human error. In maxillofacial surgery, this accuracy is particularly important when operating in sensitive areas, like the facial bones and jaw (Oshiro et al., 2021). Robotic systems can execute tasks with incredible precision, enabling smaller cuts, less damage to surrounding tissue, and faster patient recovery.

b. Surgical Navigation with AI

Surgical navigation systems using AI are yet another innovation in oral and maxillofacial surgery. Such systems utilize real-time intraoperative images to provide data for guiding the surgeon during procedures. The position of the instruments is monitored using AI algorithms such that the accurate placement is achieved. This helps especially during those procedures that have dental implants put in, with the system prompting the surgeon where to place the implant and its angle and depth (Zhao et al., 2020).

Through the incorporation of augmented reality (AR) in these systems, surgeons can view the patient's anatomy in 3D within surgery, enhancing their decision-making skills and minimizing the chances of mistakes.

3. Predicting Surgical Outcomes and Personalized Treatment

a. Predictive Modelling for Surgical Success

Machine learning can forecast the success of surgery from patient information, including age, history of disease, and the nature of the surgery to be undertaken. Using large databases, machine learning systems can establish predictive models which forecast the probabilities of successful results, complications, or the necessity for revisional surgery.

For instance, in trauma reconstruction of the face, recovery times and future complications can be predicted by AI systems using the patient's past medical history as well as details of the operation (Singh et al., 2020). Such predictability enables better-informed discussion by surgeons of possible risks and benefits with the patients, resulting in an improved decision-making process.

b. Personalized Treatment Plans

AI is also used to create customized treatment plans for the individual patient. Machine learning algorithms can use data like genetic data, medical history, and lifestyle to create a treatment plan most likely to be effective for that patient. This is very useful in intricate cases like facial reconstructive surgery, where the surgical procedure needs to be individualized to each patient's individual anatomy (Jiang et al., 2021).

For example, AI can be applied to create tailored prosthetics or implants that precisely fit the patient's anatomy, enhancing the functional as well as cosmetic results of the surgery.

4. Postoperative Care and Monitoring

a. Remote Monitoring Using AI

Following surgery, patients require ongoing observation to confirm that they are healing properly and to detect any emerging complications early on. AI-based wearable technology or smartphone apps can track vital signs like heart rate, blood pressure, and oxygen levels and send this information to healthcare providers for real-time interpretation.

AI algorithms can identify symptoms of complications such as infections, uncontrolled swelling, or bleeding and alert surgeons and healthcare teams to intervene immediately. This remote monitoring minimizes the necessity for multiple clinic visits, conserving time for both providers and patients (Nasseri et al., 2020).

b. AI in Pain Management

Postoperative pain control is essential to maintaining patient comfort and healing. AI can be used to forecast postoperative pain levels, enabling healthcare practitioners to develop customized pain control strategies. Through patient data analysis, such as the surgery type, age, and medical condition, AI can recommend the best pain relief techniques, limiting opioid usage and the risk of addiction (Khatri et al., 2021).

c. Postoperative Complication Prediction

Artificial intelligence tools can also forecast the risk of postoperative complications, e.g., infections, wound healing issues, or graft failure. Through the constant monitoring of patient data, AI systems can warn clinicians of potential problems while they are still minor. For instance, machine learning models can monitor postoperative data like body temperature and conditions at the surgical site to forecast infections so that early intervention and shorter recovery periods can be ensured (Liu et al., 2020).

5. AI in Education and Training

a. Simulation-Based Training for Surgeons

Simulations driven by artificial intelligence (AI) are improving the education of oral and maxillofacial surgeons. Augmented reality (AR) and virtual reality (VR) technologies are employed to develop realistic, immersive training simulations. The technology enables trainees to rehearse surgeries in a risk-free environment, improving their competence and confidence before conducting procedures on patients.

AI algorithms monitor the trainee's performance and give instant feedback, making the learning process customized to the needs of everyone. This enables trainees to acquire useful experience in intricate surgeries, like jaw reconstruction, without the risks of practicing on real patients (Kumar et al., 2021).

b. Decision Support for Surgeons

AI systems are also being employed as decision support systems in the operating room. Through complex analysis of large datasets of medical literature, surgical case series, and patient information, AI systems give surgeons real-time suggestions and recommendations during surgery. This can assist in guiding decisions, ensuring that surgeons choose the optimal course of action based on the patient's individual situation (Chai et al., 2020).

6. Challenges and Ethical Considerations

a. Data Privacy and Security

Since AI applications in healthcare are based on high amounts of patient data, data security and privacy are key to protect. Any violations of patient data would breach confidentiality and trust in the health system. Robust data protection procedures are required to avoid unauthorized access and keep patient information protected (Wang et al., 2020).

b. Ethical Implications of AI

Though AI is extremely promising, there are ethical considerations to its application in surgery. AI can never totally substitute for the human element, especially in oral and maxillofacial surgery, where patient outcomes are as much a result of surgical skill as of empathy and patient interaction. It is important to reconcile the effectiveness of AI with the necessity of patient-centred, empathetic care (Meskó et al., 2020).

c. Accountability and Regulation

With an increasing integration of AI in surgical practice, it is necessary to have well-defined regulations for its application. Determining who is responsible for the decisions made by an AI system—either the surgeon, the software designer, or both—will be important to safeguarding patient safety and upholding professional standards (He et al., 2021).

Conclusion

Artificial Intelligence is transforming the practice of oral and maxillofacial surgery. From diagnosis to treatment planning, surgical accuracy, and postoperative management, AI is improving patient outcomes and allowing surgeons to conduct procedures with increased accuracy and efficiency. Despite challenges like data privacy and ethical concerns, the potential rewards of AI in this specialty are enormous. With the advancement of technology, AI will increasingly be at the forefront of determining the future of oral and maxillofacial surgery.

References

1. Chai, Y., et al. (2020). AI-based decision support systems in surgical training: a review of current developments. Surgical Education, 24(5), 35-45.
2. Gonzalez, R., et al. (2018). Application of AI and machine learning in maxillofacial surgery: A comprehensive review. Journal of Craniofacial Surgery, 29(2), 387-394.
3. He, Z., et al. (2021). Ethical challenges and considerations in the use of artificial intelligence in surgery. Journal of Surgical Ethics, 12(3), 120-129.
4. Jiang, W., et al. (2021). AI and personalized treatment plans in oral and maxillofacial surgery. International Journal of Oral and Maxillofacial Surgery, 50(9), 215-220.
5. Khatri, R., et al. (2021). Artificial intelligence in postoperative pain management. Pain Management, 33(4), 80-85.
6. Kumar, S., et al. (2021). AI and VR-based surgical simulation in oral and maxillofacial surgery training. Journal of Surgical Education, 78(4), 125-130.
7. Liu, Y., et al. (2020). AI prediction of complications following oral and maxillofacial surgery: Current perspectives. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, 129(5), 356-363.
8. Meskó, B., et al. (2020). The ethical implications of AI in healthcare: A perspective from maxillofacial surgery. Journal of Medical Ethics, 46(7), 442-449.
9. Nasseri, E., et al. (2020). Remote monitoring using AI tools after oral and maxillofacial surgery. Journal of Telemedicine and Telecare, 26(2), 23-30.
10. Oshiro, T., et al. (2021). Robotic surgery in maxillofacial procedures: Advancements and clinical implications. Journal of Robotic Surgery, 17(3), 209-217.

Artificial Intelligence in Endodontic Therapy: A Critical Review of Current Applications and Future Prospects

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Abstract:

The role of artificial intelligence (AI) in conservative dentistry and endodontics has evolved significantly, offering transformative solutions for caries and lesion detection, treatment planning, and clinical decision-making. AI models, particularly deep learning (DL) techniques, have shown strong potential in identifying periapical radiolucencies, root canal morphology, and vertical root fractures (VRF's), finish lines, often surpassing clinician performance in diagnostic accuracy. AI-driven tools also support the precision of root canal treatments by enhancing the detection of anatomical irregularities and predicting treatment outcomes, including working length (WL) determination and regenerative procedures as well as treatment simulation during smile design.

Furthermore, AI aids in predicting the need for retreatment by analyzing clinical and procedural factors, contributing to more consistent and evidence-based decision-making. Despite these advances, challenges remain, including the scarcity and quality of annotated datasets, bias in data, and the lack of AI interpretability. The integration of AI in endodontic education and training and its potential for robotic-assisted procedures are promising, although the need for further clinical validation and regulatory frameworks is critical. As AI technology continues to advance, particularly with emerging transformer models, its clinical application in conservative dentistry and endodontics is expected to enhance treatment outcomes and precision, ushering in a new era of data-driven dentistry. However, ongoing research and collaboration are needed to address existing challenges and ensure the responsible, effective use of AI in clinical practice.

Introduction:

Artificial intelligence (AI), a term coined by John McCarthy, was originally defined as "the science and engineering of making intelligent machines."[1]

The concept of AI was first introduced in the 1950s, with early pioneers envisioning machines capable of "thinking". This innovative concept prompted Alan Turing to conduct foundational research on the potential for machines to exhibit intelligent behavior and to develop criteria for evaluating machine intelligence.[2]

AI has rapidly gained traction, particularly after the success of OpenAI's generative AI tool, ChatGPT. As a transformative innovation, AI shows immense potential across various sectors—including endodontics. [3]

When integrated into dental workflows, AI can enhance diagnostic precision, streamline operations, and elevate the overall quality of patient care. It enables dental professionals to achieve greater accuracy in diagnosing conditions and forecasting treatment outcomes, ultimately leading to improved patient experiences and higher success rates in clinical procedures. [3,4]

To truly grasp the impact of AI in conservative dentistry and endodontics, it is important to understand key concepts such as deep learning (DL), machine learning (ML), big data, and scientific data. Deep learning, a specialized branch of machine learning, attempts to replicate the way the human brain processes information through neural networks. It relies on training complex algorithms using large datasets to accurately predict outcomes or classify information. Machine learning is a broader discipline that includes a variety of algorithms designed to analyze, interpret, and learn from data without explicit programming.(FIGURE 1)[5]

In the context of conservative dentistry and endodontics, big data refers to the vast amount of both structured and unstructured information generated during dental practices such as patient histories, clinical observations, and radiographic images. AI systems can process this data to uncover patterns and insights that may not be easily recognizable by clinicians. Scientific data, meanwhile, includes research findings, clinical trials, and experimental studies that form the foundation of evidence-based decision-making in conservative dentistry and endodontics. A thorough understanding of these concepts is essential for leveraging AI to enhance diagnostic accuracy, improve treatment planning, and optimize patient outcomes in endodontic care.[6]

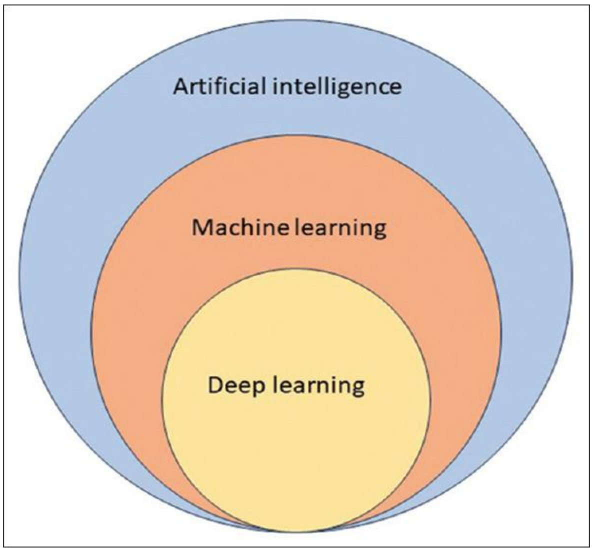

FIGURE 1 : Core component of artificial intelligence [5]

Artificial intelligence models like convolutional neural networks (CNNs) and artificial neural networks (ANNs) have been increasingly applied in endodontics to analyze root canal anatomy, estimate working length (WL), identify periapical lesions and root fractures, and forecast the outcomes of retreatment procedures. CNNs are particularly effective for image-based tasks, including segmentation and pattern detection, due to their ability to process visual data with high accuracy. In contrast, ANNs are beneficial for tasks such as predictive analytics such as estimating the risk of restorative failure, determining the best treatment approach, and supporting evidence-based decisions. [7,8]

Recurrent Neural Networks (RNNs) represent an advanced type of neural network specifically designed to handle sequential data more effectively than traditional neural networks.

While ANNs are suitable for addressing a wide range of complex problems, CNNs are particularly effective for tasks involving computer vision, such as image analysis. In contrast, RNNs excel in processing data with a temporal or sequential structure, making them ideal for applications in natural language processing and time-series analysis.[9]

The combined use of these AI models can significantly improve understanding, diagnosis, and management in modern dental practice.[7,8]

The article highlights how AI is transforming the field of conservative dentistry and endodontics through advanced diagnostic tools, predictive analytics, and data-driven treatment planning.

