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Teeth, Technology, Tomorrow: The Evolution of Artificial Intelligence inDentistry and Patient Care

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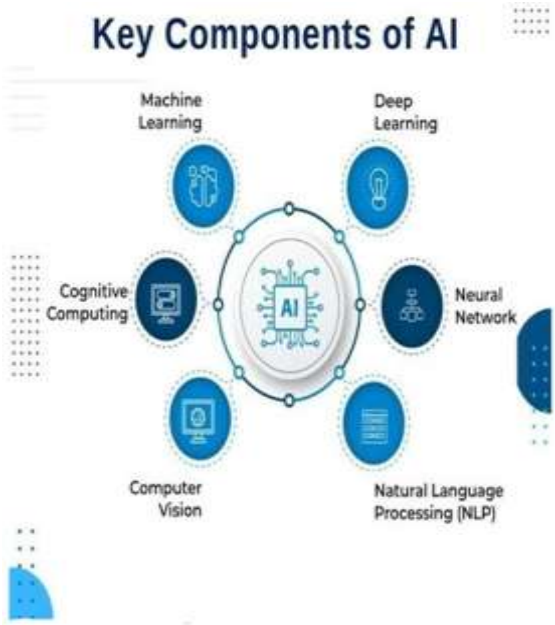
ABSTRACT
Artificial intelligence [AI] is the concept that involves utilizing computers and technology to replicate intelligent actions and analytical thinking similar to that of a human. It is a fast-moving technology that enables machines to perform tasks previously exclusive to humans. Advances in Al offer a glimpse of such health care benefits as decreasing postoperative complications, increasing quality of life, improving decision-making, and decreasing the number of unnecessary procedures.
AI applications in dentistry include image analysis, patient communication, and personalized treatment recommendations. While AI offers numerous benefits such as increased efficiency and accuracy, there are also challenges to be addressed.
This article provides a comprehensive review of the current applications of AI in dentistry, includingthe use of machine learning algorithms for image analysis, natural language processing for patient communication, and predictive analytics for personalized treatment recommendations. The benefits and challenges of integrating AI into dental practice are discussed, along with future directions for research and development in this rapidly evolving field. By leveraging the power of AI, dentists can improve efficiency, accuracy, and patient outcomes, ultimately advancing the quality of care in the dental profession.
Key Words: Artificial Intelligence, Dentistry, WHO, FDI, Patient care, Patient Perspective, Challenges, Algorithms of AI, Key Element of AI.

I. INTRODUCTION

Artificial intelligence (AI) is a field within computer science that aims to develop intelligent machines capable of performing tasks that typically require human intelligence, such as learning, reasoning, problem-solving, and decision-making.
The term artificial intelligence was coined by mathematician John McCarthy in 1955, earning him the title of "Father of Artificial Intelligence". In 1978, mathematician Richard Bellman defined AI as the automation of processes related to human cognitive abilities like learning, decision- making, and problem-solving. [1]



The FDI World Dental Federation recognizes AI as acritical technology for the future of the dental profession.[9]

Key elements of the artificial intelligencesystem.

1. Artificial intelligence involves machines demonstrat-ing intelligence by analyzing data to solve problems.
2. Machine learning is an essential part of artificial intelligence that enables systems to learn and improve from data without explicit programming.[2]
3. Neural networks function like the human brain by processing signals through artificial neurons.
4. Deep learning, is a sub-branch of ML.[2] with multiple layers of computation,

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constructs neural networks that automatically identify patterns to enhance feature detection.[1]
5. Data science involves analyzing data to extract valuable information.
6. Big data offers precise information by evaluating a large and continuously expanding dataset at the appropriate moment.

In the context of dentistry, AI technologies are being harnessed to improve diagnostic accuracy, treatment planning, and patient care.

By leveraging machine learning algorithms for image analysis, dentists can enhance their ability to detectoral diseases and abnormalities from radiographs, photographs, and other imaging modalities.

Overall, AI has the potential to make far-reaching changes in the field of dentistry by enhancing efficiency, accuracy, and patient outcomes. This article will explore the current applications of AI in dentistry, discuss the benefits and challenges of integrating AI into dental practice, and outline future directions for research and development in this rapidlyevolving field.

