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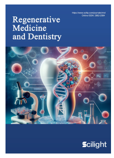

Review

AI-Enabled Dental Care

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How To Cite: Yang, C.; Bai, L.; Su, J. AI-Enabled Dental Care. *Regenerative Medicine and Dentistry* **2026**, *3*(1), 3. https://doi.org/10.53941/rmd.2026.100003

Received: 10 December 2025
Revised: 22 January 2026
Accepted: 25 February 2026
Published: 3 March 2026

Abstract: The emergence and development of artificial intelligence is rapidly promoting dental diagnosis and treatment from experience-driven to data-driven and accurate methods. With the help of AI models based on deep learning, AI has been widely used in dental fields such as oral radiology, orthodontics and maxillofacial surgery, periodontal disease and dental pulp, aesthetic restoration and so on. In addition, AI technology has also made great contributions in forensic dentistry and tele dentistry. The application of a technology can not only improve the limitations of traditional treatment methods, but also improve the accuracy of treatment of dental caries, periapical lesions, and other diseases. However, its clinical promotion is still limited by data imbalance and heterogeneity, privacy and security, lack of model interpretability and lack of standardized evaluation system. In the future, it is urgent to build high-quality multicenter data sets, introduce privacy computing technologies such as federal learning, and improve regulatory and human-computer collaboration specifications, so as to realize the safe and controllable application of AI in dentistry, and promote the overall transformation of oral medicine to prevention oriented, precision diagnosis and intelligent services.

Keywords: artificial intelligence; dentistry; stomatology; intelligent diagnosis and treatment; precision medicine

1. Introduction

Artificial intelligence (AI), as the core driving force leading a new round of scientific and technological revolution and industrial change, is gradually infiltrating into all branches of health care. Dentistry is an important part of oral health management, its traditional diagnosis method mainly depends on the experience of doctors and traditional imaging technology, but the results will be affected by the experience of doctors and other factors, facing the challenges of strong subjectivity, low efficiency and lack of standardization process. In recent years, with the rapid development of AI technologies such as deep learning and natural language processing, the dental field has ushered in unprecedented opportunities for intelligent transformation. At present, AI not only shows excellent performance in image analysis, disease detection, treatment planning and other aspects, but also plays an important role in diverse scenarios such as orthodontics, dental aesthetic restoration, periodontal disease management, and even forensic dentistry and electronic health records.

This review aims to systematically review the research progress and application status of AI technology in the field of dentistry, analyze its specific practice and effectiveness in different application directions, discuss the technical bottlenecks, ethical challenges and clinical promotion obstacles faced by the application of AI technology at the present stage, and look forward to the future reform direction of dental diagnosis and treatment mode under the empowerment of AI. Through the comprehensive analysis of the existing literature and clinical cases, a comprehensive and clear reference framework is provided to promote the scientific, standardized and landing application of AI in dentistry.

2. Basic Principles and Key Technologies of Artificial Intelligence

Artificial Intelligence, as a cutting-edge technology aimed at simulating, extending, and expanding human intelligence, can be traced back to the mid-20th century. Turing published a paper titled "Computing "Machinery and Intelligence" in the journal Mind in 1950, which systematically proposed for the first time whether machines have the ability to think" and introduced the Turing Test as a standard for measuring machine intelligence [1]. Subsequently, at the 1956 Dartmouth Conference, "artificial intelligence" was officially proposed and began the development of AI as an independent discipline [2].

From the 1960s to the 1980s, AI research went through a stage of algorithm exploration, parallel development of expert systems and machine learning (ML) [3]. Especially expert systems have demonstrated strong problem-solving abilities in specific fields such as industrial control and medical diagnosis, becoming representatives of early AI practical applications [4]. Since entering the 21st century, thanks to the significant improvement in computing power, enhanced convenience in data acquisition, and continuous evolution of algorithm systems, AI has gradually moved from theory to practice. Deep Learning (DL), as a subset of machine learning, has become the core driving force for the current development of AI [5] (Figure 1).

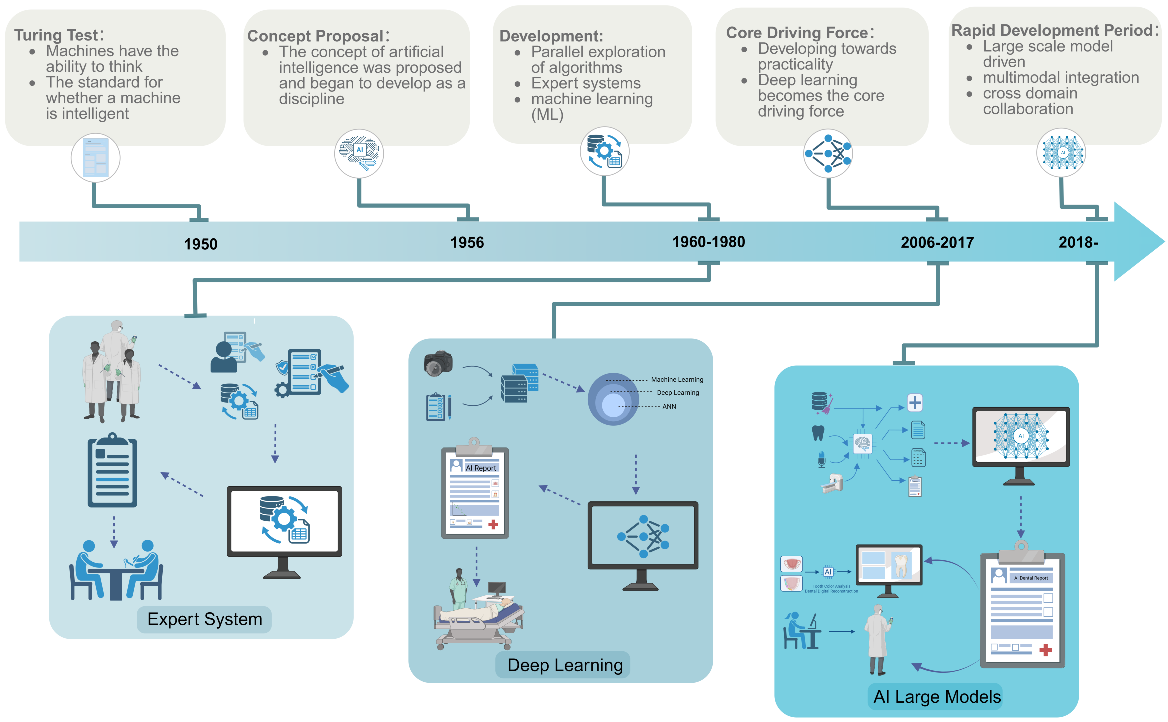

Figure 1. Development history of artificial intelligence.

Deep learning achieves feature extraction and modeling of complex unstructured data such as images, speech, and text by constructing multi-level artificial neural networks (ANN) [6]. Among them, Convolutional Neural Networks (CNN) have shown particularly outstanding performance in the field of visual recognition and are widely used in tasks such as medical image diagnosis, lesion detection, and predictive modeling; Recurrent Neural Networks (RNNs) play an important role in speech recognition and physiological signal analysis due to their superior performance in processing sequential data [7].

With the rapid development of AI, which is characterized by large model driven, multimodal integration and cross domain collaboration, its penetration in the field of health care continues to deepen. Especially in stomatology, AI technology is gradually applied to many key links, such as radiographic analysis, clinical auxiliary diagnosis, personalized treatment decision-making, prognosis evaluation and disease risk prediction [8]. For example, the image recognition model based on CNN has been used in caries detection, periodontal tissue analysis, maxillofacial image evaluation and other tasks, showing higher accuracy and stability than traditional manual interpretation. In addition, the interpretability and generalization ability of AI system have also become the current research focus [9]. In the process of clinical application, how to improve the availability, safety and ethical compliance of the model by optimizing the network structure, introducing knowledge graphs or integrating multimodal data is the key to realize the transformation of AI from "technically feasible" to "clinically credible".

In summary, artificial intelligence, as the core force of the new round of technological revolution and medical innovation, has evolved from early symbolism and knowledge driven systems to data-driven deep learning frameworks. In the future, combining clinical demand orientation and interdisciplinary collaboration, artificial intelligence is expected to continue empowering the development of dentistry in precision medicine, digital diagnosis and treatment, and intelligent assistance systems.

3. The Main Applications of AI in Various Dental Specialties

3.1. Oral Radiology and Imaging Diagnosis

Oral health is an important component of overall health. Currently, dental diseases such as dental caries, periodontal disease, pulp and periapical lesions have a high global prevalence, causing not only local pain but also being associated with systemic diseases. Periapical periodontitis and dental caries are common chronic oral diseases that affect the majority of adolescents and adults worldwide, and are also common causes of tooth pain and loss. Dental caries, commonly referred to as tooth decay, is a disease characterized by demineralization of tooth structure caused by sugar driven plaque bacteria [10]. Early detection of dental caries can prevent the development of caries from enamel to dentin and then to pulp, leading to loss of vitality in teeth. Periapical periodontitis is an inflammatory condition affecting the tissues around the root apex, commonly associated with infection from dental pulp disease. Typical features include periapical granulomas or cysts. Early detection can improve treatment effectiveness, prevent its spread to other tissues, and reduce potential problems. Therefore, image detection of diseases is particularly important for diseases such as dental caries and periapical periodontitis [11]. If dental caries and periapical periodontitis are not detected in a timely manner, these two diseases can not only cause severe pain and tooth loosening, but also penetrate the periodontal connective tissue, leading to serious maxillofacial infections [12].