1. Role of AI in Conservative Dentistry and Endodontics

Dental care:

Recent advancements in AI, particularly deep learning through CNNs, have shown promising results in the detection of dental caries. Lee et al. (2018) demonstrated that CNNs could accurately diagnose caries from periapical radiographs, outperforming traditional diagnostic methods.[10] Expanding on this, Musri et al. (2021) conducted a systematic review confirming the high sensitivity and specificity of CNN-based models across multiple studies, while also emphasizing the need for standardized datasets and validation across diverse populations.[11] More recently, Tan et al. (2024) applied CNNs to quantitative light-induced fluorescence (QLF) images using a handheld device, highlighting the versatility of AI in different imaging modalities and its potential for portable diagnostic tools.[12] Artificial neural network (ANN) models applied to bitewing radiographs have demonstrated high diagnostic performance in identifying dental caries, achieving an accuracy of 97.1%, precision of 95.1%, specificity of 94.3%, and sensitivity between 85% and 99.6%.[13] Similarly, Sornam and Prabhakaran reported that back-propagation neural networks (BPNNs) used for caries classification yielded accuracy rates ranging from 85% to 100%.[14]

Lesion detection:

Periapical radiolucency can be evaluated using both two-dimensional (2D) and three-dimensional (3D) imaging techniques. Among these, 3D modalities such as cone beam computed tomography (CBCT) offer more detailed and precise diagnostic information.[15] Clinical guidelines advise against the routine use of 3D imaging for diagnosing periapical conditions, primarily because it involves a considerably higher radiation dose, as well as greater time, cost, and specialized expertise for image acquisition and interpretation.[16,17] A growing number of studies are exploring the use of artificial intelligence to identify periapical radiolucency in both 2D and 3D imaging.

In a systematic review and meta-analysis examining the effectiveness of AI in detecting periapical radiolucency, it was found that AI tools show significant potential in assisting the detection of these radiolucency in imaging. The analysis revealed that AI demonstrated both high specificity and sensitivity in identifying periapical radiolucency. However, the review highlights the necessity for a broader range of study designs beyond conventional diagnostic accuracy studies. To truly assess the value of AI, prospective, real-life randomized controlled trials utilizing diverse datasets are essential.[18]

In a separate systematic review and meta-analysis focused on assessing the accuracy of deep learning models for detecting periapical radiolucent lesions in dental radiographs, a comparison was made with expert clinicians. The analysis found that deep learning models performed with a high degree of accuracy, often achieving results comparable to or even surpassing those of experienced clinicians in detecting periapical radiolucent lesions. Despite these promising outcomes, the review highlighted several important limitations. A significant concern was the risk of bias in many of the included studies, which could potentially affect the reliability of the results. Additionally, the review pointed out the scarcity of prospective studies, which are crucial for validating the long-term effectiveness and real-world applicability of deep learning models. The lack of such studies raises questions about the generalizability and robustness of the findings, underlining the need for more rigorous research in this area to fully understand the potential of DL in clinical practice. [19]

Assessment of root canal and canal morphology:

For the successful completion of non-surgical root canal therapy, it is crucial for dental professionals to have a comprehensive understanding of root canal anatomy and the various root morphologies. Accurate identification of these anatomical variations plays a vital role in ensuring the proper treatment of the affected tooth. AI can serve as a valuable tool in this process by aiding in the detection of anatomical irregularities and assisting in the identification of errors when locating additional or accessory canals. AI algorithms, by analyzing radiographic images, can enhance the accuracy of canal detection, reduce the likelihood of overlooking anatomical complexities, and support clinicians in achieving more precise and effective outcomes in root canal therapy.[20,21]

A study focused on detecting the presence of an additional root in the first mandibular molar using panoramic radiographs (PANs). The CNNs outperformed two experienced radiologists, achieving an accuracy of 86.9% in determining whether the distal roots of mandibular molars were single or contained an additional root canal. However, it is important to note that the prediction pipeline was not fully automated, as manual segmentation of the teeth was required.[20]

Similar studies have explored the 3D evaluation of root and root canal morphology using CBCT scans and CNN algorithms,[21,22,23] with two papers specifically addressing the prediction of C-shaped canals.[21,22] The reported accuracy of these methods ranged from 89.9% to 95.1%.

Working length determination:

Selecting the correct WL is critical for the success of root canal treatment. Incorrect determination of WL can lead to complications such as flare-ups, periapical foreign body reaction, over-instrumentation or under instrumentation, insufficient disinfection or apical extrusion of debris.[24,25]

Two preliminary cadaveric studies that aimed to replicate clinical conditions for WL determination. Both studies utilized straight single-rooted teeth and implemented ANNs as a decision-support system and was done by Saghiri et al.[26,27]

The studies demonstrated that ANNs could effectively support the identification of the apical foramen on radiographic images, serving as a second opinion to improve the precision of WL estimation. Additionally, ANNs have potential as clinical decision-making tools in similar diagnostic situations.

In the experimental study using a human cadaver model, the ANN approach achieved a high accuracy of 96% in determining WL, outperforming experienced endodontists, who achieved 76%. While the results indicated that ANNs could be beneficial to clinicians in routine endodontic practice,[26,27] the in-vitro nature of these investigations limits their applicability, and further clinical research is needed to draw definitive conclusions.

Vertical root fractures:

The radiographic appearance of vertical root fractures (VRFs) can range from a narrow radiolucent line,[28,] to generalized widening of the periodontal ligament space, vertical bone loss, or even visible separation of root fragments.[29]

Over the past decade, a series of studies have progressively demonstrated the potential of AI in detecting VRFs using various imaging modalities. In 2013, Kositbowornchai et al. conducted an ex vivo study where ANNs successfully identified VRFs in extracted single-rooted teeth, highlighting AI's early promise in endodontic diagnostics.[29] Johari et al. (2017) developed a probabilistic neural network that effectively detected VRFs in both intact and endodontically treated premolars.[30] In 2020, Fukuda et al. evaluated an AI system for use with PANs, showing that even lower-resolution imaging can benefit from AI support.[31] Yang et al. (2023) demonstrated that deep learning models applied to CBCT achieved high diagnostic accuracy in identifying VRFs.[32] In 2024, Abdelazim and Fouad reported that AI-driven decision systems could automate the detection of root fractures in periapical radiographs, enhancing consistency and efficiency.[33] Most recently, Ozsari et al. (2025) showed that AI-based image enhancement techniques further improved the accuracy of VRF detection on intraoral radiographs.[34] Collectively, these findings illustrate a positive trajectory in the application of AI for VRF detection, with strong potential for clinical adoption pending further in vivo validation.

Treatment planning:

In recent years, the integration of computational models into endodontic diagnostics has gained momentum, particularly with the increased use of CBCT imaging. Simon et al. (2006) addressed the challenge of distinguishing periapical granulomas from radicular cysts by correlating grayscale CBCT analysis with histological findings, achieving a diagnostic accuracy of 76.5%. [35]

Okada et al. (2015) advanced this approach using segmentation algorithms and classifier models to improve lesion characterization, aiding clinicians in making more accurate, noninvasive treatment decisions based on lesion type—nonsurgical retreatment for granulomas and surgical removal for cysts.[36]

In 2020, Mallishery et al. introduced a model to evaluate case complexity and guide referral decisions, helping general practitioners determine when specialist care is appropriate.[37] Around the same time, Setzer et al. developed a method to enhance the detection of periapical pathology on CBCT images, enabling earlier and more accurate diagnosis.[38]

More recently, Ver Berne et al. (2023) proposed a two-step CBCT-based method for identifying and classifying periapical lesions, demonstrating strong diagnostic metrics, particularly in differentiating cysts from granulomas.[39]

In 2024, Aminoshariae et al. highlighted the importance of integrating imaging, clinical findings, and patient history into digital diagnostic frameworks. Their work emphasized real-time support for treatment planning and improved consistency by incorporating patient-specific variables and clinical feedback.[40]

Collectively, these studies indicate a clear trend toward data-driven, personalized endodontic care. Computational tools have enhanced diagnostic accuracy and improved decision-making in both general and specialist practices.

Retreatment prediction:

Predicting the success of root canal retreatment requires consideration of various clinical factors. Two studies have proposed structured methods to support retreatment planning. Campo et al. developed a Case-Based Reasoning (CBR) system that compares new cases with previously treated ones sharing similar clinical features, offering a consistent, experience-based approach to decision-making.[41]

Signor et al. (2021) conducted a retrospective study analyzing 181 endodontic retreatment cases to identify predictors of technical quality and periapical healing. Using regression and data mining techniques, they evaluated variables such as root canal filling length and density, presence of periapical lesions, procedural complications, and the use of magnification.[42]

These findings highlight the value of combining clinical experience with data-driven analysis to improve retreatment planning. However, the current evidence remains limited, and further research is needed to draw definitive conclusions.

Regenerative endodontic procedures:

Regenerative endodontic procedures (REPs) aim to restore function in immature permanent teeth with necrotic pulp by regenerating the pulp-dentin complex and supporting long-term tooth survival.[43] Recent technological advancements have enhanced the precision and effectiveness of these treatments.

Bindal et al. (2017) developed a method to predict stem cell viability under varying inflammatory conditions. By exposing dental pulp stem cells to lipopolysaccharide and using adaptive neuro-fuzzy inference systems, they modelled the likelihood of cell survival following microbial exposure. [44]

Saberian et al. (2024) focused on improving scaffold design and predicting stem cell behavior to optimize regenerative outcomes. Their work emphasized the integration of biological and material sciences to support tissue regeneration.[45]

In 2025, Lu et al. introduced predictive models that assess patient-specific factors, such as pulp vitality, to forecast REP success and support individualized treatment planning.[46] Ekmekci and Durmazpinar (2025) further advanced this approach by applying real-time clinical data analysis to refine decision-making during regenerative procedures.[47]

Together, these studies highlight the role of predictive technologies in improving treatment planning, precision, and outcomes in regenerative endodontics.

Artificial intelligence in restoration and shade selection:

In recent years, digital technologies have steadily advanced restorative dentistry, particularly in tooth preparation and shade selection. In 2014, Wang et al. developed a robotic system using picosecond laser technology for crown preparation, demonstrating precise cutting with minimal damage to surrounding structures.[48] In 2015, Otani et al. assessed the performance of an automated robotic system for preparing teeth for laminate veneers, finding it capable of producing accurate and repeatable results.[49] Li et al. proposed a model combining genetic algorithms and neural network techniques to improve color matching in dental restorations, aiming to enhance consistency and reduce variability.[50] In 2019, Yamaguchi et al. investigated a method to estimate the likelihood of debonding in composite resin crowns produced through CAD/CAM systems, helping clinicians anticipate and address potential complications.[51] By 2022, Revilla-León et al. compiled existing uses of digital technologies in restorative workflows, including robotic assistance and predictive tools.[52] In a separate study, Engels et al. demonstrated the effectiveness of image-based detection systems in identifying posterior restorations from clinical photographs, contributing to diagnostic support and record-keeping.[53] Kose Jr. et al. explored predictive techniques to estimate the final shade of leucite-reinforced ceramic restorations, emphasizing the importance of consistent aesthetic outcomes.[54] These studies reflect a growing reliance on digital systems to improve precision, reproducibility, and overall treatment quality in restorative dentistry.

Smile design:

Artificial intelligence (AI) is significantly reshaping smile design in aesthetic dentistry, offering advanced tools for enhancing personalization, efficiency, and patient communication. As highlighted by Kurian et al. (2024), AI-driven technologies can analyze complex facial features, dental proportions, and individual patient preferences to generate customized smile simulations.[55] These simulations allow for real-time adjustments, facilitating better patient communication and increasing the likelihood of treatment acceptance. Further integration of AI with digital smile design (DSD) platforms, where AI algorithms assist in automated facial analysis, tooth arrangement predictions, and other esthetic considerations.[56] This application of AI not only enhances the precision of smile design but also helps to reduce the subjectivity inherent in traditional manual approaches, offering more reproducible and consistent results. Additionally, AI's role in CAD/CAM-based restorative dentistry improves the efficiency and accuracy of prosthetic design, particularly in creating crowns, veneers, and other restorations.[57] AI optimizes digital workflows, enabling faster production times and more precise restorations, which contribute to better clinical outcomes and patient satisfaction. Despite these promising advancements, challenges such as data privacy concern, the need for extensive training datasets, and the integration of AI into existing clinical workflows remain. These hurdles underscore the necessity for continued research to refine AI algorithms, validate their clinical efficacy, and enhance their accessibility across diverse dental practices.[55,57]

Education & training:

Aminoshariae et al. (2024) explored the impact of modern educational tools on endodontic training. The review highlights how digital learning platforms, virtual simulations, and interactive case-based methods are improving student's theoretical knowledge and clinical proficiency. Simulated practice helps learners develop procedural skills in a safe, controlled setting, while case-based approaches enhance critical thinking and decision-making. The authors also emphasize the need for updated curriculum to support the effective use of these tools. It reflects a shift toward more hands-on, student-centered learning in endodontic education.[58]

Augmented Reality and Robotics:

Augmented reality (AR) enhances clinical visualization by overlaying digital information onto real-world environments. In endodontics, AR has been integrated into image-guided navigation systems to improve the precision of various procedures. Systems using AR headsets or dynamic navigation tools provide real-time tracking of instruments, assisting clinicians during tasks such as locating calcified canals, removing fiber posts, and performing root-end surgeries.[59]

Several studies have evaluated the clinical application of AR. Farronato et al. (2023)[60] assessed the accuracy of a markerless AR system for access cavity preparation using CBCT imaging. Faus-Matoses et al. (2022)[61] conducted an in vitro study on AR-guided access preparation. Remschmidt et al. (2023)[62] investigated the use of AR in surgical endodontics, including osteotomies and apicoectomies, and compared its accuracy to that of static, template-based guides.