The **WHO offers the following guidelines** as the foundation for AI regulation and governance to minimize the dangers and optimize the opportunities inherent in the application of AI for health: [9]

1. Protecting human autonomy.
2. Advancing human well-being, safety, and thepublic interest.
3. Ensuring transparency, explainability and intelli-gibility.
4. Fostering responsibility and accountability
5. Ensuring inclusiveness and equity.
6. Promoting AI that is responsive and sustainable

Applications of Artificial intelligence in different Specialty of Dentistry.

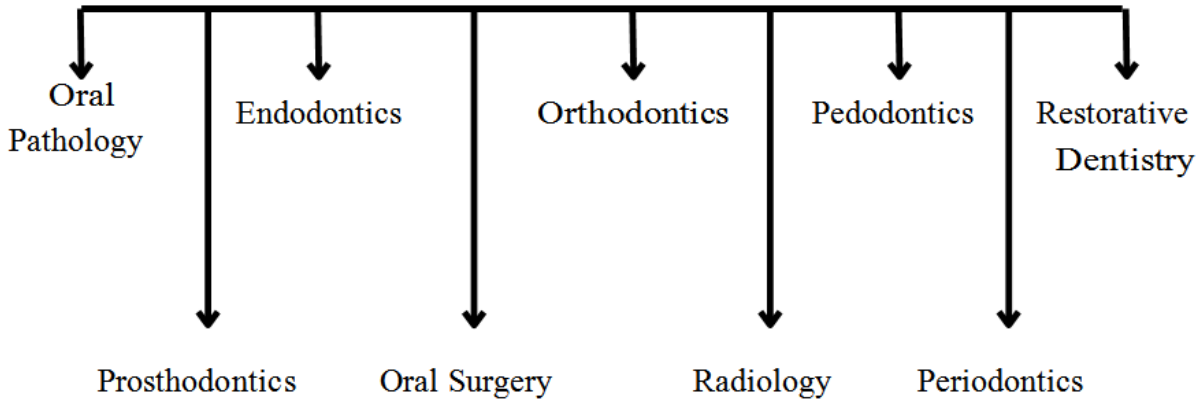
Oral Pathology

Early detection and accurate diagnosis of oral lesions are vital in dental practice, especially considering the potential for precancerous or cancerous conditions. CNNs have emerged as promising tools for aiding in the diagnosis of head and neck cancer lesions, exhibiting specificity and accuracy rates ranging from 78% to 83.3%. One study focused on distinguishing between two similar maxillary tumors, ameloblastomas, and keratocystic odontogenic tumors, achieving comparable specificity and accuracy to clinical specialists. [4]

Prosthodontics

Prosthodontics focuses on restoring lost esthetics and function using prosthetic materials, often utilizing CAD/CAM technology for precision. Intelligent software optimizes CAD/CAM systems, enhancing efficiency and reducing costs. AI aids in designing prostheses by evaluating various factors like anthropological calculations and patient expectations.

Applications of Artificial intelligence in different Specialty ofDentistry.



Studies have shown AI's potential in addressing challenges like positional errors in implant prosthesis placement, and achieving high survival and success rates. In tooth preparation,

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CNN models accurately extract margin lines, reaching a 97.43% accuracy rate.

AI algorithms can design dental prostheses mimicking natural tooth morphology, with the potential for further optimization. These advancements promise innovative dental restorations meeting high standards in fit, function, and esthetics, with significant implications for orofacial and craniofacial prostheses. [3]

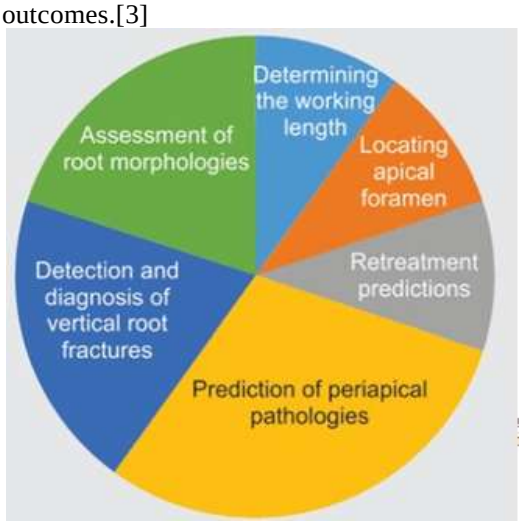
Endodontics

Endodontics, a branch of dentistry, focuses on the diagnosis and treatment of pulpal and periapical pathologies. With ongoing research, areas like root canal morphology and treatment techniques continue to evolve. AI is increasingly playing a role in endodontic diagnosis and treatment planning.