At present, the occurrence and severity of dental diseases are mainly detected through oral radiation and imaging diagnosis in clinical practice. The main diagnostic tools for detecting dental caries and periapical lesions are periapical X-ray photography, cone beam computer tomography (CBCT), etc. Among them, periapical X-ray photography is the most reliable routine examination, and CBCT is the only system that can ensure early and predictable detection of all periapical lesions in the jawbone. The main way to determine the detection image of periapical periodontitis is through visual inspection [12]. Due to the high subjectivity of manual programs and the significant differences in diagnostic accuracy among diagnostic personnel based on their background and skill level, especially when the visual acuity of the image is limited, it can cause difficulties in early detection and timely treatment Therefore, rapid and accurate detection and diagnosis are important factors in implementing appropriate prevention and treatment for patients with dental caries and periapical periodontitis.

Artificial intelligence models, especially CNN based automatic evaluation tools, will help improve the accuracy and consistency of diagnosis, treatment planning, and treatment outcomes, reduce image interpretation time, alleviate the workload of dentists, and improve efficiency. For example, the detection of oral diseases on periapical X-rays is a type of image classification task that can be automated through deep learning [12]. During the process, a large number of patient datasets are required to train the model, which can improve the accuracy and precision of recognition. The advantage of artificial intelligence lies in its significantly faster processing and interpretation speed and scale of data compared to humans, which reduces the subjectivity involved in traditional diagnostic techniques. Train artificial intelligence models using annotated datasets to classify photos of teeth and determine the presence of dental caries and periapical lesions. After training, these models can recognize subtle features on X-rays that may not be immediately noticed by the naked eye, such as changes in tooth structure and density, which is of great help for early detection and treatment.

At present, there are also many problems with the application of artificial intelligence. Firstly, when evaluating normal teeth, deep learning is difficult to identify significant features between different diseases, making it difficult to distinguish between different diseases. Secondly, due to the need to use multiple human annotations during the research process to independently evaluate diseases on images, radiological assessments inevitably tend to be subjective. Moreover, the use of artificial intelligence poses great challenges to the privacy and security of patients, and the protection of personal information is crucial, especially in the management of sensitive patient data. In addition, there are many important obstacles to integrating artificial intelligence technology into existing clinical workflows, all of which require investment of time and money. Artificial intelligence needs to be combined with population risk, social determinants, healthcare services, and economic variables to evaluate dental practices. Therefore, the development of highly specialized artificial intelligence systems should prioritize issues unrelated to frequency environment. High specificity helps reduce overtreatment and focus attention on the lesions that truly require attention, ensuring more effective use of resources [10].

In summary, AI has gradually integrated into the treatment process of oral diseases in the field of oral radiation and image detection, assisting doctors in data processing. However, due to issues such as data generalization, small sample size, clinical integration, and ethical bottlenecks, it is still unable to achieve full process intelligent healthcare. In the future, with the advancement of AI technology, AI will gradually move from technological exploration to clinical practice, becoming the core facility of oral precision medicine, reconstructing the "screening diagnosis treatment health management" chain, and providing a scientific basis for intelligent oral diagnosis (Table 1).

Table 1. Comparison of different dental AI models.

Year	Core Model	Application	Training Data	Validation Data	Limitations	References
2018	Inception v3 (CNN)	Detection and diagnosis of dental caries on periapical radiographs	2400 periapical radiographic images	600 periapical radiographic images	Lower accuracy on molars and mixed dentition	[13]
2018	VGG-16 (in Cascade Network)	Teeth recognition and classification in dental periapical radiographs	700 periapical radiographic images	300 periapical radiographic images	Ineffective on images with very few teeth	[14]
2019	MLP (Multilayer Perceptron)	Orthodontic treatment planning	182 clinical records	60 clinical records	Low accuracy for extraction pattern prediction	[15]
2019	VGG-16 (CNN)	Facial attractiveness scoring for cleft lip/palate patients	13,000 dating site images with >17 million ratings	60 images rated by 39 human raters	Unable to identify cleft-specific deformities	[16]
2020	ResNet-18, ResNeXt-50 (CNN)	Caries lesion detection in Near-Infrared Light Transillumination (NILT) images	NILT images from 226 extracted posterior teeth	Split from the 226 teeth dataset	Small sample size; in vitro study only	[17]
2021	Inception v2 (in Faster R-CNN)	Automatic deciduous tooth detection and numbering in panoramic radiographs	329 panoramic radiographs	92 panoramic radiographs	Limited to children's primary teeth; single-center	[18]
2025	DenseNet-161 (in HC-Net+)	Detection of stage II-IV periodontitis in panoramic radiographs (OPGs)	10,400 unlabeled OPGs and 481 clinically labeled OPGs	382 clinically labeled OPGs and 760 expert-labeled OPGs	Misses stage I; unstable on localized disease	[19]

3.2. Orthodontics and Maxillofacial Surgery

Orthodontics and maxillofacial surgery are two closely related but distinct specialties in the field of oral medicine, working together to solve problems such as misaligned teeth, abnormal bite relationships, and developmental deformities of the jawbone (maxilla and mandible). The positioning and numbering system of teeth and bone structure analysis are indispensable technical foundations in the collaborative treatment of orthodontics and maxillofacial surgery, especially orthognathic surgery. Together, they form a common language and quantitative basis for accurate diagnosis, scientific planning, effective communication, and successful implementation of treatment. The positioning and numbering of teeth refers to assigning specific numbers or codes to individual teeth, making it easier for doctors to develop more accurate plans for specific teeth [20]. The treatment plan prediction and operation planning of orthodontic and maxillofacial surgery can significantly improve the predictability, safety, efficiency and final aesthetic and functional effect of treatment, which is the key guarantee for the success of modern dental and maxillofacial deformity correction.

Tooth segmentation and numbering play an important role in orthodontics and maxillofacial surgery, which is helpful to evaluate oral health and accurately diagnose tooth problems. However, these tasks are usually performed manually, resulting in a large amount of time for doctors [21]. In addition, the diagnosis results are influenced by factors such as the doctor's personal emotions and experience, leading to subjectivity and the possibility of misdiagnosis and missed diagnosis [20]. Research has shown that the accuracy of artificial intelligence diagnosis is higher than that of inexperienced dentists, and literature suggests that inexperienced dentists can make faster and more accurate judgments through artificial intelligence models. Therefore, artificial intelligence can serve as an effective auxiliary tool to assist doctors in diagnosis [22], such as saving comprehensive clinical records, diagnosing dental abnormalities, designing personalized treatment plans, reducing the burden on human experts, etc. Tooth numbering can help doctors develop more accurate plans, making the dental treatment process easier and more personalized for each patient [20]. At present, AI has also been widely applied in tooth segmentation and numbering. For example, an automatic tooth detection system for bitewing images based on Region Convolutional Neural Network (R-CNN) is expected to be used for detecting and numbering teeth. This method can automatically create dental charts and electronic dental records, thereby saving time.

Artificial intelligence also plays a crucial role in predicting treatment plans and surgical planning for orthodontic and maxillofacial surgery, such as orthognathic surgery (OGS), which mainly corrects bone and facial asymmetry, facial contours, and deformities related to the jawbone. The ultimate treatment goal is to improve function and enhance facial aesthetics [23]. Surgery is complex and irreversible, and can permanently affect patients, so accurate preoperative prediction is crucial. The diagnosis, treatment plan, and prognosis prediction of traditional orthognathic surgery rely on preoperative photographs, two-dimensional (2D) cephalometric tests, and stone model surgery [24], as well as the clinical expertise and experience of the orthodontists and oral and maxillofacial surgeons involved. However, traditional methods involve sequences of multiple steps and varying levels of doctor experience, making the results more time-consuming, subjective, and prone to errors. Artificial intelligence systems can simplify tasks and provide results in a short period of time [25]. For example, artificial intelligence models based on 3D imaging have shown satisfactory performance indicators for treatment planning and outcome prediction in jaw correction surgery [24]. However, artificial intelligence still has limitations in practical applications. Firstly, the data sources are relatively single, requiring additional training of the model on large datasets from multiple centers and different populations to achieve better reliability and generality [26]. In addition, artificial intelligence cannot replace the knowledge and meticulous judgment of experienced surgeons, so in actual processes, artificial intelligence can only serve as an auxiliary tool to help doctors predict surgical and treatment plans, and cannot achieve full process intelligence.

From tooth numbering to surgical prediction and planning, AI has shown great potential. The application of AI models can help doctors complete diagnoses more efficiently and accurately. In the future, it will develop towards higher automation (intelligent planning solutions), surgical enhancement (navigation and robot assistance to improve accuracy), and remote monitoring, ultimately achieving unprecedented personalized precision medicine through the integration of bigdata, optimizing efficacy and experience.

3.3. Periodontology and Dental Endodontics

Dental caries and periodontal disease, among other oral diseases, constitute a significant disease burden and are considered nonlethal causes of disability affecting all age groups worldwide [27]. Periodontal disease is one of the most common oral diseases, characterized by pathological changes in periodontal tissue, such as damage to periodontal attachments and loss of alveolar bone. Without treatment, it can also cause tooth loss [28].Among them, periodontitis is more common. Periodontitis (PD) is a multifactorial, chronic, and complex inflammatory disease that occurs in the supporting tissues of teeth. It is related to the accumulation of dental plaque and mainly manifests as the loss of periodontal supporting tissues. If not treated properly, it can lead to irreversible bone resorption, tooth movement, and tooth loss [29].At the same time, periodontal disease may make individuals susceptible to various systemic diseases, such as cardiovascular disease, oral cancer, and pneumonia. Therefore, early diagnosis is crucial for effective treatment and good prognosis in cases of periodontitis. Periodontal bone is an important component of periodontal tissue, and the detection of periodontal bone loss is a core marker of periodontitis progression.