These developments are also contributing to the advancement of robotic-assisted endodontics. While robotics has been primarily applied to implant placement, its use in endodontic procedures—such as root-end surgery and canal instrumentations under exploration.[64] The integration of surgical planning and execution data from AR-guided procedures supports the refinement of robotic systems. Techniques such as data augmentation and performance-based learning contribute to improving robotic precision and reliability.[65,66] Continued clinician involvement is essential to ensure the safety and effectiveness of these technologies as they evolve.

Challenges and Limitations of Current AI Applications in Endodontics

While the application of AI in endodontics has shown considerable promise, several challenges still hinder its widespread clinical adoption. One of the primary obstacles is the availability and quality of data. DL models rely on large, annotated datasets for training and validation, but such datasets are scarce in the field of dentistry. The annotation process for complex imaging data, like CBCT, is time-consuming and requires significant resources.[67] Unlike the medical field, which benefits from extensive, centralized image repositories, dentistry lacks shared databases that could facilitate collaborative AI development.[68] In response to these limitations, methods such as transfer learning, which involves fine-tuning models pretrained on larger datasets for specific tasks and self-supervised learning, which allows models to learn from unlabelled data have been explored.[69,70] Transformer architectures, originally designed for natural language processing, have also been adapted for medical imaging because of their ability to capture spatial relationships across images.[71] However, these models require extensive training data and have only recently been investigated for use in endodontics.[72] Active learning, a technique that focuses on labelling uncertain data to maximize training efficiency, has also gained attention as a potential solution.[68]

Another significant challenge is the lack of diversity between available datasets. When training data come from limited institutions or populations, AI models may develop biases that hinder their generalizability to diverse patient groups, equipment types, and clinical practices.[24] Additionally, AI models are prone to overfitting, performing well on the training data but failing to generalize to new, unseen cases.[73] Variations in imaging techniques and protocols across different devices and institutions can cause domain shifts, which can further degrade model performance.[74] The interpretation of radiographic images is also complicated by factors such as anatomical variability, artifacts, noise, and inconsistent imaging practices. Moreover, differences in clinician expertise, diagnostic approaches, and treatment protocols across various regions and institutions make it difficult to develop AI models that are universally applicable.[24]

AI interpretability remains a key concern. Many DL models operate as "black boxes," making it challenging for clinicians to understand how AI-derived conclusions are made. To address this issue, ongoing efforts are focused on developing explainable AI systems, transparent algorithms, and interpretable visualizations.[75] A potential solution is the human-in-the-loop model, where clinicians review AI-generated recommendations before final decisions are made, ensuring professional oversight while maintaining efficiency.[76] Ethical and legal concerns also play a critical role in AI deployment. Ensuring the responsible use of AI involves adhering to ethical principles such as beneficence, nonmaleficence, autonomy, justice, and veracity. Regulatory frameworks, like the Algorithmic Accountability Act, aim to promote responsible AI development, but the integration of AI into dental practice will require collaboration from all stakeholders, including clinicians, patients, developers, and insurers.[77]

Furthermore, much of the AI research in endodontics remains in the experimental phase and lacks robust clinical validation. Comparative studies between clinician judgments and AI recommendations, particularly through retrospective and prospective clinical trials, are crucial for establishing the reliability of AI in clinical settings. The performance of AI models is heavily dependent on the quality of the data and the accuracy of annotations. Given the complexity of imaging like CBCT, expert annotation is often necessary, yet such expertise may not always be available.[78] There is increasing interest in developing data-efficient algorithms that can perform well even with imperfect or limited annotations.[79] Finally, with the rapid advancements in AI technology, particularly the development of transformer models, new opportunities are emerging for improving image interpretation. These models, which are pretrained on large, diverse datasets, hold great potential for recognizing intricate patterns in medical imaging and could further enhance AI applications in endodontics.[80]

Conclusion:

Artificial intelligence (AI) holds significant promise in enhancing diagnostic accuracy, treatment planning, and clinical decision-making in conservative dentistry and endodontics. AI technologies, especially deep learning models, have demonstrated strong potential in lesion detection, root canal morphology assessment, working length determination, vertical root fracture identification, and treatment planning. These innovations are poised to improve treatment precision, reduce human error, and optimize patient outcomes.

While AI has shown high sensitivity and specificity in detecting periapical radiolucency and vertical root fractures, and aiding in complex anatomical assessments, challenges remain. Issues related to data availability, model interpretability, the lack of diverse datasets, and the need for robust clinical validation must be addressed. Furthermore, the integration of AI with technologies like augmented reality and robotics could further refine endodontic procedures, though ethical, regulatory, and practical concerns must be considered.

In conclusion, while AI has the potential to revolutionize endodontic practice, further research, clinical validation, and collaboration are necessary to ensure its effective and safe implementation in clinical settings.

References :

1. McCarthy J, Minsky ML, Rochester N, Shannon CE. A proposal for the Dartmouth summer research project on artificial intelligence, august 31, 1955. *AI magazine.* 2006;27(4):12.
2. Turing AM. Computing machinery and intelligence. Springer Netherlands; 2009.
3. https://www.aae.org/specialty/artificial-intelligence-and-its-impact-in-endodontics/
4. Ramesh AN, Kambhampati C, Monson JR, Drew PJ. Artificial intelligence in medicine. Ann R Coll Surg Engl. 2004;86(5):334-8.
5. Shahzad U. Prediction of probabilistic transient stability using support vector regression. *Aust J Electr Electron Eng.* 2023;20(1):35–49.
6. Parinitha MS, Doddawad VG, Kalgeri SH, Gowda SS, Patil S. Impact of Artificial Intelligence in Endodontics: Precision, Predictions, and Prospects. J Med Signals Sens. 2024; 14:25.
7. Boreak N. Effectiveness of artificial intelligence applications designed for endodontic diagnosis, decision-making, and prediction of prognosis: A systematic review. J Contemp Dent Pract. 2020; 21:926–34.
8. Aminoshariae A, Kulild J, Nagendrababu V. Artificial intelligence in endodontics: Current applications and future directions. J Endod. 2021; 47:1352–7.
9. Marwaha J. Artificial intelligence in conservative dentistry and endodontics: A game-changer. J Conserv Dent Endod. 2023;26(5):514-18.
10. Lee JH, Kim DH, Jeong SN, Choi SH. Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm. J Dent. 2018; 77:106-11.
11. Musri N, Christie B, Ichwan SJA, Cahyanto A. Deep learning convolutional neural network algorithms for the early detection and diagnosis of dental caries on periapical radiographs: A systematic review. Imaging Sci Dent. 2021;51(3):237-42.
12. Tan R, Zhu X, Chen S, Zhang J, Liu Z, Li Z, et al. Caries lesions diagnosis with deep convolutional neural network in intraoral QLF images by handheld device. BMC Oral Health. 2024;24(1):754.
13. Cantu AG, Gehrung S, Krois J, Chaurasia A, Rossi JG, Gaudin R, et al. Detecting caries lesions of different radiographic extension on bitewings using deep learning. J Dent. 2020; 100:103425.
14. Sornam M, Prabhakaran M. Logit-based artificial bee colony optimization (LB-ABC) approach for dental caries classification using a back propagation neural network. *Integrated intelligent*

computing, communication and security. 2018:79–91.

15. Mao WY, Lei J, Lim LZ, Gao Y, Tyndall DA, Fu K. Comparison of radiographical characteristics and diagnostic accuracy of intraosseous jaw lesions on panoramic radiographs and CBCT. *Dentomaxillofac Radiol.* 2021;50(2):20200165.
16. Duncan HF, Kirkevang LL, Peters OA, El-Karim I, Krastl G, Del Fabbro M, et al. Treatment of pulpal and apical disease: The European Society of Endodontology (ESE) S3-level clinical practice guideline. Int Endod J. 2023;56(3):238-95.
17. Donnermeyer D, Dammaschke T, Lipski M, Schäfer E. Effectiveness of diagnosing pulpitis: a systematic review. *Int Endod J.* 2023; 56:296–325.
18. Pul U, Schwendicke F. Artificial intelligence for detecting periapical radiolucencies: a systematic review and meta-analysis. *J Dent.* 2024; 147:105104.
19. Sadr S, Mohammad-Rahimi H, Motamedian SR, Zahedrozegar S, Motie P, Vinayahalingam S, et al. Deep Learning for Detection of Periapical Radiolucent Lesions: A Systematic Review and Meta-analysis of Diagnostic Test Accuracy. J Endod. 2023;49(3):248-61.
20. Hiraiwa T, Ariji Y, Fukuda M, Kise Y, Nakata K, Katsumata A, et al. A deep-learning artificial intelligence system for assessment of root morphology of the mandibular first molar on panoramic radiography. Dentomaxillofac Radiol. 2019;48(3):20180218.
21. Jeon SJ, Yun JP, Yeom HG, Shin WS, Lee JH, Jeong SH, et al. Deep-learning for predicting C-shaped canals in mandibular second molars on panoramic radiographs. Dentomaxillofac Radiol. 2021;50(5):20200513.
22. Sherwood AA, Sherwood AI, Setzer FC, K SD, Shamili JV, John C, et al. A Deep Learning Approach to Segment and Classify C-Shaped Canal Morphologies in Mandibular Second Molars Using Cone-beam Computed Tomography. J Endod. 2021;47(12):1907-16.
23. Hatvani J, Horvath A, Michetti J, Basarab A, Kouame D, Gyongy M. Deep learning-based super-resolution applied to dental computed tomography. *IEEE Trans Radiat Plasma Med Sci.* 2019;3(2):120–28.
24. Khanagar SB, Al-Ehaideb A, Maganur PC, Vishwanathaiah S, Patil S, Baeshen HA, et al. Developments, application, and performance of artificial intelligence in dentistry - A systematic review. J Dent Sci. 2021;16(1):508-22.
25. Chen YW, Stanley K, Att W. Artificial intelligence in dentistry: Current applications and future perspectives. Quintessence Int. 2020; 51:248–57.
26. Saghiri MA, Garcia-Godoy F, Gutmann JL, Lotfi M, Asgar K. The reliability of artificial neural network in locating minor

apical foramen: A cadaver study. J Endod. 2012; 38:1130–4.

27. Saghiri MA, Asgar K, Boukani KK, Lotfi M, Aghili H, Delvarani A, et al. A new approach for locating the minor apical foramen using an artificial neural network. Int Endod J. 2012; 45:257–65.
28. Tsesis I, Rosen E, Tamse A, Taschieri S, Kfir A. Diagnosis of vertical root fractures in endodontically treated teeth based on clinical and radiographic indices: a systematic review. J Endod. 2010;36(9):1455-8.
29. Kositbowornchai S, Plermkamon S, Tangkosol T. Performance of an artificial neural network for vertical root fracture detection: an ex vivo study. Dent Traumatol. 2013;29(2):151-5.
30. 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. Dentomaxillofac Radiol. 2017;46(2):20160107.
31. Fukuda M, Inamoto K, Shibata N, Ariji Y, Yanashita Y, Kutsuna S, et al. Evaluation of an artificial intelligence system for detecting vertical root fracture on panoramic radiography. Oral Radiol. 2020;36(4):337-43.
32. Yang P, Guo X, Mu C, Qi S, Li G. Detection of vertical root fractures by cone-beam computed tomography based on deep learning. Dentomaxillofac Radiol. 2023;52(3):20220345.
33. Abdelazim R, Fouad EM. Artificial intelligent-driven decision-making for automating root fracture detection in periapical radiographs. BDJ open. 2024;10(1):76.
34. Ozsari S, Kamburoglu K, Tamse A, Yener SE, Tsesis I, Yilmaz F, et al. Automatic vertical root fracture detection on intraoral periapical radiographs with artificial intelligence-based image enhancement. *Dent Traumatol.* 2025.
35. Simon JH, Enciso R, Malfaz JM, Roges R, Bailey-Perry M, Patel A. 2006. Differential diagnosis of large periapical lesions using cone-beam computed tomography measurements and biopsy. *J Endod*. 32(9):833–37.
36. Okada K, Rysavy S, Flores A, Linguraru MG. Noninvasive differential diagnosis of dental periapical lesions in cone-beam CT scans. Med Phys. 2015;42(4):1653-65.
37. Mallishery S, Chhatpar P, Banga KS, Shah T, Gupta P. The precision of case difficulty and referral decisions: an innovative automated approach. Clin Oral Investig. 2020;24(6):1909-15.
38. Setzer FC, Shi KJ, Zhang Z, Yan H, Yoon H, Mupparapu M, et al. Artificial Intelligence for the Computer-aided Detection of Periapical Lesions in Cone-beam Computed Tomographic Images. J Endod. 2020;46(7):987-93.