Panoramic radiographs are often insufficient for understanding root canal morphology. In a study, CNN algorithms accurately estimated accessory roots of mandibular first molars, showcasing high performance.

Another study focused on locating and classifying root canal orifices, achieving 94% accuracy in detecting canal openings and 90% accuracy in distinguishing between upper and lower molars. This suggests that root canals can be accurately identified and classified in real time using software.

Determining the working length of root canals is crucial for successful treatment. AI was utilized to reliably determine the position of the canal file, surpassing traditional methods in accuracy. This highlights the potential of AI in improving the accuracy of root canal treatment outcomes.[3]



Oral Surgery

A study developed an artificial neural network (ANN) model to predict facial swelling after third molar extraction, achieving a reported estimation accuracy of 98%. Another study explored the use of convolutional neural networks (CNNs).

To detect mandible fractures on panoramic radiographs, achieving varying sensitivity scores for different fracture types. For diagnosingtemporomandibular joint (TMJ) disorders, ANN models were trained to distinguish between normal and irregular TMJs, showing sensitivity and specificity ranging from 37% to 100%. Additionally, AI models, such as InceptionV3 and DenseNet169, were proposed for accurate TMJ disc displacement detection, indicating promising results that could assist radiologists in interpreting MRI images. CNN-based segmentation models also demonstrated reliable performance in segmenting TMJ structures from MRI images, enhancing diagnostic accuracy and efficiency. [3]

Radiology

The practice of dentomaxillofacial radiology involves assessing oral conditions and pathologies through clinical, systemic, and radiological findings. Digital radiography, including intraoral and extraoral images, aids in diagnosing common oral diseases like dental caries and tumors.

The digitalization of radiographs has accelerated the development of artificial intelligence (AI) in radiology, enabling automatic recognition and analysis of complex patterns in imaging data. AI serves as a valuable tool for making objective assessments of radiological images, enhancing diagnostic accuracy and efficiency. While dentists interpret radiographs by recognizing normal tissues and pathologies, AI algorithms assist in image class-experienced radiologists and large datasets is crucial for accurate AI model development in dentomaxillofacial radiology.[3][Image 1]

CNNs have proven effective in identifying anatomical structures like teeth, achieving precision rates of 95.8–99.45%, comparable to clinical experts' 99.98%. They've also shown promise in detecting dental caries[image 2], outperforming clinicians' diagnoses on radiographs alone with accuracies ranging from 75.5% to 93.3% and sensitivities from 74.5% to 97.1%. This highlights CNNs'

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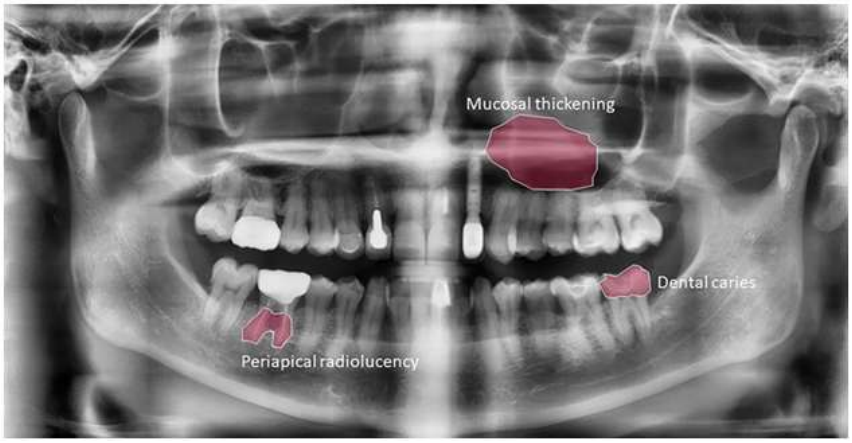
potential to enhance dental caries diagnosis sensitivity and efficiency.[4]