Therefore, periodontal bone loss detection plays a crucial role in the early diagnosis and prognosis of periodontitis [30]; Dental caries is one of the most common infectious chronic diseases and a multifactorial disease. The formation of dental caries is a dynamic process, as bacteria on the plaque biofilm produce acid, leading to local damage or demineralization of hard tissues in teeth, ultimately resulting in the formation of dental caries [31]. Untreated dental caries, especially deep cavities, can cause pulpitis, pulp necrosis, and even tooth loss, thus seriously affecting the quality of life and being the most common factor affecting health [27,32]. Moreover, the occurrence of dental caries ultimately leads to tooth decay, and diagnosing dental caries also plays an important role in preventing and diagnosing tooth decay [31].

In the diagnosis of periodontitis, radiological assessment plays a very important role. In addition to clinical periodontal assessment such as probing bag depth and attachment loss, intraoral X-ray imaging such as periapical X-ray and panoramic X-ray are also commonly used to determine periodontal conditions [33]. However, traditional diagnosis of periodontal disease relies on subjective evaluation by doctors. Due to a lack of experienced doctors and limited radiological interpretation time, there are issues with low consistency and efficiency in image interpretation. Additionally, there is a possibility of errors in human diagnosis. Therefore, the reporting requirements for X-rays pose problems in terms of time, cost, and patient care. With the increasing application of artificial intelligence models in the field of dentistry, artificial intelligence programs can be used to shorten the diagnostic process and provide more reliable results. For example, deep learning models based on YoLo-v4 and U-Net algorithms have been used to detect tooth groove bone loss in different tooth areas in panoramic images and have obtained considerable data. The use of such AI models can help dentists more effectively and easily detect local periodontal bone loss in panoramic X-ray photography in the future [30]. However, a critical limitation of many existing AI systems is their reliance on radiographic annotations by clinicians, which are inherently constrained by subjectivity and inter-examiner variability. To address this, recent studies have shifted towards using clinical probing data—the gold standard for diagnosis—as the ground truth for training deep learning models. For instance, a novel hybrid classification network (HC-Net+) developed by Li et al. demonstrated that by learning directly from clinical definitions, the AI could achieve diagnostic accuracy (AUROC: 94.2%) surpassing that of periodontal specialists [19]. In addition, it can prevent situations that may be overlooked due to doctors' lack of experience, intensity, and fatigue, ensure early diagnosis of diseases, and record patient data more accurately and regularly in digital environments [33].

In traditional treatment methods, dental caries are mainly detected through tactile examination and X-ray photography, which are mainly judged based on subjective symptoms such as color, hardness, and transparency of the caries to assess an individual's caries status. However, due to the varying levels of experience and diagnostic fatigue among dentists, the consistency of diagnosis is poor, and these traditional diagnostic methods have low sensitivity, specificity, and repeatability, and cannot even determine the activity and progression of caries [34]. There are several advanced diagnostic methods based on radiography, visible light, resistance, etc., but there is still a problem of low specificity in the testing process, which increases the risk of false positives in the detection process. Based on this, people have begun to consider introducing artificial intelligence (AI)models for detecting dental caries. The potential of AI based pattern recognition in large data can lead to early detection of dental caries, even before visible signs become clear to the naked eye [31]. Therefore, applying artificial intelligence to detect and classify dental caries can improve the accuracy and sensitivity of teeth, help detect dental caries early, save clinical doctors' time, enrich treatment decisions, reduce biological complications, and reduce the need for root canal treatment [35].

In the future, with the prospect of the future, with multimodal data fusion, enhanced model interpretability and in-depth integration of clinical workflow, AI is expected to realize the leap from diagnosis to personalized treatment planning, efficacy prediction and large-scale population oral health management, and ultimately promote the transformation of dental care to a preventive, accurate and intelligent paradigm.

3.4. Aesthetic Dentistry and Restoration

Aesthetic dentistry and restoration is a comprehensive branch of dentistry, which mainly focuses on improving the color, shape, arrangement, and overall coordination of teeth, that is, enhancing the appearance and beauty of teeth; Dental restoration mainly focuses on restoring the physiological functions of teeth such as chewing and pronunciation, while protecting oral health. Therefore, aesthetic dentistry and restoration are the use of techniques such as porcelain veneers, veneers, and resin fillings to treat dental diseases and restore chewing function, making teeth and smiles look more natural and beautiful. In aesthetic dentistry and restoration, the main steps include collection, construction, fusion and simulation, as well as output and implementation. In the collection work, detailed information such as tooth color and optical properties can be obtained through tooth color analysis and influence enhancement. Based on this information, accurate three-dimensional shape data of teeth can be obtained through dental digital reconstruction, and the final effect can be rendered through realistic modeling in fusion and simulation, ultimately achieving output and implementation.

In actual treatment, tooth color analysis is a crucial step. The determination of tooth color is affected by factors such as lighting environment and insufficient visual color. Mismatching color measurements can affect the overall effect of treatment, ultimately leading to treatment failure. In the traditional tooth color analysis, dentists mainly rely on their own manual skills and experience knowledge to analyze and judge the tooth color. For example, in clinical practice, the chromaticity Guide matching system is used to select the chromaticity, but the chromaticity range provided by the dental chromaticity guide is limited and cannot fully cover the color space of natural teeth, and the choice of color depends on factors such as shape, size, background color and lighting conditions [36], resulting in changes in everyone's perception of each color, making the judgment of the result with great subjectivity and uncertainty, especially for inexperienced dentists. In addition, the lack of reliable instructions from dental manufacturers will also bring challenges to tooth color analysis. The development of artificial intelligence has a far-reaching impact on tooth color analysis. The progress of dental restoration technology, especially in color reproduction, represents the key intersection between AI technology and traditional technology [37]. For example, the shadow matching technology developed to improve the performance of color matching systems, under certain assumptions and constraints, proposes a color based image classification algorithm to classify and process color images. In clinical practice, it helps to determine and identify tooth color, reflecting objectivity and quantification rather than misleading subjectivity and qualitative information, and can solve problems related to human visual subjectivity [36].There is also a dental color matching method based on the HSV color model, which can combine machine learning and fuzzy decision-making techniques to improve the accuracy and consistency of color matching in dental restorations.

Dental digital reconstruction is a huge leap forward in dental restoration treatment. The process of dental digital reconstruction completely changes the traditional dental model that relies on plaster models and handmade restorations. It is a symbol of the digital age of dentistry. It mainly uses digital means to obtain three-dimensional data of teeth, and designs and manufactures the entire process of dental restorations and substitutes on computers. That is, it replaces the traditional manual simulation process with high-tech digital processes, thereby achieving more accurate, efficient, and comfortable dental restorations. For example, the Transpomer based AI model TM and the diffusion based AI model DM can determine the feasibility and accuracy of single and multiple tooth reconstruction based on a limited number of datasets. Both models have shown satisfactory results in the reconstruction of missing teeth, and the results show that the accuracy of a single true tooth is higher than that of multiple true teeth, providing a new method for simplifying and improving the accuracy of implant planning [38].

To sum up, aesthetic dentistry and prosthodontics are developing in the direction of precision and intelligence. From the traditional reliance on doctors' subjective judgment to the image technology assisted by AI model to achieve objective and accurate quantitative matching and personalized design, dental treatment has transitioned from the traditional experience led "craft" era to the data-driven Digital Era. Looking forward to the future, aesthetic dentistry and prosthodontics will gradually move towards the direction of comprehensive intelligence and high personalization. AI will no longer be just an auxiliary tool, but become the core driving force of diagnosis and treatment, and realize the whole process from accurate analysis to intelligent design and even automation.

3.5. Other Applications

3.5.1. Forensic Dentistry

Forensic dentistry (FO), as an important branch of dentistry, primarily identifies individuals by analyzing the unique anatomical structures of the oral cavity. This discipline is mainly applied in large-scale disaster events, identifying unidentifiable remains by comparing dental records, or assisting in confirming the identity of human remains. Traditional body recognition often relies on the visual observation of relatives, friends, or acquaintances, such as facial features, clothing, or personal belongings, for identification. However, when the body undergoes significant morphological changes due to decay, burning, or other reasons, the reliability of visual recognition is greatly reduced. In this case, forensic analysis of objective and scientific dental features becomes an indispensable means of individual identification [39].

The application of artificial intelligence in forensic dentistry has improved its accuracy and efficiency, mainly reflected in various aspects such as age judgment, gender determination, and bite mark analysis. Bitemarks are often regarded as key physical evidence in violent crime cases such as sexual assault and murder, but their recognition and judgment have long been mainly through manual identification, which has a strong subjectivity problem and may vary with the experience and professional ability of professionals. In order to solve this problem, Mahasantipiya and other scholars attempted to use artificial neural networks (ANN) to construct bitemark recognition models, aiming to improve matching accuracy and reduce human bias. Researchers trained the model by extracting specific features of bite marks, and preliminary results showed that the network has a certain matching ability, demonstrating the potential application of artificial intelligence in this field. Although the current accuracy has not yet met the standards for routine clinical applications, these achievements undoubtedly provide encouraging directions for future research [40].