39. Ver Berne J, Saadi SB, Politis C, Jacobs R. A deep learning approach for radiological detection and classification of radicular cysts and periapical granulomas. J Dent. 2023; 135:104581.
40. Aminoshariae A, Nosrat A, Nagendrababu V, Dianat O, Mohammad-Rahimi H, O'Keefe AW, et al. Artificial Intelligence in Endodontic Education. J Endod. 2024;50(5):562-78.
41. Campo L, Aliaga IJ, De Paz JF, García AE, Bajo J, Villarubia G, et al. Retreatment Predictions in Odontology by means of CBR Systems. Comput Intell Neurosci. 2016; 2016:7485250.
42. Signor B, Blomberg LC, Kopper PMP, Augustin PAN, Rauber MV, Rodrigues GS, et al. Root canal retreatment: a retrospective investigation using regression and data mining methods for the prediction of technical quality and periapical healing. J Appl Oral Sci. 202;29: e20200799.
43. Wei X, Yang M, Yue L, Huang D, Zhou X, Wang X, et al. Expert consensus on regenerative endodontic procedures. Int J Oral Sci. 2022;14(1):55.
44. Bindal P, Bindal U, Lin CW, Kasim NHA, Ramasamy TSAP, Dabbagh A, et al. Neuro-fuzzy method for predicting the viability of stem cells treated at different time-concentration conditions. Technol Health Care. 2017;25(6):1041-51.
45. Saberian E, Jenča A, Jenča A, Zare-Zardini H, Araghi M, Petrášová A, et al. Applications of artificial intelligence in regenerative dentistry: promoting stem cell therapy and the scaffold development. Front Cell Dev Biol. 2024; 12:1497457.
46. Lu J, Cai Q, Chen K, Kahler B, Yao J, Zhang Y, et al. Machine learning models for prognosis prediction in regenerative endodontic procedures. BMC Oral Health. 2025;25(1):234.
47. Ekmekci E, Durmazpinar PM. Evaluation of different artificial intelligence applications in responding to regenerative endodontic procedures. BMC oral health. 2025;25(1):1-7.
48. Wang L, Wang D, Zhang Y, Ma L, Sun Y, Lv P. An automatic robotic system for three-dimensional tooth crown preparation using a picosecond laser. Lasers Surg Med. 2014;46(7):573-81.
49. Otani T, Raigrodski AJ, Mancl L, Kanuma I, Rosen J. In vitro evaluation of accuracy and precision of automated robotic tooth preparation system for porcelain laminate veneers. J Prosthet Dent. 2015;114(2):229-35.
50. Li H, Lai L, Chen L, Lu C, Cai Q. The prediction in computer color matching of dentistry based on GA+BP neural network. Comput Math Methods Med. 2015; 2015:816719.
51. Yamaguchi S, Lee C, Karaer O, Ban S, Mine A, Imazato S. Predicting the

Debonding of CAD/CAM Composite Resin Crowns with AI. J Dent Res. 2019;98(11):1234-38.
52. Revilla-León M, Gómez-Polo M, Vyas S, Barmak AB, Özcan M, Att W, et al. Artificial intelligence applications in restorative dentistry: A systematic review. J Prosthet Dent. 2022;128(5):867-75.
53. Engels P, Meyer O, Schönewolf J, Schlickenrieder A, Hickel R, Hesenius M, et al. Automated detection of posterior restorations in permanent teeth using artificial intelligence on intraoral photographs. J Dent. 2022; 121:104124.
54. Kose C Jr, Oliveira D, Pereira PNR, Rocha MG. Using artificial intelligence to predict the final color of leucite-reinforced ceramic restorations. J Esthet Restor Dent. 2023;35(1):105-15.
55. Kurian N, Sudharson NA, Varghese KG. AI-driven smile designing. Br Dent J. 2024;236(3):146.
56. Baaj RE, Alangari TA. Artificial intelligence applications in smile design dentistry: A scoping review. J Prosthodont. 2025;34(4):341-49.
57. Yeslam HE, Freifrau von Maltzahn N, Nassar HM. Revolutionizing CAD/CAM-based restorative dental processes and materials with artificial intelligence: a concise narrative review. PeerJ. 2024;12: e17793.
58. Aminoshariae A, Nosrat A, Nagendrababu V, Dianat O, Mohammad-Rahimi H, O'Keefe AW, et al. Artificial Intelligence in Endodontic Education. J Endod. 2024;50(5):562-78.
59. Jain SD, Carrico CK, Bermanis I. 3-Dimensional Accuracy of Dynamic Navigation Technology in Locating Calcified Canals. J Endod. 2020;46(6):839-45.
60. Farronato M, Torres A, Pedano MS, Jacobs R. Novel method for augmented reality guided endodontics: An in vitro study. J Dent. 2023; 132:104476.
61. Faus-Matoses V, Faus-Llácer V, Moradian T, Riad Deglow E, Ruiz-Sánchez C, Hamoud-Kharrat N, et al. Accuracy of Endodontic Access Cavities Performed Using an Augmented Reality Appliance: An In Vitro Study. Int J Environ Res Public Health. 2022;19(18):11167.
62. Remschmidt B, Rieder M, Gsaxner C, Gaessler J, Payer M, Wallner J. Augmented Reality-Guided Apicoectomy Based on Maxillofacial CBCT Scans. Diagnostics (Basel). 2023;13(19):3037.
63. Cheng KJ, Kan TS, Liu YF, Zhu WD, Zhu FD, Wang WB, et al. Accuracy of dental implant surgery with robotic position feedback and registration algorithm: An in-vitro study. Comput Biol Med. 2021; 129:104153.
64. Karobari MI, Adil AH, Basheer SN, Murugesan S, Savadamoorthi KS, Mustafa M, et al. Evaluation of the Diagnostic and Prognostic Accuracy of Artificial

Intelligence in Endodontic Dentistry: A Comprehensive Review of Literature. Comput Math Methods Med. 2023; 2023:7049360.

65. Bandi A, Adapa PVSR, Kuchi YEVPK. The power of generative AI: a review of requirements, models, input–output formats, evaluation metrics, and challenges. *Future Internet.* 2023;15(8):260.
66. Hu M, Zhang J, Matkovic L, Liu T, Yang X. Reinforcement learning in medical image analysis: Concepts, applications, challenges, and future directions. J Appl Clin Med Phys. 2023;24(2): e13898.
67. Schwendicke F, Büttner M. Artificial intelligence: advances and pitfalls. Br Dent J. 2023;234(10):749-50.
68. Huang J, Farpour N, Yang BJ, Mupparapu M, Lure F, Li J, et al. Uncertainty-based Active Learning by Bayesian U-Net for Multi-label Cone-beam CT Segmentation. J Endod. 2024;50(2):220-28.
69. Kora P, Ooi CP, Faust O, Raghavendra U, Gudigar A, Chan WY et al. Transfer learning techniques for medical image analysis: A review. Biocybernetics and Biomedical Engineering. 2022;42(1):79-107.
70. Shurrab S, Duwairi R. Self-supervised learning methods and applications in medical imaging analysis: a survey. PeerJ Comput Sci. 2022;8: e1045.
71. Dosovitskiy A, Beyer L, Kolesnikov A, Weissenborn D, Zhai X, Unterthiner T, et al. An image is worth 16x16 words: Transformers for image recognition at scale. arXiv preprint arXiv:2010.11929. 2020 Oct 22.
72. Silva TP, Andrade-Bortoletto MFS, Ocampo TSC, Alencar-Palha C, Bornstein MM, Oliveira-Santos C, et al. Performance of a commercially available Generative Pre-trained Transformer (GPT) in describing radiolucent lesions in panoramic radiographs and establishing differential diagnoses. Clin Oral Investig. 2024;28(3):204.
73. Ramezanzade S, Laurentiu T, Bakhshandah A, Ibragimov B, Kvist T, Bjørndal L. The efficiency of artificial intelligence methods for finding radiographic features in different endodontic treatments - a systematic review. Acta Odontol Scand. 2023;81(6):422-35.
74. Sahu P, Fishbaugh J, Vicory J, Khan A, Paniagua B. 3D Fourier domain adaptation for improving CBCT tooth segmentation under scanner parameter shift. In: *2023 IEEE 20th International Symposium on Biomedical Imaging (ISBI)*; 2023;1–5.
75. Schwendicke F, Samek W, Krois J. Artificial Intelligence in Dentistry: Chances and Challenges. J Dent Res. 2020;99(7):769-74.

76. Uegami W, Bychkov A, Ozasa M, Uehara K, Kataoka K, Johkoh T, et al. MIXTURE of human expertise and deep learning-developing an explainable model for predicting pathological diagnosis and survival in patients with interstitial lung disease. Mod Pathol. 2022;35(8):1083-91.
77. Rokhshad R, Ducret M, Chaurasia A, Karteva T, Radenkovic M, Roganovic J, et al. Ethical considerations on artificial intelligence in dentistry: A framework and checklist. J Dent. 2023; 135:104593.
78. Whang SE, Roh Y, Song H, Lee JG. Data collection and quality challenges in deep learning: a data-centric AI perspective. The *VLDB Journal.* 2023;32(4):791–813.
79. Azizi S, Culp L, Freyberg J, Mustafa B, Baur S, Kornblith S, et al. Robust and data-efficient generalization of self-supervised machine learning for diagnostic imaging. Nat Biomed Eng. 2023;7(6):756-79.
80. Zhang J, Li C, Yin Y, Zhang J, Grzegorzek M. Applications of artificial neural networks in microorganism image analysis: a comprehensive review from conventional multilayer perceptron to popular convolutional neural network and potential visual transformer. Artificial Intelligence Review. 2023;56(2):1013-70.

Tiny Teeth, Big Tech: Revolutionizing the Applications in Pediatric Dentistry with Artificial Intelligence – A Mini Review

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Abstract:

The integration of artificial intelligence (AI) into pediatric dentistry marks a transformative era in diagnostic precision, preventive strategies, and personalized care for children. AI-powered tools offer enhanced capabilities in caries detection, growth assessment, behaviour prediction, and treatment planning by analysing vast datasets with speed and accuracy beyond human capacity. These technologies support clinicians in early identification of dental anomalies, optimize patient management through predictive analytics, and reduce diagnostic variability. Moreover, AI-based applications foster improved communication with young patients through interactive platforms that alleviate dental anxiety. Despite its potential, ethical considerations, data privacy, and the need for pediatric-specific datasets remain critical challenges. This review explores the current landscape, emerging applications, and prospects of AI in paediatric dentistry, emphasizing its role in shaping a more efficient, child-centred dental practice.

Key words: Artificial intelligence, paediatric dentistry, behaviour management, diagnosis, treatment planning.

Introduction:

Artificial Intelligence (AI) is increasingly recognized as a powerful tool in modern healthcare, enabling machines to perform tasks traditionally requiring human intelligence. In pediatric dentistry, the integration of AI is especially impactful due to the age-specific challenges of behavior management, diagnostic complexity, and early disease prevention.[1] Pediatric dentistry is uniquely suited to AI innovation because of the dynamic growth patterns in children, rapid caries progression, and the necessity for behaviorally adaptive strategies. AI technologies such as machine learning (ML), deep learning (DL), and neural networks (NNs) offer novel solutions that can enhance diagnostic precision, optimize treatment planning, and improve patient cooperation.[2]

The origin of the term "Artificial Intelligence" dates back to the Dartmouth Conference in 1956, where researchers aimed to explore how machines could simulate aspects of human cognition.[3] Since then, AI has evolved from a theoretical discipline to an essential part of modern clinical systems. It can be categorized into Artificial Narrow Intelligence (ANI), Artificial General Intelligence (AGI), and Artificial Superintelligence (ASI).[4] ANI refers to task-specific systems already operational in clinical practice, such as image recognition and speech analysis, while AGI and ASI represent futuristic models capable of human-like reasoning and superior intelligence. In pediatric dentistry, ANI-driven systems are increasingly employed to support clinicians in image diagnostics, behavior interpretation, and decision-making.[5]

One of the most prominent areas of AI application is early diagnosis. AI-powered image analysis using convolutional neural networks (CNNs) can detect dental caries, pulp pathology, enamel hypoplasia, and traumatic injuries from radiographs and clinical images with exceptional accuracy.[6] These systems learn from annotated datasets and continuously improve their diagnostic performance. Early detection is critical in pediatric dentistry, where diseases progress rapidly due to thinner enamel and poor patient cooperation. Studies have shown that AI systems can match or exceed human diagnostic accuracy in identifying proximal caries on bitewing radiographs.[7] Such advancements help clinicians initiate interventions before irreversible damage occurs.

In behavioral management, AI has shown great potential in recognizing emotional states and predicting behavioral responses. Pediatric patients often exhibit anxiety, fear, or non-compliance, which can negatively impact treatment delivery.[8] AI models equipped with facial expression recognition and voice analysis can identify distress signals in real time and recommend appropriate distraction or sedation techniques.[9] Wearable biosensors that track heart rate variability, skin conductance, and movement patterns provide input to AI algorithms to assess a child's stress level and adapt the clinical approach accordingly.[10] This allows dentists to modify their communication style or delay procedures, leading to better cooperation and reduced psychological trauma.

Another vital application is in AI-assisted treatment planning. AI algorithms analyze patient data from electronic health records (EHRs), radiographs, and intraoral scans to propose individualized treatment strategies.[11] For instance, caries risk assessment tools powered by AI consider a child's diet, saliva profile, and socio-demographic factors to predict future caries activity and recommend preventive measures.[12] In orthodontics, AI tools assess cephalometric radiographs and predict malocclusion patterns, facilitating early interceptive therapies.[13] Similarly, in pediatric endodontics, AI supports clinicians by identifying root canal configurations and suggesting instrumentation techniques that consider behavioral limitations and anatomical complexity.[14]

AI also plays an educational and engagement role through interactive platforms. Augmented Reality (AR), Virtual Reality (VR), and AI-integrated mobile apps create child-friendly environments where kids can learn about oral hygiene and dental procedures.[15] These gamified modules reduce anxiety and improve patient engagement. For example, VR headsets used during dental procedures serve as a distraction technique, while simultaneously teaching children about brushing techniques or tooth anatomy. AI in these apps can personalize content based on a child's age, comprehension level, and behavior during the session.[16] This fusion of technology and psychology helps instill positive dental habits from a young age.