Orthodontics

Orthodontics addresses dental placement irregularities and jaw development disorders. AI aids in treatment planning, such as predicting extraction needs before orthodontic treatment, improving accuracy significantly. Deep learning models also estimate unerupted tooth sizes, offering potential as an alternative to traditional methods. Additionally, AI automates cephalom-etric analysis, reducing clinician burden and saving time, with results comparable to manual measurements. Recent studies demonstrate the accuracy of AI in segmenting and classifying anatomical structures like the Sella Turcica using CBCT images, indicating its potential to streamline orthodontic diagnosis.[3]

ANNs offer significant potential in enhancing clinical decision-making, particularly in orthodontic treatments aimed at achieving predictable outcomes. Considering the occasional necessity of tooth extractions in these treatments, ensuring optimal clinical deci--ions before irreversible procedures is crucial. In assessing the need for tooth extraction in patients with malocclusion, four ANNs, incorporating various clinical indices, demonstrated an accuracy range of 80–93%. This underscores the valuable role ANNs can play in optimizing treatment plans and improving patient care in orthodontics. [4]

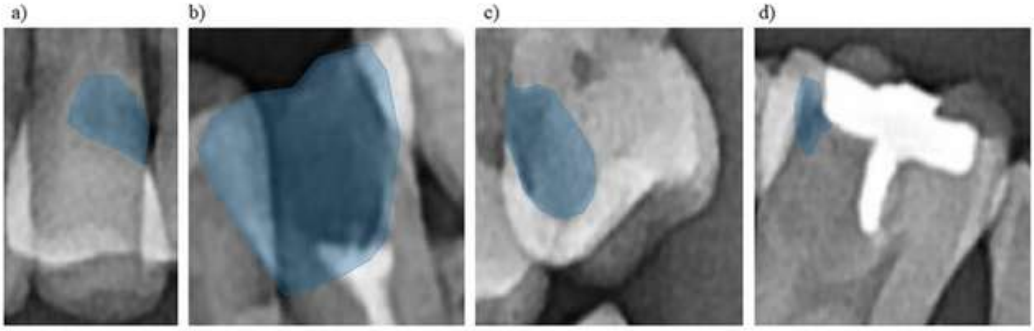
Image 1



Example image of automatic anomaly detection.[11]

Image credit: Detecting dental diseases with AI dental image analysis.
Behind the research.Sangyeon Lee, Donghyun Kim, Hogul Jeong, Jaehyeong Park

Image 2



Examples of labelled carious lesions: a) cervical caries or cervical abrasions, b) dental caries or coronal defects, c) proximal caries, and d) secondary caries.[11]

Image credit: Detecting dental diseases with AI dental image analysis.
Behind the research.Sangyeon Lee, Donghyun Kim, Hogul Jeong, Jaehyeong Park

Pedodontics

A machine learning algorithm was developed to assess children's oral health and treatment needs based on questionnaire data, potentially serving as a screening tool in schools. An AI model was created to predict individual pain levels and analgesicresponses for postoperative pain management. Additionally, assistive tools have been developed to aid communication in populations who struggle to express their pain, such as children and individuals with disabilities.

Regarding molar-incisor-hypomineralization

(MIH), a deep learning-based convolutional neural network (CNN) was developed to automatically detect and classify affected teeth in intraoral photographs with 95.2% accuracy. In another study, a deep learning model demonstrated clinically acceptable performance in detecting dental plaque in primary teeth compared to experienced pediatric dentists.

Furthermore, a deep learning system was evaluated for detecting permanent tooth germs in panoramic radiographs, achieving high precision and accuracy, potentially aiding in the early diagnosis of missing or supernumerary teeth and guiding treatment decisions more effectively.[3]

Periodontics

Detecting periodontal bone loss (PBL) on radiographs is challenging, but AI-assisted systems offer more reliable assessments. Lin et al. developed a model to measure PBL accurately, showing promising results compared to manual analysis. In another study, a CNN algorithm classified microbial dental plaque levels in intraoral photographs, offering a cost-effective and time-saving alternative to manual analysis. AI's role in periodontology is expected to grow, with further advancements anticipated in the future. [3]