3.5.2. Electronic Health Record Management

Electronic health records (EHRs) are mainly used to store and record patients' health information, such as identity information, medical history, medication, allergies, and immune status [41,42], aiming to store data with high precision, achieve real-time monitoring and information sharing of patient information, ensure that patients receive more timely and accurate personalized treatment, and can receive correct and understandable information in a timely manner. At the same time, information digitization also has great value in evaluating patients' potential problems and long-term changes [42]. However, due to the large and complex nature of medical data, traditional information management is difficult to meet the needs of practical clinical applications. Therefore, advanced technology needs to be introduced to solve existing problems and maximize their value [41].The integration of artificial intelligence and electronic health records not only improves the accuracy and management efficiency of medical data, but also demonstrates enormous potential in predictive analysis, managing patient prognosis, enhancing clinical decision-making, and automating management tasks [42].

Predictive analysis is an important application of artificial intelligence in electronic health record management. It mainly uses machine learning algorithm to analyze the patient's historical health data to predict the patient's disease progression, admission risk and potential complications. Through these data, medical staff can implement intervention measures and optimize the treatment plan earlier, so as to improve the quality of treatment, reduce the risk of patients and reduce the medical expenditure of patients at the same time. For example, Esteva et al.'s research shows that the deep learning model has great potential in predicting the prognosis of patients based on historical data, especially in identifying the risk of readmission of patients [41]. in addition, the clinical decision-making system (CDSS) driven by artificial intelligence can provide real-time data analysis assistance to medical staff and timely warn potential risks such as drug interactions or abnormal detection results, so as to optimize the clinical decision-making process. The system not only improves the accuracy of diagnosis, but also significantly reduces the cognitive pressure of doctors, avoids human errors, and makes more scientific decisions. another important application of artificial intelligence in electronic health records is mainly reflected in natural language processing (NLP) technology, which can parse unstructured text, and then significantly improve the efficiency and accuracy of patient retrieval, so as to play the potential of electronic health records and enhance their availability. For example, in a study by JHA et al., it was found that the accessibility of medical information can be improved by analyzing massive clinical data through NLP. NLP can convert text-based treatment notes into institutional data, provide doctors with a more complete treatment process, and ultimately improve the overall quality of care [41]. In summary, the combination of artificial intelligence and electronic health record management is a double-edged sword. It has great potential in improving efficiency, empowering healthcare, and enhancing patient resolution. However, the successful implementation of AI models still faces challenges in terms of security and privacy, interoperability, algorithmic bias, and ethical ethics. Only through technological innovation and multi-party collaboration can AI safely reshape the future of healthcare [42].

3.5.3. Large Language Models in Dental Education and Patient Communication

The application of large-scale language model in dental education and doctor-patient communication the rapid development of generative artificial intelligence, especially the large-scale language model (LLM), has brought a paradigm shift beyond traditional image analysis in the field of dentistry. Different from the previous NLP model focusing on information extraction, LLM uses transformer architecture to understand and generate human like text, showing great potential in education and doctor-patient interaction.

In dental education, LLM is actively reshaping the learning paradigm from passive information retrieval to interactive collaboration. A recent study using hybrid methods showed that dental students who completed learning tasks using chatgpt performed significantly better in knowledge assessment than their peers who used traditional literature retrieval methods, highlighting the potential of this tool in improving academic performance [43]. In addition to information integration, LLM can also be used as a virtual tutor to generate various clinical scenarios, such as periodontal medical records and cases, and provide personalized feedback to help students improve the diagnosis basis [44].

In terms of patient communication and management, AI is filling the gap between professional terminology and patient understanding, and fundamentally reshaping doctor-patient interaction [45]. Using NLP technology, artificial intelligence algorithm can now customize the education content according to the patient's anxiety and learning preferences, and convert complex medical terms into easy to understand language, so as to improve the patient's understanding of the disease [46]. In addition to automatic triage, the virtual assistant integrated with artificial intelligence can also provide 24/7 support, including active postoperative monitoring, such as tracking pain degree and medication compliance.

However, the application of large-scale language models faces many challenges, the most important of which is the risk of "hallucination", that is, generating seemingly reasonable but actually inaccurate medical information. Therefore, although large-scale language models can achieve efficient automated communication, manual supervision is still essential to ensure the accuracy and security of information (Figure 2).

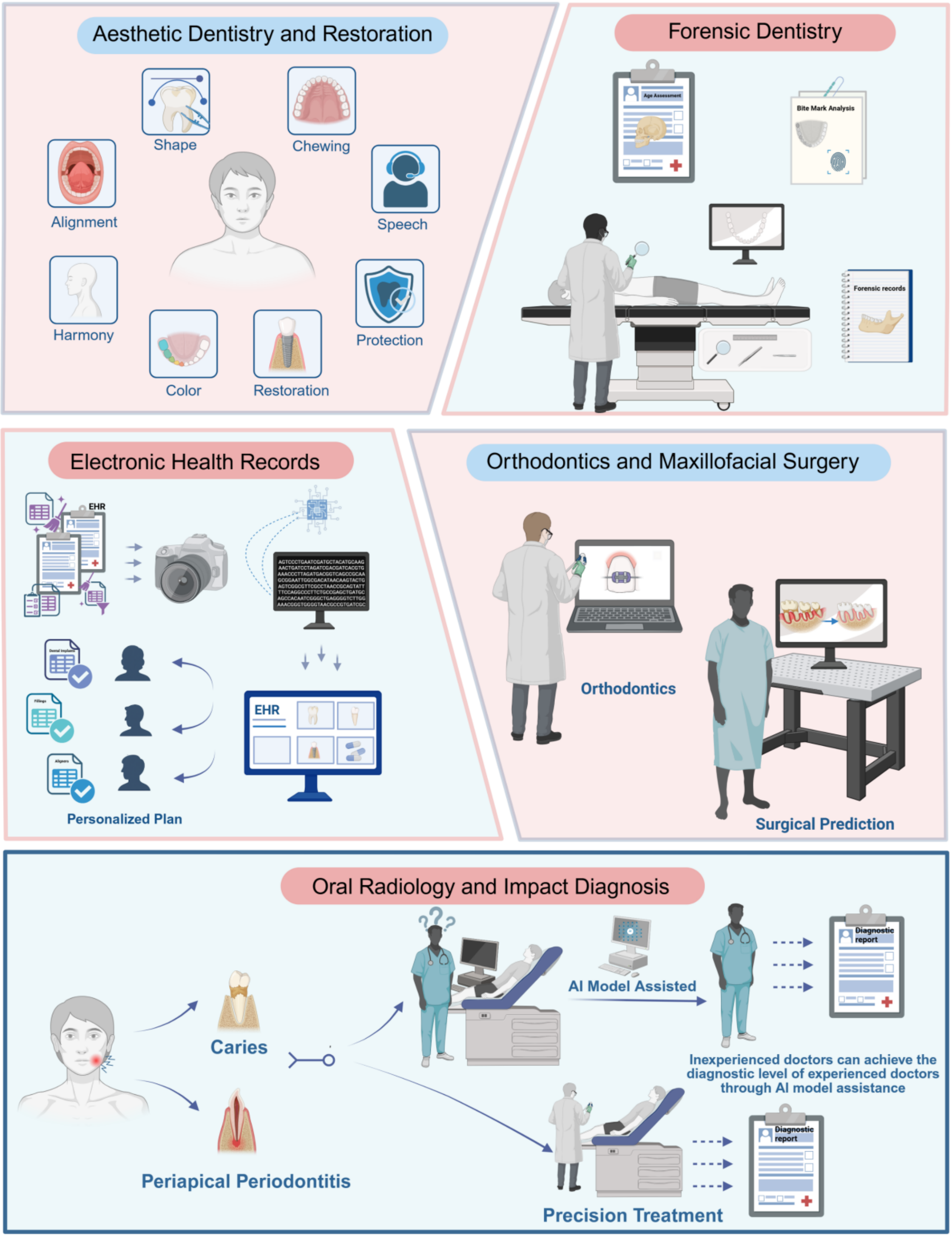

Figure 2. Application of artificial intelligence in dentistry.

4. Performance Evaluation and Clinical Validation

With the development of AI, its application in the field of dentistry is also increasing, significantly improving work efficiency in simplifying diagnostic processes and assisting clinical decision-making. Corresponding AI models have been developed in multiple fields involved in dentistry, such as maxillofacial radiology, caries detection, and orthodontics. However, there are still many prominent shortcomings of AI in practical applications. Therefore, before implementing AI, performance evaluation must be conducted to comprehensively understand the pros and cons, so that it can be widely applied in clinical practice [47].

In the evaluation of artificial intelligence models, a standard can be established to assess the performance of different models and their effectiveness in practical clinical applications, such as Julian Boldt By establishing a gold standard based on histology, the performance of artificial intelligence based dental caries detection systems was evaluated. This was mainly achieved by establishing an unbiased dataset to evaluate the detection of dental caries in the biting and maxillofacial regions based on artificial intelligence, and comparing the detection results with the judgments of human professionals. This provided a standard for evaluating the performance of different artificial intelligence models, thereby helping dental practitioners choose reliable and efficient diagnostic tools. The database allows for the comparison of different artificial intelligence models and performance evaluation before practical clinical applications, improving the reliability of the data and helping to identify and develop more accurate diagnostic models. However, due to the time-consuming construction of standard datasets based on histology and the high requirements for equipment and resources, there are still difficulties in achieving the popularization of standards. Nevertheless, the standardized evaluation scheme for artificial intelligence caries detection is an important step towards the transparency, reliability, and credibility of future dental diagnosis [48].