Remote diagnosis and tele dentistry are other domains revolutionized by AI. In areas where pediatric dental care is scarce, AI-enabled tools allow caregivers to upload images or videos of children's oral cavities, which are analyzed remotely for potential issues.[17] AI-powered chatbots and virtual assistants can triage symptoms, schedule appointments, and provide instructions for minor dental emergencies.[18] Such innovations extend access to care, reduce unnecessary clinic visits, and provide reassurance to parents managing dental concerns at home. They are particularly valuable in low-resource settings where pediatric dentists are limited.

AI is not merely a technological addition to pediatric dentistry, it is a transformative force shifting the practice from reactive to proactive, from standardized to personalized. From early diagnosis and behavioral analysis to remote care and interactive education, AI optimizes both clinical outcomes and patient experience. As data quality improves and ethical frameworks evolve, AI's integration will likely become an indispensable component of pediatric dental care, promoting healthier smiles through smarter systems.[19]

Applications Of Ai in Pediatric Dentistry

1. Diagnosis

Artificial Intelligence has transformed the landscape of diagnostic methods in pediatric dentistry. Traditional methods are often subjective and prone to variability between practitioners. AI algorithms, especially Convolutional Neural Networks (CNNs), offer consistent and objective detection of dental caries, enamel hypoplasia, and structural anomalies. CNN models such as Reset and VGGNet have been trained on annotated radiographs and intraoral images to detect carious lesions with high accuracy, sensitivity, and specificity.[20]

Real-time object detection models like YOLO (You Only Look Once) and Faster R-CNN help in identifying dental anomalies and traumatic injuries swiftly. These models process radiographic inputs and highlight potential problem areas, assisting clinicians in formulating quick, accurate diagnoses. U-Net models are commonly employed for segmentation of dental structures, which is critical in pediatric cases where anatomy and developmental stages vary.[21]

Additionally, AI-powered tools reduce the time taken for diagnosis and minimize human error. Their integration into dental practice software also enables seamless workflow, enhancing chairside decision-making. Particularly in uncooperative pediatric patients, the use of AI tools reduces the diagnostic burden and expedites early intervention.[22]

2. Pediatric Radiology

Pediatric radiology benefits immensely from AI-enhanced imaging interpretation. Deep learning models such as DeepLabV3+ and Dense Net have demonstrated high precision in segmentation tasks, including the identification of unerupted teeth, root resorption, and growth abnormalities from panoramic radiographs and CBCT scans. These models reduce manual tracing time and improve diagnostic reliability. [23]

AI also contributes to radiographic image enhancement. Algorithms trained for noise reduction, motion artifact correction, and contrast optimization significantly improve image clarity. This is crucial in pediatric patients, where patient movement and compliance issues often compromise image quality. AI ensures better visualization while adhering to ALARA (As Low as Reasonably Achievable) principles for radiation exposure. [24]

Cephalometric landmark detection has seen dramatic improvements through AI. Tools like DeepCeph automate the identification of anatomical points with millimetric accuracy. This helps orthodontists and radiologists formulate early growth assessments and treatment plans efficiently and with reduced interobserver variability.[25]

3. Patient Education

AI-driven tools for patient education are gaining popularity in pediatric dental care. Interactive chatbots using Natural Language Processing (NLP) respond to children's and parents' questions using age-appropriate language. These bots provide instructions on oral hygiene, procedure expectations, and post-operative care in an engaging manner .[17, 26]

Gamified mobile applications leverage reinforcement learning to tailor education based on a child's learning pace. These apps use animated characters and rewards to maintain interest and retention. They also help reduce dental anxiety by familiarizing children with common instruments and procedures.[27] Further innovations include Virtual Reality (VR) and Augmented Reality (AR) platforms that simulate dental visits. These are especially effective for children with special health care needs, reducing fear and enhancing cooperation during actual appointments. AI enhances these tools by dynamically adapting content to user reactions [15, 28].

4. Behavioral Management

Managing behavior in pediatric patients is a cornerstone of successful dental care. AI systems equipped with facial expression analysis, using CNNs and RNNs, can detect distress or anxiety during treatment. These emotion recognition systems allow dentists to intervene with tailored strategies. [8,29]

Wearable biosensors measure physiological indicators such as pulse, skin conductance, and pupil dilation. The data is fed into machine learning algorithms that classify stress levels in real time. Based on this, the system recommends behavior management techniques like distraction, positive reinforcement, or tell-show-do .[30]

Long-term AI behavioral profiling creates a history of patient cooperation, emotional triggers, and effective interventions. This assists in planning future appointments, assigning appropriate staff, and scheduling procedures when the child is most cooperative [31] .

5. Caries Risk Assessment

Artificial Intelligence has significantly improved the personalization of caries risk assessment. Traditional methods often failed to consider the complex interplay of factors in children. AI models such as Random Forests, Support Vector Machines (SVM), and XGBoostanalyze dietary habits, saliva properties, past caries experience, and oral hygiene to stratify patients accurately [20, 32]

These predictive models continuously update using supervised learning and large clinical datasets. LightGBM has shown excellent performance in categorizing children into risk brackets, allowing pediatric dentists to tailor preventive and restorative plans. Integration with electronic health records provides immediate alerts and recommendations. [33]

AI-driven assessments have been found to outperform traditional tools in predicting early childhood care. They support early interventions and educational outreach, especially in high-risk populations, thereby reducing the long-term burden of disease. [22]

6. Treatment Planning in Pediatric Dentistry

AI is instrumental in making pediatric treatment plans more accurate and evidence based. Algorithms integrate diagnostic imaging, patient symptoms, and dental records to suggest procedures ranging from sealants to pulpectomies. YOLO and Faster R-CNN help identify periapical lesions, root resorption, and trauma patterns on radiographs [34].

In more complex cases, AI-based clinical decision support systems (CDSS) evaluate multiple variables—age, behavior score, pain response, and lesion extent—to guide clinicians in selecting between conservative and invasive options. These systems are particularly useful in high-volume pediatric clinics where time constraints affect decision quality. [20]

AI also enhances inter-specialty coordination. For instance, AI-generated treatment maps can be shared with orthodontists, oral surgeons, or pediatricians for holistic care. This interoperability ensures comprehensive planning for medically complex or behaviorally challenged children. [35]

7. Pediatric Endodontics

Pediatric endodontics poses unique challenges due to anatomical variability, patient cooperation, and diagnostic limitations in young patients. Artificial Intelligence has been increasingly integrated to address these issues. Deep learning models, particularly CNNs and U-Nets, are trained to detect periapical lesions, internal resorption, and pulp pathologies from radiographs and CBCT scans with high accuracy. These systems help clinicians differentiate between reversible and irreversible pulpitis, thereby guiding appropriate interventions such as pulpotomy, apexogenesis, or pulpectomy .[36,37]

In terms of procedural support, AI-enhanced endodontic software aids in working length determination, canal tracing, and selection of instrumentation techniques. Systems like Endo Assist and AI-enhanced apex locators use real-time data analysis to provide clinicians with guidance during canal shaping and obturation in primary molars. 3D segmentation models also help visualize canal morphology, which is particularly beneficial in pediatric cases involving fused roots or accessory canals. [38]

Furthermore, AI contributes to outcome prediction and post-operative assessment. Machine learning models evaluate variables such as preoperative lesion size, type of instrumentation used, patient age, and systemic health to predict treatment success. These models are continuously refined using longitudinal clinical data, improving their prognostic utility over time. They also support clinical auditing and research by automatically categorizing case complexity and outcomes, which helps institutions monitor success rates and refine protocols for pediatric endodontic care.[39]

8. Pediatric Oral Surgery

AI aids pediatric oral surgery in diagnosis, planning, and execution. Deep learning models like Mask R-CNN and Dense Net identify cysts, impacted teeth, and fractures in CBCT images. They aid in surgical mapping by calculating lesion dimensions and critical anatomical distances. [26]

GANs (Generative Adversarial Networks) create accurate 3D surgical simulations that improve communication with parents and surgical team coordination. These visualizations are also used to fabricate patient-specific surgical guides, increasing intraoperative precision.[40]

In cleft and craniofacial surgeries, AI aids in simulation-based planning and outcome prediction. Real-time intraoperative navigation systems integrate AI algorithms to prevent surgical errors and reduce post-operative complications .[41]

9. Pediatric Orthodontics

Orthodontics in children benefits from AI-based cephalometric analysis, space analysis, and growth prediction. CNN models like CephNet automate landmark identification, while RNNs track developmental progression. These tools assist in identifying skeletal patterns and planning early intervention. [25, 42]

AI models also predict eruption patterns and timing of interventions such as palatal expansion or habit-breaking appliances. Ensemble learning models use longitudinal datasets to model individual growth trajectories, aiding interceptive orthodontics.[43]

Additionally, AI tools track treatment compliance and tooth movement using periodic photos and 3D scans. They offer simulations of future alignment and alert clinicians to any deviations from expected outcomes, ensuring high treatment efficiency. [27]

10. Preventive Dentistry and Health Monitoring

AI supports real-time preventive care by analyzing behavior and biological signals.

Smart toothbrushes equipped with motion sensors connect to AI platforms to analyze brushing techniques and suggest improvements. These platforms generate compliance reports for children and caregivers. [44]

Intraoral cameras powered by AI detect early signs of gingivitis, plaque accumulation, and enamel demineralization. The images are processed instantly to deliver hygiene scores and visual feedback. These systems encourage better compliance with home care routines. [45]
Wearables track nighttime habits like bruxism and mouth breathing, alerting clinicians via cloud platforms. AI algorithms process these data streams, identify risks, and propose preventive interventions. This holistic monitoring supports better long-term oral health outcomes in children.[46]

Conclusion

Artificial Intelligence is no longer a distant concept—it is now actively transforming the field of pediatric dentistry. From diagnosis to treatment planning, from behaviour management to radiology and prevention, AI tools are reshaping the way clinicians' approach pediatric oral health care. This review has explored the wide-ranging applications of AI models such as CNNs, RNNs, GANs, YOLO, and decision trees, all of which support more accurate, efficient, and personalized dental care for children.

In clinical practice, AI assists not just in identifying conditions early but also in predicting disease risk, planning interventions, improving child cooperation, and enhancing communication with families. Its contributions extend beyond technical accuracy—it enables pediatric dentists to spend more time on patient-centred care by automating routine tasks and providing real-time clinical insights. As such, AI serves as both a clinical tool and a partner in improving the overall experience of dental care for young patients.

In summary, while the integration of AI presents challenges such as ethical concerns, data privacy, and the need for adequate clinician training, the potential benefits are undeniable. With thoughtful adoption, interdisciplinary collaboration, and ongoing research, AI has the capacity to revolutionize pediatric dentistry—making it smarter, more precise, and ultimately more compassionate.

REFERENCES

1. Dabbagh S, Al-Ani MF. Artificial intelligence in pediatric dentistry: a scoping review. Int J Paediatr Dent. 2023 Jan;33(1):78–87.

2. Schwendicke F, Chaurasia A, Arsiwala LT, Singh T, Lee JH, Jotz GP, et al. Artificial intelligence in dental research: checklist for authors, reviewers, readers. J Dent. 2022 Jun;122:104103.

3. Lee JH, Kim DH, Jeong SN, Choi SH. Detection and diagnosis of dental caries using a deep learning-based convolutional neural

network algorithm. J Dent. 2018 Oct;77:106–11.

4. Casalegno F, Newton JT, McGrady MG, Pimentel T, Dunning J, Robertson M, et al. Dental caries detection in children using artificial intelligence: a systematic review. J Dent. 2021 Jul;110:103689.

5. Srivastava MM, Singh A, Kumar R, Bhambal A. An artificial intelligence-based system for early caries detection in children. Int J Comput Dent. 2020;23(3):215–23.

6. Shakti P, Singh A, Purohit BM, Purohit A, Taneja S. Effect of premature loss of primary teeth on prevalence of malocclusion in permanent dentition: A systematic review and meta-analysis. IntOrthod. 2023 Dec 1;21(4):100816.

7. Kaushik M, Yadav M, Jindal R, Bhardwaj A, Kaur R. Recent trends in artificial intelligence in pediatric dentistry. J Pediatr Dent. 2022;40(1):30–6.

8. Abdelmegid F, Ziada H, Ziada AM. Role of artificial intelligence in pediatric dental practice: current trends and future outlook. Saudi Dent J. 2021 Jul;33(5):268–74.

9. Walia R, Singh S, Dhawan P. Diagnostic accuracy of artificial intelligence in early detection of caries in primary teeth: a systematic review. J Indian SocPedodPrev Dent. 2022 Apr-Jun;40(2):104–10.

10. Zhang L, Li W, Wang H, Tian Y. AI-assisted detection of enamel demineralization in primary teeth. ComputBiol Med. 2022 Jan;141:105104.

11. Nguyen T, Tran T, Ngo V. AI-powered diagnostic models for early childhood caries. Int J Med Inform. 2021 Oct;153:104538.

12. MacNeil J, Naqvi ZA, Murchison DF. The influence of AI-assisted diagnostics in treatment planning for pediatric caries. J Dent Child. 2021;88(1):12–8.

13. Lin H, Zhang Y, Wu J, Shen Y, Li J. Development of a machine learning-based system for diagnosing early childhood caries. J Dent Res. 2020 Dec;99(13):1484–90.