Papantanopoulos et al. utilized an ANN to classify patients as AgP or CP based on immunologic parameters, achieving 90–98% accuracy. Similarly, Lee et al. explored the use of deep CNN algorithms in diagnosing and predicting periodontally compromised teeth (PCT), with accuracies ranging from 76.7% to 81.0%. However, accuracy varied between tooth types, with premolars more accurately diagnosed than molars, likely due to their simpler anatomy for CNN interpretation. These studies highlight the potential of ANNs and CNNs in aiding accurate diagnosis and prognosis assessment in periodontal diseases. [4]

Restorative Dentistry

Dentistry addresses dental hard tissue diseases using protective, restorative, and esthetic methods, with dental caries being a prevalent concern. AI assists in diagnosing caries, especially those not easily detected on radiographs due to image quality issues. Several studies have achieved high accuracy in classifying dental cariesson radiographs using AI-based methods. For caries on occlusal surfaces, clinical examination remains effective, but AI models have been developed to diagnose caries in photographs, albeit with varying reliability levels.[3]

AI in Dental Education

Artificial intelligence is revolutionizing dental education by enhancing teaching methods and improving learning quality. Through intelligent teaching systems, students benefit from simulated clinical scenarios, reducing educational risks and accelerating skill development. These systems also provide valuable feedback, facilitating faster mastery of competencies compared to traditional methods. Additionally, the integration of robotic models in preclinical training labs further enhances motor skill development. As AI continues to advance, it becomes essential to incorporate AI-based subjects into the curriculum to prepare future dental professionals to utilize and innovate within this evolving field.[3]

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Artificial Intelligence Revolutionizing the Patient Care.

Current state of AI in dentistry

Artificial intelligence (AI) is reshaping the landscape of dentistry, offering new possibilities for improved patient care, diagnosis, and treatment planning. [10]

1. Diagnosis

- AI algorithms can analyze dental images and patient data to assist in diagnosing conditions like cavities, gum disease, and oral cancer.

2. Treatment Planning

- By leveraging AI for diagnosis, dentists can make more accurate and timely treatment decisions, leading to better outcomes for patients.

3. Patient Communication:

- Chatbots powered by AI can provide patients with information on dental procedures, appointment scheduling, and post-treatment care.
- AI-driven communication tools enhance patient engagement and satisfaction by providing personalized and timely information.

4. Administrative Tasks:

- AI can streamline administrative tasks such as appointment scheduling, billing, and insurance processing, freeing up time for dental professionalsto focus on patient care.
- Automating administrative processes with AI improves practice efficiency and reduces the burden on staff.

5. Personalized Treatment:

- AI can analyze patient data to create personalized treatment plans tailored to individual needs and preferences.
- Personalized treatment plans based on AI insights lead to better treatment outcomes and patient satisfaction.

6. Education and Simulation:

- Dental students can benefit from the development of practical skills through AI-based simulations. They also give people the chance to learn about and try out novel treatment approaches, which advances the field continuously.

Future Direction of AI in Dentistry

The innovative propels combine the utilization ofmechanical back in dentistry. Too in today's situation, "increased insights" has been embraced a small as well before long. In any case, the points of interest of computerized applications will complement human aptitudes and capacities in arrange to give patients superior and more cost-effective healthcare. Huge data-based increased insights can offer assistance to decrease the number of misdiagnoses and give more important bits of knowledge quickly, accurately, and easily. [6]

- **Enhanced Diagnostic Capabilities**: AI algorithmsare improving in accuracy, leading to more precise diagnoses.
- **Predictive Analytics**: AI can predict future oral health issues and recommend preventive measures.
- **Tele-dentistry**: AI-powered tools facilitate remote consultations, expanding access to dental care.
- **Robotics in Dentistry:** Robots with AI capabilities could assist dentists in procedures with precision andefficiency.
- **Customised treatment**: AI can make it

possible to design individualized treatment regimens depending on a patient's genetic and lifestyle characteristics. Adverse effects will be avoided and treatment effectiveness will be maximised.[10]

Patient's perspective on AI in Dentistry.

While most patients find it difficult to interpret X- rays, AI-generated overlays can help them see their symptoms more clearly by adding colour and quantification.

The AI markings can be used to illustrate how bone loss and degradation develop over time. This visualization method helps patients not only comprehend what their dentists are recommending, but also gives them confidence in those recommendations.