In the performance evaluation of the model for detecting dental caries and recognizing the number of teeth through oral photos based on cascaded CNN, a three-stage classification system is mainly used for evaluation. The model predictions generated by the validation dataset are compared with the real values, and the compared data mainly includes sensitivity, specificity, accuracy, and AUC of the real box. By comparing these data, the accuracy of the model can be judged and performance evaluation can be conducted. At present, the AI model studied by Kyubaek Yoon et al. Has demonstrated effective detection and recognition capabilities, accurately identifying and locating different stages of dental caries, and possessing robust tooth recognition capabilities, which helps to improve automatic analysis and understanding of dental health. Due to the fact that deep learning models are trained on complete intraoral images, they can be effectively integrated into clinical practice and achieve comprehensive clinical applications [49]. Another example is the artificial intelligence image analysis system researched by Viktor Szabó, which can assist the healthcare process during radiological assessment and compare its results with the true values determined by professional doctors to test its reliability in dental caries diagnosis. Research has found that the DC model outperforms Schwendicke et al. in multiple performance indicators such as sensitivity, specificity, and accuracy in diagnosing dental caries using red light transmission images. At the same time, the values obtained by the DC model are also better than those obtained by human observers in Devito et al.'s study. However, there are still limitations in the practical use of this model, mainly due to the lack of clinical evaluation, which can be solved by collecting existing clinical information in the subsequent process. Therefore, the reliability of the DC artificial model has not yet reached the level where it can be independently used for diagnosing dental caries. However, as an auxiliary tool, it can significantly help observers make more reliable and efficient diagnostic results [50].

In summary, the application of artificial intelligence models can significantly improve the detection and diagnostic efficiency of multiple dental fields such as caries detection and tooth quantity recognition. Multiple deep learning based models have shown high accuracy and reliability in the performance evaluation stage, even surpassing the judgment of human experts in sensitivity and specificity. However, currently these models still lack clinical validation and objective standardized evaluation, and due to low transparency in the detection process, they are prone to trust issues in practical applications, seriously affecting the independent application of AI models. In the future, efforts should be made to invest in high-quality annotated datasets, strengthen robustness verification in real medical scenarios, and establish human-machine collaborative diagnostic standards and approval admission systems to promote the development of AI dental tools towards safety, reliability, and practicality.

5. Key Elements to Promote the Implementation of AI in Dentistry

The rapid development of artificial intelligence has pushed medical care into a new stage. It has effectively improved the accuracy of disease diagnosis, and has shown great potential in improving the quality of patient care and optimizing treatment options. As an important part of medical care, dentistry will also achieve more efficient diagnosis and service with the integration of artificial intelligence. There are many key factors to promote the landing of AI in dentistry, among which high-quality, standardized and desensitized dental data is the cornerstone of the development of AI. The realization of high-quality data and sharing can effectively promote the landing of AI in dentistry. Secondly, data acquisition and sharing face strict legal and ethical constraints. It must be carried out under the premise of protecting patient privacy, following data security regulations, and obtaining informed consent. Only by ensuring the compliance and transparency of data applications can we build doctor-patient trust and promote the safe and responsible implementation of AI [51] (Figure 3).

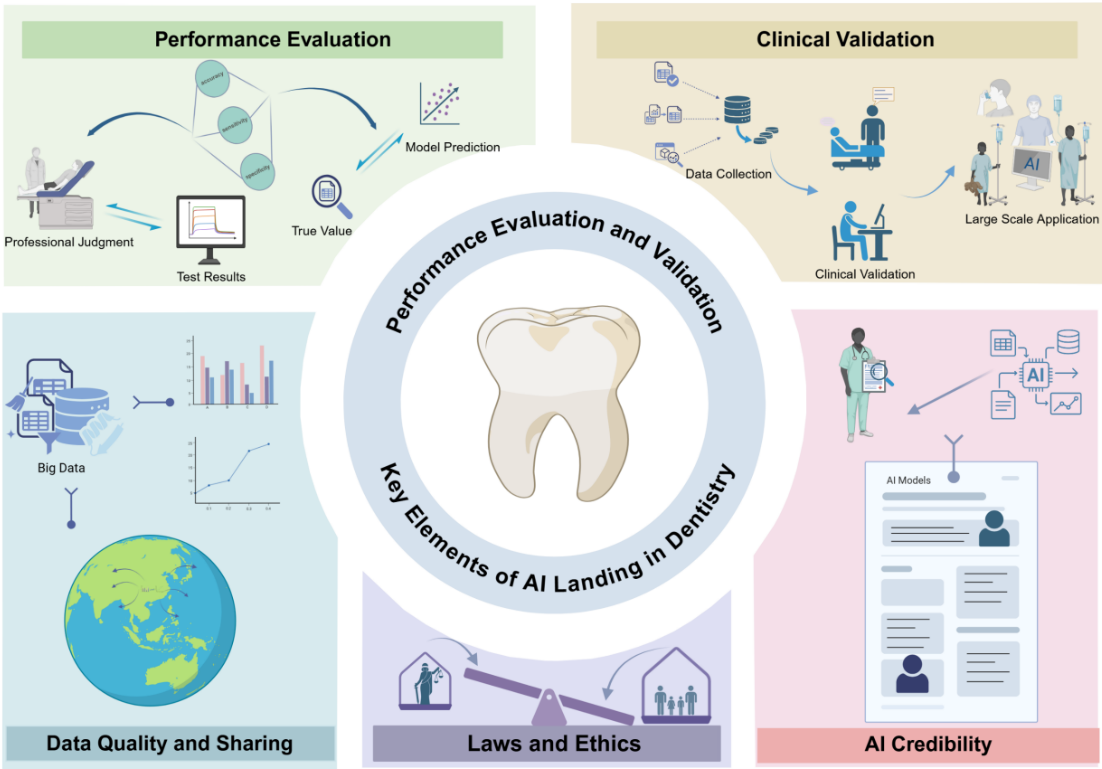

Figure 3. Key elements of AI implementation.

Data quality and sharing is one of the key elements to promote the implementation of AI in dentistry. Clinical data mainly include radiological images, medical history, treatment results, etc. high quality and structured clinical data not only provide a solid foundation for model training, but also directly determine its effectiveness and reliability in actual diagnosis and treatment. In addition, the artificial intelligence model trained by high-quality data can also recognize complex patterns, correlations and abnormal phenomena that are difficult for humans to detect. The importance of clinical data is not only reflected in its huge amount of data, but also in its diversity. The data covering a wider range of pathological types helps to improve the generalization type and robustness of artificial intelligence models [51]. Data sharing also plays a crucial role, but in the process of promotion, it faces security issues such as privacy protection. Therefore, while achieving data sharing, it is also necessary to ensure the protection of personal and public interests. At present, the balance between public interest and personal data protection is being coordinated and achieved in different ways around the world. The secure and compliant sharing of dental data can bring enormous benefits in various aspects while strictly protecting privacy. In clinical practice, the aggregation of a large amount of anonymous data can help improve the accuracy of disease diagnosis and treatment plans. In addition, it also provides a necessary foundation for training and validating artificial intelligence tools in scientific research experiments. Therefore, high-quality data and sharing can further promote the application of artificial intelligence in dentistry [52].

Legal and ethical issues are also one of the key factors affecting the implementation of AI in dentistry. Although integrating AI into dentistry can bring great benefits, it is also accompanied by multiple challenges, including data privacy and security risks, artificial intelligence algorithm bias, regulatory compliance and other issues. First of all, in terms of data privacy, AI training involves highly sensitive patient information. Once leaked, it may lead to serious consequences. With the expansion of the data set, potential threats will also increase. In Seerammullankandy's research, it is proposed that end-to-end encryption and multi factor authentication (MFA) and other enhanced encryption methods can be used to strengthen the protection of medical data, help identify and block potential crises, and prevent them from happening. Secondly, AI algorithm bias will also affect the clinical application of AI in dentistry. Artificial intelligence models trained on biased or incomplete data sets may lead to unequal treatment recommendations or exacerbate the existing health gap, and ultimately affect the accuracy of diagnosis, treatment recommendations and prediction results. Therefore, algorithm audit and data sets from different populations can be carried out to reduce bias and ensure fair service for patients through continuous monitoring and verification of artificial intelligence models. Finally, the use of AI models must strictly comply with national data protection regulations, such as the European Union's general data protection regulation (GDPR) and the United States' health insurance circulation and Liability Act (HIPAA). As AI related data transmission may involve cross-border data transmission and the processing of sensitive health information, which makes data compliance complex, in order to strengthen compliance management, automated compliance tools can be introduced to continuously monitor the data processing process to ensure compliance with a series of regulatory requirements such as GDPR and HIPAA [42]. Therefore, it is also very important for AI landing dentistry to properly handle legal and ethical issues.

To sum up, the realization of AI enabled dentistry should be based on high-quality data, guaranteed by legal and ethical compliance, and supported by technology. Finally, under the premise of protecting privacy, eliminating prejudice and complying with laws and regulations, we can realize the potential of AI in diagnosis and treatment, and promote the development of dentistry in the direction of intelligence. In the future, with the maturity of the data collaboration ecosystem, the improvement of laws and regulations, and the deeper integration of AI and clinic, dentistry will enter a new stage of human-computer collaborative precision medicine, providing patients with more efficient, personalized and fair diagnosis and treatment services.

6. Existing Challenges and Development Bottlenecks

The application of artificial intelligence in dentistry provides feasible solutions to various existing problems, however, AI solutions have not yet been widely applied in dental clinical practice and are affected by various challenges. Data imbalance and heterogeneity pose the primary challenges. Due to the limited quantity and scale of high-quality and finely annotated data, as well as uneven sample distribution, factors such as gender, socio-economic background, and racial bias can lead to poor data collection performance for specific populations, resulting in a lack of sufficient coverage of demographic characteristics. Ultimately, a model trained on this dataset has poor generalization ability, which can easily cause algorithm bias and significantly reduce the performance of the model in these populations, forming a vicious cycle that damages the fairness of diagnosis itself and the accuracy of treatment planning. In addition, different data formats and labeling standards are not unified, and clinical text data itself involves highly sensitive information, further increasing the difficulty of data acquisition, sharing, and compliant use [53].