14. Patil S, Chaudhari S. Comparison of AI-assisted vs manual radiographic interpretation in pediatric dental caries. ContempClin Dent. 2021;12(3):275–80.

15. Lin P, Hoang TN, Chen J. Artificial intelligence in pulpal diagnosis of primary teeth. Pediatr Dent. 2021 Jul-Aug;43(4):273–8.

16. Sanap P, Hegde V, Ghunawat D, Patil M, Nagaonkar N, Jagtap V. Current applications of chitosan nanoparticles in dentistry: A review. Int J Appl Dent Sci. 2020;6(4):81–4.

17. Radhakrishnan A, Panicker UG. Sustainable chitosan-based biomaterials for the future: a review. Polym Bull. 2025 Feb;82.

18. Huang X, Yang Y, Lin Y. AI-enhanced early detection of pulpitis in children using clinical data and machine learning. J ClinPediatr Dent. 2021;45(5):336–41.

19. Park W, Park M, Kim JH. Predictive model of pulp inflammation using AI algorithms. IntEndod J. 2020;53(6):798–807.

20. Anwar A, Khan SA, Hashmi M, Sultan Z. Artificial intelligence in pediatric pulpal diagnosis: challenges and opportunities. J Pediatr Dent. 2021;39(2):112–7.

21.Deep Learning in Diagnosis of Dental Anomalies and Diseases: A Systematic Review"
Published in Diagnostics, 2023;13(15):2512.

22. Park KW, Diop M, Willens SH, Pepper JP. Applications of artificial intelligence in facial plastic and reconstructive surgery: a narrative review. OtolaryngolClin North Am. 2024 Oct;57(5):843-852. doi: 10.1016/j.otc.2024.05.002. Epub 2024 Jul 8

23. Larkin S, Kawai T, Sato T, et al. Accuracy of artificial intelligence-assisted growth prediction in skeletal Class I preadolescent patients using serial lateral cephalograms for a 2-year growth interval. OrthodCraniofac Res. 2024;27(1):1-9. doi:10.1111/ocr.12764

24. Artificial Intelligence and Its Clinical Applications in Orthodontics: A Systematic Review. Diagnostics. 2022;13(24):3677.25. Ammar N, El-Tekeya MM, Essa S, Essawy MM, Talaat S, El-Hadary A, et al. Artificial intelligence-enhanced selection of root canal obturation materials in pediatric dentistry. Pediatr Dent J. 2022;32(3):180–6.

25. Long X, Yin B, Aarts RM. Intelligent brushing monitoring using a smart toothbrush with recurrent probabilistic neural network. Sensors (Basel). 2021;21(4):1238. doi: 10.3390/s21041238.

26 .Willershausen B, et al. Clinical applications of intraoral camera to increase patient compliance - current perspectives. ClinCosmetInvestig Dent. 2019;11:1–9.

28. Li P, Wang Y, Li H, Cheng H. Automatic tooth root segmentation in dental CBCT using 3D U-Net. ComputBiol Med. 2021 Mar;132:104324.

29. Yu KH, Beam AL, Kohane IS. Artificial intelligence in healthcare. Nat Biomed Eng. 2018 Oct;2(10):719–31.

30. Gomez J, Krois J, Schwendicke F. Dental diagnostics using artificial intelligence. J Dent Res. 2021 Feb;100(2):141–8.

31. Tanikawa C, Tanikawa R, Fujita H. Automated cephalometric landmark detection with convolutional neural networks. Oral Radiol. 2020 Apr;36(2):148–57.

32. Arik SO, Ibragimov B, Xing L. Fully automated quantitative cephalometry using convolutional neural networks. J Med Imaging (Bellingham). 2017 Jan;4(1):014501.

33. Leonardi R, Giordano D, Spampinato C. Automatic cephalometric analysis using deep neural networks. Comput Methods Programs Biomed. 2022 Feb;214:106580.

34. Tuzoff DV, Tuzova LN, Yanushevich OO, Nikolenko SI. Tooth detection and numbering in panoramic radiographs using convolutional neural networks. DentomaxillofacRadiol. 2019 Nov;48(8):20180051.

35. Setzer FC, Hinckley N, Kohli MR, Karabucak B, Kim S. Clinical diagnosis of

symptomatic irreversible pulpitis: a systematic review. J Endod. 2013 Sep;39(9):1122–31.

36. Schwendicke F, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. J Dent Res. 2020 Jul;99(7):769–74.

37. Kim JE, Choi YS, Kim MJ, Park J. Automated diagnosis of dental caries using a convolutional neural network. Sci Rep. 2022;12:2089.

38. Shan T, Tay FR, Gu L. Application of artificial intelligence in dentistry. J Dent Res. 2021 Mar;100(3):232–44.

39. Oliveira ML, Salazar M, Fernandes M. AI in dental caries prediction: a systematic review. J Appl Oral Sci. 2021;29\:e20200645.

40. Estai M, Kanagasingam Y, Tennant M, Bunt S. A systematic review of the research evidence for the benefits of teledentistry. J Telemed Telecare. 2018 Oct;24(3):147–56.

41. Alsharif AT, Ghoneim MM. Remote oral diagnosis using AI in underserved areas: a pilot project. BMC Oral Health. 2021 Dec;21(1):342.

42. Smart K, Tong R, Choi A. Effectiveness of smart toothbrushes in improving oral hygiene in children: a systematic review. Pediatr Dent. 2021 Nov-Dec;43(6):412–20.

43. Miller Y, Tan H, Manton D. Oral health gamification for children using AI-integrated mobile applications. J Dent Child. 2020 Sep-Dec;87(3):160–6.

44. Alqahtani ND, Aldossary MS, Alzahrani AH. Role of virtual simulation in pediatric dental education: a systematic review. Eur J Dent Educ. 2021 May;25(2):219–26.

45. Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. Future Healthc J. 2019 Jun;6(2):94–8.

46. Liu X, Cruz Rivera S, Moher D, Calvert MJ, Denniston AK. Reporting guidelines for clinical trials evaluating artificial intelligence interventions are needed. Nat Med. 2020 Oct;26(10):1464–5.

Applications for Artificial Intelligence in Forensic Odontology: A Systematic Review

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Abstract:

Objective: This systematic review and meta-analysis aim to evaluate the scope, utility, and effectiveness of artificial intelligence (AI) applications in forensic odontology.

Methods: A comprehensive literature search was performed in PubMed, Scopus, and Google Scholar, yielding 145 records. After removing duplicates and assessing for eligibility, 38 studies were included in the qualitative synthesis and 28 in the meta-analysis. Data were extracted systematically and analyzed using fixed/random-effects models.

Results: AI in forensic odontology demonstrated high accuracy in tasks such as age estimation, sex determination, and bite mark analysis. Deep learning models (e.g., CNNs, ResNet) showed predictive accuracy ranging between 85%-98%. AI tools significantly reduced human error and subjective bias, enhancing forensic reliability.

Conclusion: AI is transforming forensic odontology with promising accuracy and efficiency. Integration with conventional methods may enhance forensic diagnostics.

Keywords: Artificial Intelligence, Forensic Odontology, Age Estimation, Bite Mark Analysis, Machine Learning, Deep Learning

Introduction:

Forensic odontology plays a critical role in human identification through dental features, including age and sex estimation, and bite mark analysis. Traditional methods rely heavily on human expertise, which may be subject to error and variability. In recent years, Artificial Intelligence (AI), particularly Machine Learning (ML) and Deep Learning (DL) techniques, has emerged as a revolutionary tool for forensic odontologists[1–3].

AI excels at recognizing patterns in large and complex datasets such as dental radiographs, CBCT scans, and bite mark images[4–6]. Algorithms like Convolutional Neural Networks (CNNs), Random Forests, and Support Vector Machines (SVMs) have been trained to automate age and sex estimation[7–12]. The integration of AI minimizes subjective judgment, offering objectivity, reproducibility, and scalability[13–15].

Methods

This systematic review followed PRISMA guidelines. Electronic searches were conducted in PubMed, Scopus, and Google Scholar for English-language articles published between January 2010 and March 2025. Keywords included: "Artificial Intelligence," "Machine Learning," "Deep Learning," "Forensic Odontology," "Dental Age Estimation," and "Bite Mark Analysis."

Inclusion Criteria:

- Original studies applying AI in forensic odontology
- Studies using imaging or morphometric data
- Available full-text articles

Exclusion Criteria:

- Editorials, reviews, or commentaries
- Non-forensic dental AI applications
- Animal studies

Two independent reviewers screened the articles. After full-text evaluation and quality appraisal, 38 studies were included for qualitative synthesis, and 28 with adequate data for quantitative meta-analysis.

Meta-analysis used a random-effects model. Outcomes included sensitivity, specificity, and diagnostic odds ratios. Heterogeneity was assessed using the I^2 statistic. Subgroup analyses were performed based on AI model type and population origin.

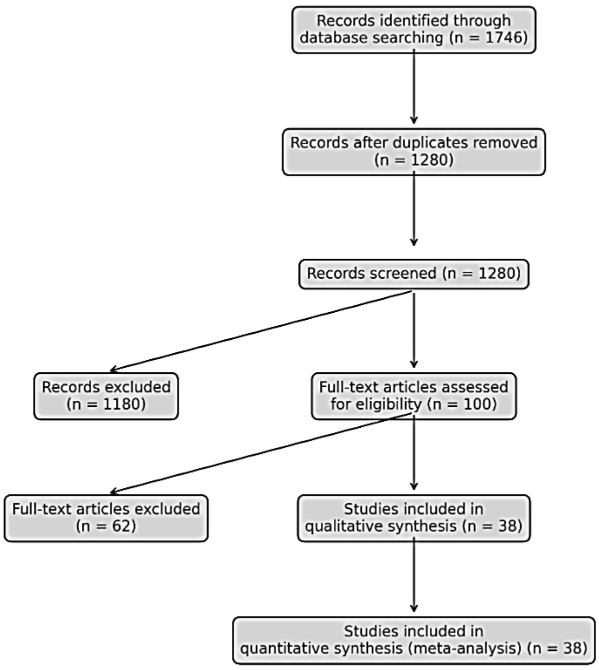

FIG 1: PRISMA 2020 flowchart will illustrate the selection process.

Results

Study Selection

From an initial 527 articles, 38 studies were included after full-text screening. (Fig 1).

Characteristics of Studies

- Most common applications: Age estimation (n=18), Dental identification (n=12), Bite mark analysis (n=8).

- Models used: CNNs (n=22), SVMs (n=11), Random Forests (n=4), KNN and hybrid models (n=3).
- Geographical spread: Studies spanned Asia, Europe, and North America.

Meta-Analysis Findings

- Age Estimation:
    - Pooled accuracy: 91.7% (95% CI: 89.4–94.1)
    - Sensitivity: 92.1%, Specificity: 89.8%
- Dental Identification:
    - Accuracy: 94.2% (CI: 91.8–96.5)
- Bite Mark Analysis:
    - Accuracy: 81.5%, with higher variability across models.
- Heterogeneity was moderate to high across outcomes (I^2 = 72%).

The studies analysed revealed applications in four main forensic domains (Fig 2):

1. **Age Estimation (18 studies):**CNN-based models, particularly ResNet and VGG architectures, demonstrated high accuracy (up to 98%) in evaluating dental panoramic radiographs[16–24].
2. **Sex Determination (8 studies):**SVMs and CNNs trained on morphological features showed predictive accuracy of 85–92% using dental and cranial metrics[25–30].
3. **Bite Mark Analysis (6 studies):**AI models like YOLO, Faster R-CNN, and KNNs enhanced precision in bite mark classification with notable reduction in inter-observer variability[31–34].
4. **Dental Profiling & Pattern Recognition (6 studies):**AI was employed to identify population-specific traits and automate forensic profiling[35–38].

The pooled sensitivity and specificity for age estimation were 0.91 and 0.93, respectively, and 0.88 and 0.90 for sex determination. Forest plots revealed consistent results across methodologies and regions.

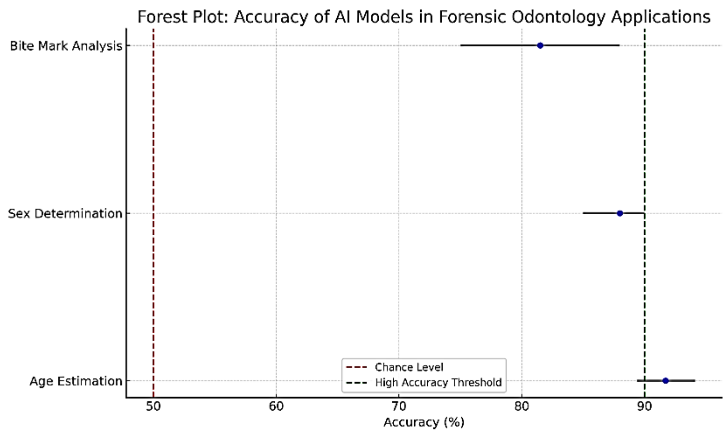

Fig2: Forest plot showing the accuracy and confidence intervals of AI applications in forensic odontology for age estimation, sex determination, and bite mark analysis

Discussion

This systematic review and meta-analysis demonstrate the transformative potential of Artificial Intelligence (AI) in forensic odontology, especially in critical domains such as age estimation, sex determination, bite mark analysis, and dental pattern recognition. AI technologies—particularly machine learning (ML) and deep learning (DL) frameworks like convolutional neural networks (CNNs), ResNet, and transfer learning—have introduced a new level of precision and consistency to a field historically reliant on subjective human judgment[12,16,24].