Additionally, AI technology helps patients comprehend why their dentist is recommending a course of treatment on a particular timeline and lends a third degree of objectivity to the diagnosis made by the dentists.[5]

Patients generally see advantages in using AI in dentistry, such as improved diagnostic confidence and time reduction. However, they are concerned about the impact on workforce needs, challenges in doctor-patient relationships, and increased costs. Most patients expect AI to be integrated into dental workflows within the next 1-10 years. Older patients have higher expectations for AI performance compared to younger patients.

Overall, patients have a positive attitude toward the use of AI in dentistry, and understanding their perceptions can help shape the future of AI-drivendentistry. [4]

Challenges of Implementing AI in Dentistry

- **Data Privacy and Security:** Protecting patient data is crucial when using AI in dentistry.
- **Regulatory Compliance:** Ensuring AI systems comply with healthcare regulations is essential.
- **Integration with Existing Systems:** Integrating AI technologies with current practice management systems can be complex.
- **Training and Education:** Dental professionals need training to effectively use AI tools.

II. FINAL CONCLUSION

Artificial intelligence shows promise in diagnosing dental issues like caries and dysfunction, but its full potential in dentistry is still being explored. Future research could focus on using AI to predictperiodontitis, especially in diabetic patients. While AI has been used to assist doctors in treatment decisions, its clinical accuracy in dentistry needs further testing across various imaging sources. The opacity of current AI algorithms poses challenges for human understanding and modification of diag- -nostic criteria, highlighting the need for visualization and modification tools. While AI can enhance healthcare delivery, it cannot replace human expertise and judgement in dentistry.

Hybrid intelligence, combining human and machine intelligence, shows promise in advancing human capabilities in dentistry. The use of hybrid intelligent image fusion methods for diagnosis and treatment planning is expected to become widespread. While AI models have shown high success rates, their generalizability and reliability need to be verified with diverse image datasets before clinical use. Despite technical and ethical challenges, the potential of artificial intelligence to revolutionize healthcare and dentistry is significant. Collaboration between dentists and technology is essential for further development and integration of AI in dental practice. Thispartnership will drive rapid progress and enhance the usefulness of current advancements in the field.

REFRENCES

[1]. Artificial Intelligence in Dentistry: Chances and Challenges, Journal of Dental Research , Vol. 99(7) 769–774 F. Schwendicke, W. Samek , and J. Krois,2020

[2]. Artificial Intelligence in Dentistry: Seyide Tugce Gokdeniz, Arda Buyuksungur and Mehmet Eray Kolsuz, In book: Human Teeth - From Function to Esthetics[Working Title], May 2020

[3]. Use of Artificial Intelligence in Dentistry: Current Clinical Trends and Research Advances-Thomas T. Nguyen, Naomie Larrivée, Alicia Lee, Olexa Bilaniuk, Robert Durand.Article in Journal of the Canadian Dental Association , May 2021

[4]. Patients' perspectives on the use of artifcial intelligence in dentistry: a regional survey- Nasim Ayad, Falk Schwendicke, Joachim Krois, Stefanie van den Bosch, Stefaan Bergé, Lauren Bohner, Marcel Hanisch and Shankeeth Vinayahalingam, Head & FaceMedicine

(2023)
[5]. How AI Is Transforming Dental Practices. Eric Giesecke, Forbes Councils Member
[6]. Artificial Intelligence in dentistry: Concepts, Applications and Research Challenges Achsha Babu, J. Andrew Onesimu, and K. Martin Sagayam, January 2021
[7]. AI in dentistry: The revolution is now Cris Mark Baroro. July 17, 2023
[8]. Artificial Intelligence in Dentistry: Shaping the Future of Dental Care. Craniocatch.
[9]. Artificial Intelligence for dentistry Falk Schwendicke, Markus Blatz, Sergio Uribe, William Cheung, Mahesh Verma, Jina Linton, and Young Jun Kim. FDI ARTIFICIAL INTELLIGENCE WORKING GROUP.
[10]. Artificial intelligence in dentistry: current state and future directions.Author K Dhingra Publication: The Bulletin of the Royal Collegeof Surgeons of England, Volume 105, Number 8 https://doi.org/10.1308/rcsbull.2023.132
[11]. Detecting dental diseases with AI dental image analysis Research Outreach