Secondly, significant limitations in computing power and resources have hindered the development and application of AI models. Developing high-performance AI modules requires a significant amount of computing resources to complete model training and parameter optimization. However, this poses a heavy burden for most dental clinics and research institutions [53], especially for small clinics with limited budgets, where high initial investment costs become a key financial barrier for their adoption of AI technology [54].

Thirdly, the challenges of multi center and multimodal fusion are significant, and various technologies and systems (such as digital imaging and diagnosis and treatment management software) are widely used in dental clinical practice. However, different systems often operate independently and lack unified data standards and interoperability support. The dispersion of this information makes it difficult to effectively integrate data from different institutions and collection methods, which in turn makes it difficult to truly utilize the data in practical development, restricting the development of high-performance artificial intelligence models that comprehensively utilize multi-source information [54]. Although establishing extensive research cooperation networks and adopting distributed training methods such as federated learning can promote data sharing to a certain extent, in the actual process of promotion, multiple challenges in technology implementation and cross machine collaboration still need to be addressed [53].

Finally, medical ethics, trust between doctors and patients, and barriers to clinical promotion are challenges that constrain the implementation and application of AI. In terms of ethics, it is mainly reflected in patient privacy and data security, and the processing of data information must strictly comply with data protection regulations such as HIPAA. Therefore, extremely high standards are proposed for data protection technologies such as anonymization processing technology and secure storage mechanisms [53]. In terms of trust between doctors and patients, practitioners hold a reserved attitude towards the use of AI due to their unfamiliarity with technology and fear of legal responsibility for AI misdiagnosis. Additionally, due to doctors' lack of understanding of algorithms, they are unable to clearly introduce them to patients, leading to patients' skepticism towards doctors' diagnoses. Therefore, there are still significant challenges in the actual use of patient trust in traditional Chinese medicine. In addition, the lack of a clear regulatory framework and effective evidence further increases the difficulty of clinical promotion [55].

However, the existing challenges are not limited to data privacy, but also include the risk of automated bias and over diagnosis. People are increasingly worried that clinicians, especially inexperienced doctors, may rely too much on the output of artificial intelligence and accept algorithm recommendations without sufficient critical evaluation. This dependence will lead to “automatic bias”, and may weaken the ability of independent clinical judgment and critical thinking over time [56,57]. In addition, if the technical limitations inherent in some models, such as false positive, are not strictly verified, these limitations may inadvertently lead to over diagnosis and unnecessary treatment [58]. Therefore, it is important to ensure artificial supervision to prevent artificial intelligence errors from endangering the safety of patients. In summary, the development of AI in dentistry mainly faces four challenges: data imbalance and heterogeneity, limitations in computing power and resources, difficulties in multi center and multimodal fusion, and medical ethics. In the future, by adopting new technological paradigms such as federated learning and generative AI synthesis of data, relying on cloud platforms to lower the threshold for computing power, and establishing transparent and interpretable AI evaluation systems and standards, it is expected to gradually overcome these challenges and ultimately promote the fair, efficient, and safe clinical application of dental AI.

7. The Transformation and Future Prospects of Dental Diagnosis and Treatment Models Empowered by AI

Artificial intelligence is changing the dental diagnosis and treatment mode with unprecedented depth and breadth, and promoting the development of dentistry in a more intelligent, personalized and inclusive direction. Its impact is mainly reflected in the personalization of the diagnosis and treatment process, the promotion of new service modes, and the improvement of the accessibility of telemedicine and remote areas.

First, in terms of personalized diagnosis and treatment, the artificial intelligence system can deeply analyze the patient’s dental history, daily oral hygiene habits and potential risk factors, so as to formulate a highly personalized treatment plan. These programs cover many aspects, such as diet adjustment, health practice and lifestyle optimization. Based on the data analysis ability of AI and the comprehensive consideration of its personal data, AI can generate more targeted and easier to implement personalized suggestions and treatment plans, so as to improve oral health. For example, when patients have enamel erosion problems, the AI system will recommend that they reduce the intake of acid food to reduce the risk of tooth damage. This personalized diagnosis and treatment scheme can closely combine the guidance and suggestions with the actual situation of patients, so as to significantly improve the success rate of improving oral health [59].

Secondly, AI has demonstrated a particularly prominent role in remote healthcare and improving accessibility in remote areas. Remote dental platforms have become an indispensable tool for dental healthcare, providing services such as remote consultation, online diagnosis, and postoperative follow-up, especially for residents living in remote or rural areas, people with limited mobility, and those who are busy with offline life and work and find it difficult to arrange offline medical treatment. Patients do not need to physically visit the clinic, and can complete consultations, preliminary diagnoses, and receive personalized treatment recommendations through the platform. At present, the integration of artificial intelligence has further advanced the development of telemedicine. More and more platforms are integrating advanced digital tools to assist online diagnosis and treatment through AI based auxiliary diagnostic systems. Patients can take pictures of their oral cavity and upload them through the platform.AI algorithms can assist in identifying early signs of dental caries, periodontal disease, and even oral cancer, allowing dentists to remotely assess the condition and develop treatment plans. For example, during the COVID-19 pandemic, there was a surge in demand for remote dentistry. Patients can take oral images and upload them through a mobile application equipped with AI. The AI algorithm can perform preliminary emergency triage, such as identifying whether it is a common toothache or a severe abscess, and deciding whether immediate referral is needed, thereby reducing face-to-face contact and ensuring continuity of dental care for patients. In addition, users’ daily brushing data can be synchronized to a cloud based AI platform through wearable devices. Dentists can remotely monitor patients’ compliance and send personalized improvement suggestions to patients in a timely manner through applications. This model is particularly suitable for long-term oral health management of elderly people in nursing homes or special needs groups. While breaking geographical limitations, it significantly improves service accessibility and efficiency [59] (Figure 4).

In the future, AI will completely reshape the dental diagnosis and treatment model, upgrading it from traditional “experience driven” and “passive treatment” to “data-driven” “active health management”. By deeply integrating multidimensional data, AI can not only achieve ultra early and accurate disease diagnosis, but also build predictive treatment plans, providing personalized oral health solutions for each patient throughout their life cycle. Ultimately, the role of dentists will be liberated from repetitive operations, focusing more on complex decision-making and humanized care, and collaborating with AI to build an efficient, accurate, and preventive new ecosystem of intelligent diagnosis and treatment.

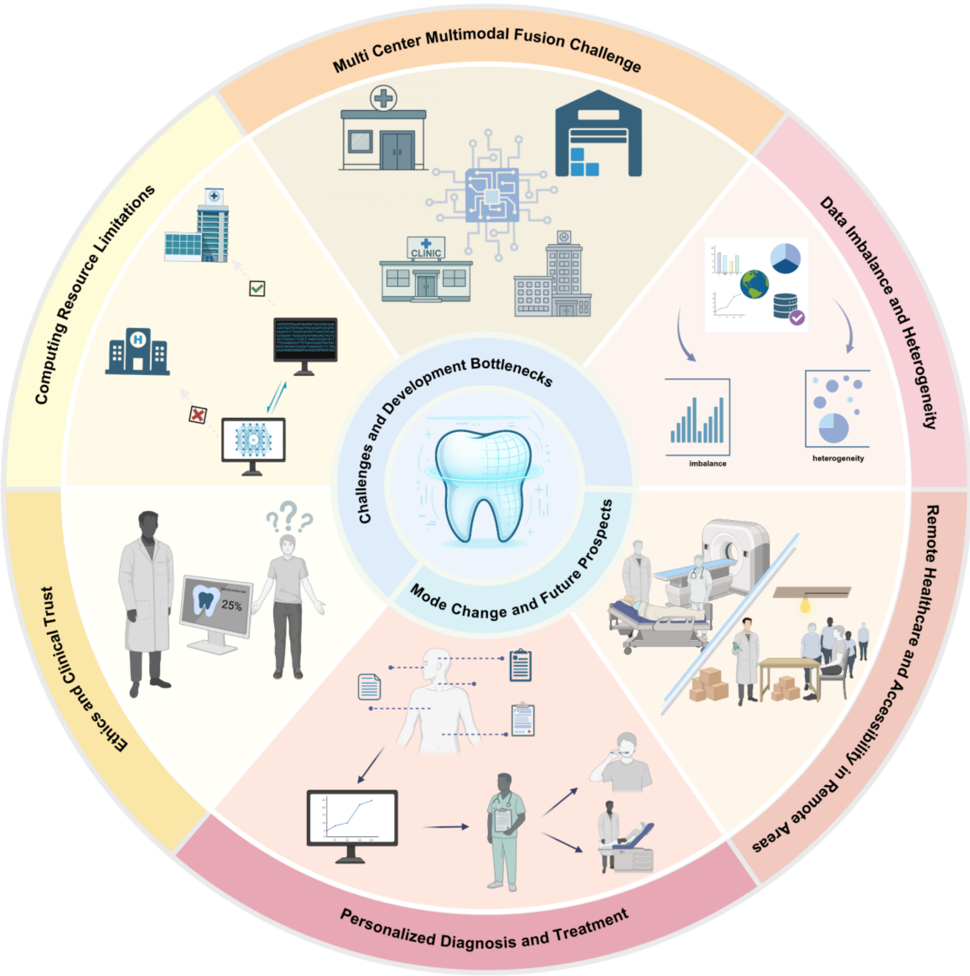

Figure 4. Prospects and outlook of artificial intelligence empowering dentistry.