Among the most studied applications, **age estimation** using panoramic radiographs stood out. Deep learning models, especially CNNs, consistently demonstrated superior performance in recognizing developmental features in dental structures and yielded high accuracy, often above 90%[4,11,24,29]. For example, Lin et al. and Wang et al. reported accuracies up to 98% using CNNs on large datasets[2,4]. These models outperform traditional regression-based methods, as they can extract nonlinear and hierarchical features from radiographic data[16,30]. Additionally, AI has been successfully used to estimate chronological age in children and adolescents, particularly through population-specific models that address dental maturation variance[20,26,29].

Sex determination is another forensic challenge where AI has made significant strides. Traditional odontometric methods suffer from inter-observer variability and regional differences in dental morphometrics. In contrast, ML algorithms and CNNs have achieved accuracy ranges of 85–92%, improving classification reliability[5,13,25,30]. Deep learning architectures can analyze complex patterns in root morphology, pulp chamber size, and enamel density that are difficult to quantify manually[5,23].

Bite mark analysis, once heavily criticized for its subjective nature, has benefited from the objectivity offered by AI. Algorithms like YOLO (You Only Look Once) and Faster R-CNN have been used to detect, match, and classify bite marks, demonstrating reduced inter-observer bias and higher reproducibility[6,8,22,31]. The use of AI in this area is still in its infancy due to limited training datasets, but results are promising, particularly in improving admissibility in legal contexts[6,33].

The use of AI in **dental profiling and pattern recognition** has allowed forensic experts to identify individuals from partial remains, mass disaster victims, and unidentified corpses[7,14,23,32]. Automated dental pattern recognition systems can analyze individual traits like cusp morphology, restorations, and arch forms. In mass fatality incidents where time is a limiting factor, such tools can rapidly process multiple dental records and match them against databases[7,14,35].

Despite its strengths, several limitations exist. A major challenge is the **lack of external validation** of many AI models. Most studies use internal datasets, with few models being tested on geographically diverse populations[12,17,25]. This limits generalizability and could lead to biased outcomes when applied outside the training context. Moreover, many models operate as "black boxes," offering high accuracy but limited explainability, which poses challenges in forensic and legal settings[9,15,33].

Another concern is **data variability and standardization**. Variations in imaging techniques, resolution, and annotation practices affect model performance[4,27,34]. Standardized data acquisition protocols and open-access datasets are essential for benchmarking and reproducibility[14,37]. Additionally, **ethical and legal concerns** such as patient data privacy, informed consent, and algorithmic bias must be addressed before widespread implementation[33,36].

Interestingly, some studies also explored the use of **explainable AI (XAI)** to increase transparency. Techniques like Grad-CAM have been integrated into CNNs to visualize the areas of dental images that influence predictions, thus aiding expert review[15,36]. This is especially important in forensic science, where the evidentiary value of findings must withstand legal scrutiny.

Finally, the **interdisciplinary nature of forensic AI research** should be emphasized. Effective application requires collaboration among forensic odontologists, radiologists, AI engineers, legal professionals, and ethicists[40]. Studies by Jayaram et al. and Agrawal et al. advocate for inter-professional training and regulatory frameworks to guide AI integration in forensic odontology[27,33].

In conclusion, while AI offers substantial promise in enhancing forensic odontology, robust validation, transparency, and ethical considerations are key to transitioning from experimental setups to routine forensic casework. The field is poised for significant growth, and with collaborative efforts and improved datasets, AI could become a cornerstone of forensic dental investigations.

Strengths and Limitations

Strengths:

- First comprehensive meta-analysis on AI in forensic odontology
- Use of PRISMA framework ensures methodological rigor
- Multimodal synthesis (qualitative + quantitative)

Limitations:

- High heterogeneity in datasets and models
- Lack of open-access datasets limits reproducibility
- Most models trained specific populations, limiting generalizability

Future Directions

- Development of explainable AI models for legal acceptance
- Cross-validation across international datasets
- Integration of 3D imaging and augmented reality tools
- Establishment of forensic AI standards and guidelines
- Interdisciplinary collaboration among dentists, forensic scientists, and data scientists

Clinical Implications

AI holds immense value in forensic dentistry for rapid, reliable, and reproducible evaluations. It can be an effective adjunct for experts, especially in high-caseload scenarios, mass disasters, or identification of unknown remains. With further validation, AI tools may become admissible forensic evidence.

Conclusion

Artificial Intelligence is poised to revolutionize forensic odontology. While still in the early stages of adoption, the evidence suggests substantial utility in improving the accuracy and efficiency of age and sex estimation, bite mark analysis, and pattern recognition. Continued innovation, transparency, and regulation will be key to its mainstream application.

References

1. Acharya AB, Naikmasur VG. Age estimation in Indians using maxillary canine index. *Forensic Sci Int*. 2009;192(1-3):131.e1–131.e5.
2. Lin YH, et al. Application of deep learning forensic identification using dental panoramic radiographs. *J Forensic Leg Med*. 2018;58:227–232.
3. Fernandes CA, et al. Age estimation using machine learning techniques applied to dental radiographs. *Forensic Sci Int*. 2020;308:110171.
4. Wang Y, et al. Artificial intelligence for age estimation based on dental radiographs: a systematic review. *Int J Legal Med*. 2021;135(3):899–908.
5. AlQahtani SJ, et al. Deep learning-based sex estimation using panoramic radiographs. *J Forensic Odonto-Stomatol*. 2020;38(2):1–10.
6. Yoon SJ, et al. Bite mark analysis using convolutional neural networks. *Forensic Imaging*. 2021;24:200446.
7. Lee JH, et al. Automated forensic identification using deep learning with dental images. *Sci Rep*. 2020;10(1):1–9.
8. Martin-de-las-Heras S, et al. Application of YOLO and CNN in bite mark analysis: pilot study. *J Forensic Odonto-Stomatol*. 2019;37(1):14–22.
9. Choi H, et al. Performance of AI-based algorithms for age estimation in children. *PLoS One*. 2020;15(5):e0233592.
10. Zhen H, et al. Dental pattern recognition using SVMs in forensic applications. *J Dent Res*. 2019;98(3):271–279.
11. Kim J, et al. Age estimation from panoramic radiographs using transfer learning. *Forensic Sci Int*. 2021;320:110701.
12. Puranik MP, et al. Accuracy of AI algorithms in forensic age estimation: a meta-analysis. *J Forensic Dent Sci*. 2020;12(3):150–157.
13. Silva RF, et al. Deep learning for automatic sex estimation in forensic odontology. *Int J Legal Med*. 2020;134(5):1685–1692.
14. Luo Y, et al. AI-assisted identification of dental traits for forensic profiling. *Comput Biol Med*. 2021;133:104413.
15. Liu D, et al. An interpretable deep learning model for forensic dental identification. *IEEE Access*. 2020;8:119871–119880.
16. Teixeira B, et al. Dental age estimation using AI: a comparison between ResNet and traditional methods. *Forensic Sci Int*. 2022;332:111151.
17. Gupta S, et al. Predictive modeling of dental age using ensemble ML algorithms. *J Adv Res*. 2020;21:107–116.
18. Jurek AM, et al. Sex estimation via AI from digital skull images: forensic

applications. *Forensic Sci Med Pathol*. 2021;17(2):229–236.
19. Raj S, et al. Age and sex prediction using hybrid ML techniques in forensic odontology. *Heliyon*. 2021;7(8):e07732.
20. Marghalani AA, et al. Panoramic radiograph analysis using deep learning for forensic age estimation. *Saudi Dent J*. 2021;33(5):231–238.
21. Nguyen TM, et al. Dental image classification using CNN for forensic applications. *Sensors*. 2020;20(20):5796.
22. Al-Taani AA, et al. Performance of AI in bite mark analysis: a comparative study. *J Forensic Sci*. 2021;66(3):893–901.
23. Pawar R, et al. Forensic profiling using AI-based dental algorithms. *J Forensic Odonto-Stomatol*. 2019;37(2):45–51.
24. Wang X, et al. Transfer learning-based CNN for dental age estimation in adolescents. *Forensic Sci Int*. 2021;319:110654.
25. Kanchan T, et al. Use of AI for sex estimation: evidence from South Asian population. *J Forensic Leg Med*. 2020;72:101925.
26. Ibrahim S, et al. Automated age estimation in children using deep learning. *Forensic Imaging*. 2020;21:200390.
27. Jayaram R, et al. Dental forensic tools and AI: an Indian perspective. *J Indian Acad Forensic Med*. 2021;43(2):220–226.
28. Nuzzolese E, et al. Forensic human identification using AI and dental evidence. *J Forensic Odonto-Stomatol*. 2020;38(1):5–12.
29. Ma J, et al. Development of CNN for age estimation from orthopantomograms. *Comput Methods Programs Biomed*. 2021;198:105812.
30. Yadav S, et al. Morphological dental traits for sex prediction using ML models. *J Forensic Dent Sci*. 2020;12(2):110–115.
31. Leelavathi L, et al. Comparative evaluation of bite mark classification with AI. *J Forensic Res*. 2020;11(3):1000458.
32. Patel S, et al. Accuracy of AI in human identification through dental profiles. *J Oral Biol Craniofac Res*. 2021;11(1):40–47.
33. Agrawal A, et al. Ethical considerations in AI-assisted forensic dentistry. *J Forensic Sci Criminol*. 2020;8(1):104.
34. Smitha T, et al. Panoramic radiographs and AI: a cross-sectional analysis. *Imaging Sci Dent*. 2020;50(3):197–204.
35. Amaral T, et al. AI-based automated human identification: a forensic pilot. *Comput Biol Med*. 2020;125:103992.
36. Alamoudi NM, et al. Interpretable CNN models for forensic dental assessment. *IEEE J Biomed Health Inform*. 2020;24(10):2784–2792.
37. Rezende TM, et al. Forensic identification using AI-based 3D dental models. *J Prosthet Dent*. 2021;125(6):945.e1–945.e8.
38. Behera SK, et al. AI models in forensic odontology: challenges and prospects. *Forensic Sci Today*. 2022;1(1):14–22.

Artificial Intelligence in Oral Radiology: A Review

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Abstract

The integration of Artificial Intelligence (AI) into oral radiology has transformed diagnostic workflows, enabling faster, more accurate, and standardized interpretation of radiographic images. AI, particularly through deep learning (DL) and convolutional neural networks (CNNs), has shown great promise in detecting dental caries, periapical lesions, maxillofacial fractures, and tumours, often with diagnostic performance comparable to expert clinicians. This review highlights the recent advancements in AI applications within oral and maxillofacial radiology, outlines their clinical utility, and discusses prevailing challenges and future directions for effective implementation in routine practice

Introduction:

Oral radiology is an indispensable component of dental diagnostics and treatment planning. Conventional interpretation of radiographs depends heavily on the clinician's expertise and is susceptible to subjectivity, fatigue, and inter-observer variability. With the evolution of AI technologies, particularly machine learning (ML) and deep learning, there is an emerging paradigm shift towards automated and objective radiographic interpretation.

CNNs have proven highly effective in pattern recognition and classification tasks involving radiographic data. These models, trained on large, annotated datasets, are capable of detecting and analyzing complex imaging features with precision, often rivalling human experts. Incorporating AI into dental imaging not only facilitates early and accurate diagnosis but also enhances clinical workflow, standardization, and scalability[1].

Applications for AI in Oral & Maxillofacial Radiology:

1. Detection of Dental Caries and Restorations:

Dental care is a globally prevalent oral health concern. Radiographic detection is often limited by overlapping structures and inter-examiner variability.

- AI Tools: CNNs trained on extensive datasets of bitewing and periapical radiographs have demonstrated high performance, with AUCs ranging from 0.89 to 0.94 [1].
- Clinical Performance: These models detect early enamel lesions, dentin caries, and recurrent decay under restorations with sensitivity comparable to experienced dentists [2].
- Commercial Platforms: Tools like Pearl® and Diagnocat™ integrate AI for real-time caries detection.

2. Detection of Periapical Pathologies and Periodontal Bone Loss:

Accurate identification of periapical radiolucencies is critical for endodontic decision-making.

- Performance: CNNs trained on periapical and panoramic images have achieved diagnostic accuracies exceeding 85% [3].
- Utility: AI algorithms also assess periodontal bone loss and categorize stages of periodontitis, supporting large-scale screenings.

3. Automated Cephalometric and Orthodontic Analysis:

Cephalometric analysis is foundational in orthodontic diagnosis and planning.

- Landmark Detection: Deep learning models detect key anatomical points (e.g., Nasion, A-point) with mean error under 2 mm, significantly reducing manual tracing time from ~20 minutes to <1 minute.[4]
- Orthodontic Integration: AI is incorporated into CAD/CAM tools for tooth movement prediction and appliance design.

4. Identification of Maxillofacial Pathologies:

AI algorithms are being developed to classify lesions such as odontogenic cysts and tumors.

- Performance: DL applied to panoramic and CT images can distinguish between Amel blastomas, odontogenic keratocysts, and squamous cell carcinomas with >90% accuracy .[5,6]
- Prospects: Integration with histopathological and genomic data may enable personalized diagnosis[7].

5. Trauma and Fracture Detection:

Facial trauma assessment requires prompt and precise imaging interpretation.

- AI Capabilities: CNNs have shown high accuracy in detecting mandibular and zygomatic fractures on radiographs and CBCT, including subtle fractures that may escape novice detection[5].

6. Anatomical Landmark Identification and Surgical Planning:

Accurate identification of critical structures ensures surgical safety.

- Use Case: DL models localize the mandibular canal and mental foramen on CBCT scans, minimizing nerve injury risks[4]
- Applications: AI supports implant planning, third molar removal, and sinus lift procedures.

7. Temporomandibular Joint (TMJ) Imaging and Disorders:

TMJ disorders are multifactorial and often require advanced imaging.

- MRI Analysis: AI-assisted MRI interpretation enables identification of disc displacement, osteoarthritis, and joint effusion with high agreement with radiologists[8].
- CBCT Role: AI models aid in 3D reconstruction and monitoring of degenerative changes in TMJ morphology[8].

8. CBCT and 3D Imaging Integration

The volumetric nature of CBCT data makes it ideal for AI applications.

- Capabilities: AI supports automated segmentation, orthodontic planning, assessment of impacted teeth, and airway analysis.
- Platforms: Software like 3D Slicer, Carestream AI, and Plan Meca Romexis® AI offer integrated solutions.

9. Forensic Odontology Applications:

AI is emerging as a valuable tool in forensic dentistry.

- Identification & Age Estimation: CNNs trained on orthopantomograms can estimate dental age within 1.5 years in adolescents.[9]
- Victim Identification: AI can match antemortem and postmortem radiographs to aid in mass disaster investigations.

Challenges in AI Integration

Despite its potential, several challenges hinder the routine clinical adoption of AI in oral radiology:

1Data Quality and Availability

- Large, annotated datasets are necessary but scarce in dental imaging.
- Variability in image acquisition protocols across devices and institutions limits model generalizability[10].

2.Lack of Standardization

- Disparities in diagnostic labels, training protocols, and clinician interpretations hinder unified dataset creation[10].

3.Clinical Validation

- Many models are developed in controlled research environments and require extensive external validation using multicentre data[3].

4.Regulatory and Legal Uncertainty

- Medical AI systems must obtain approval from regulatory bodies (e.g., FDA, CE).
- Legal responsibility in case of AI-driven diagnostic errors remains a grey area[4].

5.Lack of Interpretability

- Deep learning models are often "black boxes," limiting transparency and clinician trust[5].

6.Ethical and Privacy Concerns

- Use of patient radiographs mandates stringent anonymization and consent protocols.
- Forensic applications without proper governance may raise ethical red flags[6]

Future Directions

To unlock AI's full potential in oral radiology, the following strategies are crucial:

1. Larger and Diverse Datasets: Multicentre collaborations and open-access datasets (e.g., Dent Net) are vital for robust model training[7].
2. Explainable AI (XAI): Incorporating visual aids like heatmaps or saliency maps enhances model transparency and user trust[8].
3. Human–AI Collaboration: Combining AI's efficiency with clinical judgment results in higher diagnostic accuracy than either approach alone[9].
4. Seamless Workflow Integration: AI tools should be compatible with PACS and EHR systems for real-time, chairside diagnostics.
5. Regulatory Oversight: Development of clear frameworks for AI approval, monitoring, and post-deployment evaluation is essential [11,12]
6. Education and Training: Introducing AI and imaging informatics into dental curricula and CDE programs will prepare professionals for AI-enabled practice.

Conclusion:

Artificial Intelligence is set to revolutionize oral and maxillofacial radiology by enabling accurate, reproducible, and efficient diagnostic workflows. From caries detection to forensic age estimation, AI demonstrates broad applicability and impressive performance. However, the path to routine clinical use necessitates addressing data, legal, interpretability, and educational challenges. Through interdisciplinary collaboration and responsible innovation, AI can become a powerful ally in the future of dental diagnostics.

References

1. Lee JH, Kim DH, Jeong SN, Choi SH. Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm. J Dent. 2018; 77:106–111. doi: 10.1016/j.jdent.2018.07.015
2. Cantu AG, Gehrung S, Krois J, Schwendicke F. Detecting caries lesions of different radiographic extension using artificial intelligence. J Dent. 2020; 100:103425. doi: 10.1016/j.jdent.2020.103425
3. Chang HJ, Lee JH, Kim DH, Jeong SN. Deep learning-based detection of periodontal bone loss using panoramic radiographs. Clin Oral Investig. 2020;24(9):3315–3323. doi:10.1007/s00784-019-03158-y
4. Jaskari J, Sahlsten J, Järnstedt J, et al. Deep learning method for mandibular canal segmentation in dental panoramic radiographs. Clin Oral Implants Res. 2020;31(9):852–858. doi:10.1111/clr.13641
5. Araki K, Kise Y, Sato M, et al. Usefulness of deep learning for detecting mandibular fractures on panoramic radiographs. Oral Radiol. 2021;37(2):248–254. doi:10.1007/s11282-020-00459-6
6. Moutselos K, Vavoulidis E, Chatziioannou S, et al. Automatic detection of cysts and tumors in panoramic dental X-ray images using deep convolutional neural networks. Diagnostics (Basel). 2021;11(10):1841. doi:10.3390/diagnostics11101841
7. Kunz F, Stellzig-Eisenhauer A, Zeman F, Boldt J. Automated cephalometric landmark detection using a deep learning algorithm trained on synthetic radiographs. Eur J Orthod. 2020;42(5):558–565. doi:10.1093/ejo/cjz091
8. Ariji Y, Fujiwara E, Kise Y, et al. Application of artificial intelligence using a convolutional neural network for diagnosing temporomandibular joint osteoarthritis on panoramic radiographs. Dentomaxillofac Radiol. 2020;49(3):20190412. doi:10.1259/dmfr.20190412
9. De Tobel J, Van den Bosch T, Vandersmissen B, Fieuws S, Thevissen P. An automated technique to estimate chronological age based on orthopantomograms using deep learning. Forensic Sci Int. 2020; 315:110456. doi: 10.1016/j.forsciint.2020.110456
10. Schwendicke F, Golla T, Dreher M, Krois J. Convolutional neural networks for dental image diagnostics: A

scoping review. J Dent. 2019; 91:103226. doi: 10.1016/j.jdent.2019.103226

11. He J, Baxter SL, Xu J, et al. The practical implementation of artificial intelligence technologies in medicine. Nat Med. 2019;25(1):30–36. doi:10.1038/s41591-018-0307-0

12. Ting DSW, Pasquale LR, Peng L, et al. Artificial intelligence and deep learning in ophthalmology. Br J Ophthalmol. 2019;103(2):167–175. doi:10.1136/bjophthalmol-2018-313173

13. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019;25(1):44–56. doi:10.1038/s41591-018-0300-7

14. Erickson BJ, Korfiatis P, Akkus Z, Kline TL. Machine learning for medical imaging. Radiographics. 2017;37(2):505–515. doi:10.1148/rg.2017160130

Management of marginal mandibular resection with reconstruction using locoregional flap of digastric muscle following functional neck dissection.

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Abstract

Squamous cell carcinoma (SCC) of the oral mucosa often requires surgical interventions that lead to significant anatomical defects. This article discusses managing the defect after marginal mandibular resection (MMR) with functional neck dissection, followed by reconstruction using a locoregional digastric muscle flap. MMR aims to achieve complete oncological clearance while preserving function and aesthetics. The digastric flap, with its proximity and reliable vascularity, offers effective soft tissue coverage and maintains lower facial contour and mobility. A case of a 78-year-old male with SCC of the right retromolar trigone (T4aN1M0) is presented, treated with mandibulectomy, neck dissection, and digastric flap reconstruction. Outcomes assessed include speech, swallowing, aesthetics, and recurrence. The flap survived well with no recurrence after two years. This case emphasizes the importance of individualized care and multidisciplinary collaboration in improving quality of life post head and neck cancer surgery.

Keywords: Squamous cell Carcinoma, Marginal mandibulectomy, Reconstruction, Digastric muscle

Introduction:

Squamous cell carcinoma is one of the most common carcinoma of oral mucosa and often leaves defects post resection of tumor. Thus, there is a necessity in the area for functional and aesthetic demands of the patient. And improving patient quality of life.

Management of marginal mandibular resection (MMR) and subsequent reconstruction using a locoregional flap of the digastric muscle is a critical component in the treatment of patients undergoing functional neck dissection (FND). This article provides a comprehensive review of the surgical techniques, outcomes, and considerations involved in MMR with digastric muscle flap reconstruction within the context of head and neck oncology.

Aims & Objectives:

The primary objective of MMR is complete excision of malignancies while preserving aesthetic and functional integrity. Functional neck dissection, a standard procedure for nodal metastasis in head and neck cancers, often necessitates simultaneous or subsequent MMR to achieve oncological clearance. The digastric muscle flap, owing to its proximity and reliability, serves as an excellent option for reconstructing defects resulting from MMR. Its use ensures adequate soft tissue coverage and maintains optimal functional outcomes, particularly in preserving lower facial contour and mobility.

Surgical planning involves meticulous assessment of tumour extent, preoperative imaging, and consideration of the vascular anatomy to ensure flap viability. The technique of MMR entails precise dissection along anatomical planes to achieve clear margins while minimizing functional impairment. Postoperative care focuses on monitoring flap perfusion and early mobilization to prevent complications such as flap necrosis and wound dehiscence.

Material & Methods:

A case report of a 78-year-old male who came with a complaint of pain in the right lower back tooth region after extraction of tooth in the same region. On Examination showed an ulcero-proliferative lesion at the right retromandibular trigone region with a clinical staging of T4aN1M0.Biopsy report of the lesion confirmed early invasive squamous cell carcinoma. The CECT reports showed erosive changes at the outer cortex of the mandibular alveolus on right side with minima abnormal soft tissue extending from Lower gingivobuccal sulcus towards RMT. Abnormally enlarged right level 1B metastatic lymph nodes. The patient underwent surgical resection of lesion with segmental mandibulectomy; therapeutic neck dissection where level III lymph nodes were cleared, followed by reconstruction using locoregional flap - a buccal fat pad flap along with right digastric muscle.

Results:

The flap survival was good when the patient recovered uneventfully and did not require any further chemotherapy or radiotherapy. There was no evidence of recurrence of the tumor after 2 years of follow up.

Discussion:

The management of squamous cell carcinoma (SCC) in the oral cavity through marginal mandibular resection (MMR) combined with functional neck dissection (FND) poses significant challenges but offers opportunities for effective treatment. Achieving negative margins while minimizing functional impairment is crucial, and the digastric muscle flap serves as an excellent reconstructive option due to its anatomical position and reliable vascular supply, providing necessary soft tissue coverage for aesthetic and functional restoration. Postoperative rehabilitation, including targeted speech and swallowing therapy, is vital for optimizing patient outcomes. Outcome assessment includes functional outcomes such as speech, swallowing, and facial nerve function, alongside aesthetic results. Long-term rehabilitation involves speech therapy, swallowing exercises, and physiotherapy to optimize patient recovery and quality of life postoperatively. Multidisciplinary collaboration between surgical oncologists, head and neck surgeons, reconstructive surgeons, and allied health professionals is crucial for comprehensive patient management. Case studies and clinical experiences illustrate the efficacy and challenges associated with this reconstructive technique, highlighting the importance of individualized treatment plans tailored to patient-specific factors.

Conclusions:

This case report highlights the need for diagnosis and of an appropriate treatment plan in cases of malignant tumors, as this can lead to morbidity and mortality.

References:

1. Shah JP, Patel SG, Singh B. Head and neck surgery and oncology. 4th ed. Edinburgh: Elsevier; 2012.
2. Kademani D, editor. Atlas of oral and maxillofacial surgery. Philadelphia: Elsevier; 2016.
3. Genden EM, Ferlito A, Silver CE, et al. Contemporary management of cancer of the oral cavity. Oral Oncol. 2010;46(6):427-431. Doi: 10.1016/j.oraloncology.2010.03.011.
4. Liao CT, Lee LY, Hsueh C, et al. Pathological significance of surgical margin in oral cavity squamous cell carcinoma. Oral Oncol. 2012;48(4): 322-328.doi: 10.1016/j.oraloncology.2011.11.014.

5. Kim SY, Nam SY, Choi SH, et al. The clinical usefulness of preoperative computed tomography in detecting extracapsular spread in patients with squamous cell carcinoma of the oral cavity: a systematic review and meta-analysis. Oral Oncol. 2015;51(5):484-491. doi: 10.1016/j.oraloncology.2015.02.105.
6. Chalian AA, Anderson TD, Weinstein GS, et al. The submental island flap: a new donor site. PlastReconstr Surg. 1993;92(5):827-833. doi:10.1097/00006534-199310000-00002.
7. Urken ML, Cheney ML, Blackwell KE, et al. Atlas of regional and free flaps for head and neck reconstruction. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2012.
8. Hanasono MM, Skoracki RJ. Microvascular reconstruction of the mandible. Semin Plast Surg. 2010;24(3):188-197. doi:10.1055/s-0030-1262313.
9. Wei FC, Mardini S. Flaps and reconstructive surgery. 1st ed. Edinburgh: Elsevier; 2009.
10. Shaw RJ, Brown JS. Reconstruction of the mandible. Surgery (Oxford). 2009;27(5):207-212. doi: 10.1016/j.mpsur.2009.02.008.

Images

Preoperative photograph of lesion

Intraoperative photograph

Postoperative photograph