8. Conclusions

AI in stomatology has shifted from exploration to clinical practice, and has significant advantages in the fields of oral imaging, orthodontics, Periodontology, oral cosmetology and prosthodontics. Artificial intelligence solves the limitations of traditional methods, improves the accuracy and efficiency of diagnosis, and promotes personalized treatment. It can also improve accessibility in remote areas, optimize resource allocation, and encourage patient participation. However, challenges remain, including data imbalances, ethical issues, and computational resource constraints. Future research should focus on the construction of high-quality multi center data sets, the application of privacy computing technology and the development of collaborative artificial intelligence diagnostic standards. With the maturity of technology and the deepening of clinical integration, artificial intelligence will become an important part of dental systems, promoting prevention, accurate diagnosis and human artificial intelligence collaboration. Ultimately, this will lead to a more efficient, affordable, personalized dental care system.

Author Contributions

L.B.: conceptualised the review; C.Y.: wrote and edited the manuscript the manuscript; C.Y.: collected published papers; L.B. and J.S.: revised the manuscript. L.B. and J.S.: provided funding support. The illustrations in this review were created with Biorender.com by C.Y. All authors reviewed and approved the final version of the manuscript.

Funding

This work was financially supported by Key program of the National Natural Science Foundation of China (82530072), National Natural Science Foundation of China (82230071, 32471396, 82427809), Shanghai Committee of Science and Technology (23141900600, Laboratory Animal Research Project), Young Elite Scientist Sponsorship Program by China Association for Science and Technology (YESS20230049).

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflicts of Interest

All authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

References

1. Champa-Bujaico, E.; Díez-Pascual, A.M.; García-Díaz, P. Synthesis and Characterization of Polyhydroxyalkanoate/Graphene Oxide/Nanoclay Bionanocomposites: Experimental Results and Theoretical Predictions via Machine Learning Models. *Biomolecules* **2023**, *13*, 1192. https://doi.org/10.3390/biom13081192.
2. Zhang, X.; Gu, Y.; Yin, J.; et al. Development, Reliability, and Structural Validity of the Scale for Knowledge, Attitude, and Practice in Ethics Implementation Among AI Researchers: Cross-Sectional Study. *JMIR Form. Res.* **2023**, *7*, e42202. https://doi.org/10.2196/42202.
3. Kourounis, G.; Elmahmudi, A.A.; Thomson, B.; et al. Computer Image Analysis with Artificial Intelligence: A Practical Introduction to Convolutional Neural Networks for Medical Professionals. *Postgrad. Med. J.* **2023**, *99*, 1287–1294. https://doi.org/10.1093/postmj/qgad095.
4. Intelligence, C.; Neuroscience, C. Retracted: Street Landscape Planning and Design Guided by Artificial Intelligence Interactive Experience. *Comput. Intell. Neurosci.* **2023**, *2023*, 9791253. https://doi.org/10.1155/2023/9791253.
5. Pauwels, R. A Brief Introduction to Concepts and Applications of Artificial Intelligence in Dental Imaging. *Oral Radiol.* **2021**, *37*, 153–160. https://doi.org/10.1007/s11282-020-00468-5.
6. Goecks, J.; Jalili, V.; Heiser, L.M.; et al. How Machine Learning Will Transform Biomedicine. *Cell* **2020**, *181*, 92–101. https://doi.org/10.1016/j.cell.2020.03.022.
7. Parvin, N.; Joo, S.W.; Jung, J.H.; et al. Multimodal AI in Biomedicine: Pioneering the Future of Biomaterials, Diagnostics, and Personalized Healthcare. *Nanomaterials* **2025**, *15*, 895. https://doi.org/10.3390/nano15120895.
8. Li, Q.; Fan, Q.-L.; Han, Q.-X.; et al. Machine Learning in Nephrology: Scratching the Surface. *Chin. Med. J.* **2020**, *133*, 687–698. https://doi.org/doi:10.1097/CM9.0000000000000694.
9. Dai, J.; Kim, M.-Y.; Sutton, R.T.; et al. Comparative Analysis of Natural Language Processing Methodologies for Classifying Computed Tomography Enterography Reports in Crohn's Disease Patients. *NPJ Digital Med.* **2025**, *8*, 324. https://doi.org/10.1038/s41746-025-01729-5.
10. Negi, S.; Mathur, A.; Tripathy, S.; et al. Artificial Intelligence in Dental Caries Diagnosis and Detection: An Umbrella Review. *Clin. Exp. Dent. Res.* **2024**, *10*, e70004. https://doi.org/10.1002/cre2.70004.
11. Huang, Y.; Zhou, P.; Liu, S.; et al. Metabolome and Microbiome of Chronic Periapical Periodontitis in Permanent Anterior Teeth: A Pilot Study. *BMC Oral Health* **2021**, *21*, 599. https://doi.org/10.1186/s12903-021-01972-8.
12. Prados-Privado, M.; García Villalón, J.; Martínez-Martínez, C.H.; et al. Dental Caries Diagnosis and Detection Using Neural Networks: A Systematic Review. *J. Clin. Med.* **2020**, *9*, 3579. https://doi.org/10.3390/jcm9113579.
13. Lee, J.-H.; Kim, D.-H.; Jeong, S.-N.; et al. Detection and Diagnosis of Dental Caries Using a Deep Learning-Based Convolutional Neural Network Algorithm. *J. Dent.* **2018**, *77*, 106–111. https://doi.org/10.1016/j.jdent.2018.07.015.
14. Zhang, K.; Wu, J.; Chen, H.; et al. An Effective Teeth Recognition Method Using Label Tree with Cascade Network Structure. *Comput. Med. Imaging Graphics* **2018**, *68*, 61–70. https://doi.org/10.1016/j.compmedimag.2018.07.001.
15. Li, P.; Kong, D.; Tang, T.; et al. Orthodontic Treatment Planning Based on Artificial Neural Networks. *Sci. Rep.* **2019**, *9*, 2037. https://doi.org/10.1038/s41598-018-38439-w.
16. Patcas, R.; Timofte, R.; Volokitin, A.; et al. Facial Attractiveness of Cleft Patients: A Direct Comparison Between Artificial-Intelligence-Based Scoring and Conventional Rater Groups. *Eur. J. Orthod.* **2019**, *41*, 428–433. https://doi.org/10.1093/ejo/cjz007.

17. Schwendicke, F.; Elhennawy, K.; Paris, S.; et al. Deep Learning for Caries Lesion Detection in Near-Infrared Light Transillumination Images: A Pilot Study. *J. Dent.* **2020**, *92*, 103260. https://doi.org/10.1016/j.jdent.2019.103260.
18. Kılıc, M.C.; Bayrakdar, I.S.; Çelik, Ö.; et al. Artificial Intelligence System for Automatic Deciduous Tooth Detection and Numbering in Panoramic Radiographs. *Dentomaxillofacial Radiol.* **2021**, *50*, 20200172. https://doi.org/10.1259/dmfr.20200172.
19. Li, Y.; Cui, Z.; Mei, L.; et al. A Novel AI-Powered Radiographic Analysis Surpasses Specialists in Stage II–IV Periodontitis Detection: A Multicenter Diagnostic Study. *npj Digital Med.* **2025**, *8*, 691. https://doi.org/10.1038/s41746-025-02077-0.
20. Maganur, P.C.; Vishwanathaiah, S.; Mashyakhy, M.; et al. Development of Artificial Intelligence Models for Tooth Numbering and Detection: A Systematic Review. *Int. Dent. J.* **2024**, *74*, 917–929. https://doi.org/10.1016/j.identj.2024.02.009.
21. Ghorbani, Z.; Mirebeigi-Jamasbi, S.S.; Hassannia Dargah, M.; et al. A Novel Deep Learning-Based Model for Automated Tooth Detection and Numbering in Mixed and Permanent Dentition in Occlusal Photographs. *BMC Oral Health* **2025**, *25*, 455. https://doi.org/10.1186/s12903-025-06023-0.
22. Ayyıldız, H.; Orhan, M.; Bilgir, E.; et al. Tooth Numbering with Polygonal Segmentation on Periapical Radiographs: An Artificial Intelligence Study. *Clin. Oral Invest.* **2024**, *28*, 610. https://doi.org/10.1007/s00784-024-05999-3.
23. Khanagar, S.B.; Alfouzan, K.; Awawdeh, M.; et al. Performance of Artificial Intelligence Models Designed for Diagnosis, Treatment Planning and Predicting Prognosis of Orthognathic Surgery (OGS)—A Scoping Review. *Appl. Sci.* **2022**, *12*, 5581. https://doi.org/10.3390/app12115581.
24. Sankar, H.; Alagarsamy, R.; Lal, B.; et al. Role of Artificial Intelligence in Treatment Planning and Outcome Prediction of Jaw Corrective Surgeries by Using 3-D Imaging: A Systematic Review. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol.* **2025**, *139*, 299–310. https://doi.org/10.1016/j.oooo.2024.09.010.
25. Khanagar, S.B.; Al-Ehaideb, A.; Vishwanathaiah, S.; et al. Scope and Performance of Artificial Intelligence Technology in Orthodontic Diagnosis, Treatment Planning, and Clinical Decision-Making—A Systematic Review. *J. Dent. Sci.* **2021**, *16*, 482–492. https://doi.org/10.1016/j.jds.2020.05.022.
26. Albalawi, F.; Abalkhail, K.A. Trends and Application of Artificial Intelligence Technology in Orthodontic Diagnosis and Treatment Planning—A Review. *Appl. Sci.* **2022**, *12*, 11864. https://doi.org/10.3390/app122211864.
27. Khanagar, S.B.; Alfouzan, K.; Awawdeh, M.; et al. Application and Performance of Artificial Intelligence Technology in Detection, Diagnosis and Prediction of Dental Caries (DC)—A Systematic Review. *Diagnostics* **2022**, *12*, 1083. https://doi.org/10.3390/diagnostics12051083.
28. Tariq, A.; Nakhi, F.B.; Salah, F.; et al. Efficiency and Accuracy of Artificial Intelligence in the Radiographic Detection of Periodontal Bone Loss: A Systematic Review. *Imaging Sci. Dent.* **2023**, *53*, 193–198. https://doi.org/10.5624/isd.20230092.
29. Alotaibi, G.; Awawdeh, M.; Farook, F.F.; et al. Artificial Intelligence (AI) Diagnostic Tools: Utilizing a Convolutional Neural Network (CNN) to Assess Periodontal Bone Level Radiographically—A Retrospective Study. *BMC Oral Health* **2022**, *22*, 399. https://doi.org/10.1186/s12903-022-02436-3.
30. Uzun Saylan, B.C.; Baydar, O.; Yeşilova, E.; et al. Assessing the Effectiveness of Artificial Intelligence Models for Detecting Alveolar Bone Loss in Periodontal Disease: A Panoramic Radiograph Study. *Diagnostics* **2023**, *13*, 1800. https://doi.org/10.3390/diagnostics13101800.
31. Anil, S.; Porwal, P.; Porwal, A. Transforming Dental Caries Diagnosis Through Artificial Intelligence-Based Techniques. *Cureus* **2023**, *15*, e41694. https://doi.org/10.7759/cureus.41694.
32. Zheng, L.; Wang, H.; Mei, L.; et al. Artificial Intelligence in Digital Cariology: A New Tool for the Diagnosis of Deep Caries and Pulpitis Using Convolutional Neural Networks. *Ann. Transl. Med.* **2021**, *9*, 763. https://doi.org/10.21037/atm-21-119.
33. Kurt-Bayrakdar, S.; Bayrakdar, İ.Ş.; Yavuz, M.B.; et al. Detection of Periodontal Bone Loss Patterns and Furcation Defects from Panoramic Radiographs Using Deep Learning Algorithm: A Retrospective Study. *BMC Oral Health* **2024**, *24*, 155. https://doi.org/10.1186/s12903-024-03896-5.
34. Al-Khalifa, K.S.; Ahmed, W.M.; Azhari, A.A.; et al. The Use of Artificial Intelligence in Caries Detection: A Review. *Bioengineering* **2024**, *11*, 936. https://doi.org/10.3390/bioengineering11090936.
35. Ahmed, W.M.; Azhari, A.A.; Fawaz, K.A.; et al. Artificial Intelligence in the Detection and Classification of Dental Caries. *J. Prosthet. Dent.* **2025**, *133*, 1326–1332. https://doi.org/10.1016/j.prosdent.2023.07.013.
36. Justiawan; Wahjuningrum, D.A.; Hadi, R.P.; et al. Comparative Analysis of Color Matching System for Teeth Recognition Using Color Moment. *Med. Devices Evid. Res.* **2019**, *12*, 497–504. https://doi.org/10.2147/MDER.S224280.
37. Awdaljan, M.W.; Roque, J.C.; Choi, J.; et al. Introducing a Novel Approach to Dental Color Reproduction Using AI Technology. *J. Esthet. Restor. Dent.* **2024**, *36*, 1623–1637. https://doi.org/10.1111/jerd.13300.
38. Saleh, O.; Spies, B.C.; Brandenburg, L.S.; et al. Feasibility of Using Two Generative AI Models for Teeth Reconstruction. *J. Dent.* **2024**, *151*, 105410. https://doi.org/10.1016/j.jdent.2024.105410.
39. Mohammad, N.; Ahmad, R.; Kurniawan, A.; et al. Applications of Contemporary Artificial Intelligence Technology in Forensic Odontology as Primary Forensic Identifier: A Scoping Review. *Front. Artif. Intell.* **2022**, *5*, 1049584. https://doi.org/10.3389/frai.2022.1049584.

40. Khanagar, S.B.; Vishwanathaiah, S.; Naik, S.; et al. Application and Performance of Artificial Intelligence Technology in Forensic Odontology—A Systematic Review. *Leg. Med.* **2021**, *48*, 101826. https://doi.org/10.1016/j.legalmed.2020.101826.
41. Mullankandy, S.; Mukherjee, S.; Ingole, B.S. Applications of AI in Electronic Health Records, Challenges, and Mitigation Strategies. In Proceedings of the 2024 International Conference on Computer and Applications (ICCA), Cairo, Egypt, 17–19 December 2024; pp. 1–7. https://doi.org/10.1109/ICCA62237.2024.10927863.
42. Rahdar, M.; Esmaeili, H. Artificial Intelligence and Its Role in Electronic Patient Record. *Hosp. Pract. Res.* **2023**, *8*, 333–343. https://doi.org/10.30491/hpr.2024.454379.1424.
43. Claman, D.; Sezgin, E. Artificial Intelligence in Dental Education: Opportunities and Challenges of Large Language Models and Multimodal Foundation Models. *JMIR Med. Educ.* **2024**, *10*, e52346. https://doi.org/10.2196/52346.
44. Kavadella, A.; Dias da Silva, M.A.; Kaklamanos, E.G.; et al. Evaluation of ChatGPT's Real-Life Implementation in Undergraduate Dental Education: Mixed Methods Study. *JMIR Med. Educ.* **2024**, *10*, e51344. https://doi.org/10.2196/51344.
45. Semerci, Z.M.; Yardımcı, S. Empowering Modern Dentistry: The Impact of Artificial Intelligence on Patient Care and Clinical Decision Making. *Diagnostics* **2024**, *14*, 1260. https://doi.org/10.3390/diagnostics14121260.
46. Thorat, V.; Rao, P.; Joshi, N.; et al. Role of Artificial Intelligence (AI) in Patient Education and Communication in Dentistry. *Cureus* **2024**, *16*, e59799. https://doi.org/10.7759/cureus.59799.
47. Ghods, K.; Azizi, A.; Jafari, A.; et al. Application of Artificial Intelligence in Clinical Dentistry, a Comprehensive Review of Literature. *J. Dent.* **2023**, *24*, 356–371. https://doi.org/10.30476/dentjods.2023.96835.1969.
48. Boldt, J.; Schuster, M.; Krastl, G.; et al. Developing the Benchmark: Establishing a Gold Standard for the Evaluation of AI Caries Diagnostics. *J. Clin. Med.* **2024**, *13*, 3846. https://doi.org/10.3390/jcm13133846.
49. Yoon, K.; Jeong, H.-M.; Kim, J.-W.; et al. AI-Based Dental Caries and Tooth Number Detection in Intraoral Photos: Model Development and Performance Evaluation. *J. Dent.* **2024**, *141*, 104821. https://doi.org/10.1016/j.jdent.2023.104821.
50. Szabó, V.; Szabó, B.T.; Orhan, K.; et al. Validation of Artificial Intelligence Application for Dental Caries Diagnosis on Intraoral Bitewing and Periapical Radiographs. *J. Dent.* **2024**, *147*, 105105. https://doi.org/10.1016/j.jdent.2024.105105.
51. Sadegh-Zadeh, S.; Bagheri, M. Harnessing the Power of Clinical Data in Dentistry: Importance and Guidelines for Dentists in AI Modelling for Enhanced Patient Care. *Open J. Clin. Med. Images* **2024**, *4*, 1188.
52. Schwendicke, F.; Krois, J. Data Dentistry: How Data Are Changing Clinical Care and Research. *J. Dent. Res.* **2022**, *101*, 21–29. https://doi.org/10.1177/00220345211020265.
53. Tuygunov, N.; Samaranayake, L.; Khurshid, Z.; et al. The Transformative Role of Artificial Intelligence in Dentistry: A Comprehensive Overview Part 2: The Promise and Perils, and the International Dental Federation Communique. *Int. Dent. J.* **2025**, *75*, 397–404. https://doi.org/10.1016/j.identj.2025.02.006.
54. Ali, M.A. The Role of Artificial Intelligence in Modern Dentistry: Applications, Challenges, and Future Directions. *Future Dent. Res.* **2024**, *2*, 39–49. https://doi.org/10.57238/fdr.2024.152576.1012.
55. Schwendicke, F.; Samek, W.; Krois, J. Artificial Intelligence in Dentistry: Chances and Challenges. *J. Dent. Res.* **2020**, *99*, 769–774. https://doi.org/10.1177/0022034520915714.
56. Khera, R.; Simon, M.A.; Ross, J.S. Automation Bias and Assistive AI: Risk of Harm From AI-Driven Clinical Decision Support. *JAMA* **2023**, *330*, 2255–2257. https://doi.org/10.1001/jama.2023.22557.
57. Mehta, N.; Born, K.; Fine, B. How Artificial Intelligence Can Help Us 'Choose Wisely'. *Bioelectron. Med.* **2021**, *7*, 5. https://doi.org/10.1186/s42234-021-00066-8.
58. Komorowski, M.; Celi, L.A. Will Artificial Intelligence Contribute to Overuse in Healthcare? *Crit. Care Med.* **2017**, *45*, 912–913. https://doi.org/10.1097/ccm.0000000000002351.
59. Mahesh Batra, A.; Reche, A. A New Era of Dental Care: Harnessing Artificial Intelligence for Better Diagnosis and Treatment. *Cureus* **2023**, *15*, e49319. https://doi.org/10.7759/cureus.49319.