Keywords
Artificial intelligence; Oral healthcare; Dental imaging; Implant surgery; Oral diagnostics

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Received: 20.03.2026
Revised: 06.04.2026
Accepted: 22.04.2026
Doi:10.1922/ejprd.v34i1s.1371

Integrating Artificial Intelligence into Oral Healthcare: Advances in Surgery, Imaging, and Diagnostics

Abstract
Through assisting with diagnosis and imaging analysis, surgery planning, decision-making, and digital restoration processes, artificial intelligence (AI) is increasingly taking a significant role in oral care. This narrative review evaluates the impact of AI on oral health, especially focusing on advancements in dental imaging, oral diagnostics, and oral or implant surgical operations. Articles on published research, clinical trials, diagnostic accuracy, review articles, and experimental studies of AI models built using radiographs, cone-beam computed tomography (CBCT) imaging, intraoral photography, digital impressions, clinical data, and diagnostics were considered in this review. It was established that machine learning, deep learning, CNN, computer vision, and decision support tools have been used in detecting dental caries, periapical, PDCL, OMA, and anatomical markers. AI helped with CBCT image segmentation, mandibular canal localization, assessment of implant sites, and surgical guide planning and prediction. AI aided in creating digital impressions, CAD/CAM designs, evaluation of restorations, and material choices in prosthodontics and restoration operations. The most reported metrics for performance were accuracy, sensitivity, specificity, area under the curve, precision, recall, F1-score, diagnostic concordance, and efficiency in time management. Overall, AI had proven effective in improving diagnostics, analysing imaging, surgical operations, and clinical processes. However, it required thorough validation, monitoring, clinician supervision, and proper management to ensure patient safety.

1. Introduction

In recent years, artificial intelligence (AI) has become a significant technological breakthrough in contemporary dental practice, providing new opportunities for diagnostic, treatment planning, clinical decision making and workflow optimization processes. AI in oral health typically involves AI technologies such as machine learning, deep learning, artificial neural networks, computer vision, and systems for supporting decisions with data. These technologies are intended to process complex clinical and imaging information, identify patterns and support clinicians in their decision-making process to make more accurate and efficient decisions. The potential of bringing AI techniques in various domains of dentistry has been reported by a systematic review conducted by Ahmed et al. [1] who found that AI techniques have been widely used in the field of dentistry for diagnosis, prediction, classification, and support for treatment, with the belief that these technologies could enhance both clinical and research outcomes.

With the growing trend of dental practices relying on digital records, radiographic imaging, intraoral scanning, CAD/CAM systems, and electronic patient information, the impact of AI on dentistry has grown significantly. These digital tools generate vast amounts of information which can be analysed and interpreted by AI algorithms, aiding clinical interpretation and treatment planning. Ding et al. discussed that AI was

becoming an integral part of dentistry, which includes imaging, diagnosis, prosthodontics, restorative dentistry, orthodontics, periodontics, oral surgery, and dental materials research [2]. AI systems have also been explored in clinical dentistry for their capacity to provide improved diagnostic accuracy, consistency, and evidence-based decision-making [3].

The conventional, diagnostic, and treatment-planning methods used in dental practice serve as the basis for the necessity of integrating AI technology into oral health care. Traditional dental diagnostics rely on the experience of the dentist, image quality, interpretation, and subjective opinion. There may be variations in the opinions of practitioners, especially when dealing with complex cases or early diagnosis. AI-enabled systems might solve these problems by offering automatic image processing, objective evaluation, risk assessment, and decision-making. According to the results of a scoping review of the existing literature done by Vashisht et al., novel applications of AI in dentistry include disease identification, radiographic interpretations, patient management, and improving clinical workflows [4].

The application of AI in dental practice is now a hot topic in recent years; however, it is not a novel concept. In previous literature, the revolutionary potential of AI in the dental practice was discussed in terms of diagnostics, digital workflow optimization, and the achievement of predictable results in treatment outcomes. As pointed out by Alexander et al., AI could potentially transform the future of dental practice in various ways, such as clinical decision-making and automation in dental care procedures [5]. Over the past few years, the clinical significance and technological advancements of AI in dentistry have evolved.

AI has demonstrated great promise in the field of endodontics. The models based on AI can help with the detection of periapical lesions, root canal morphology, working length estimation, treatment difficulty prediction and diagnosis of endodontic disease. Aminoshariae et al. mentioned that AI can be practically used in endodontics as a tool for image interpretation, diagnosis, prediction of treatment outcome and treatment planning, and has great potential for future applications [6]. Applications can assist clinicians in making more accurate and consistent endodontic decisions, particularly in the more complicated cases in which there are anatomical complexities.

AI's impact is not limited to endodontics, as it can be applied to various other oral health fields. Nguyen et al. outlined the current trends and advancement in the use of AI in various dental practice fields, particularly in diagnosis, radiology, orthodontics, prosthodontics, oral surgery, and patient-centred care [7]. With regard to the expansion of these technologies, it is believed that AI has much wider use in addition to the particular discipline. The integration of AI into dentistry will allow us to improve effectiveness, reduce repetition and contribute to decision making while keeping the value of the professional's opinion intact.

Among other possible areas where AI can be effectively applied, its contribution to the processes of diagnosis and treatment planning should be mentioned. In turn, the above-mentioned processes can be done using such types of pictures as radiographs, panoramics, cone-beam computed tomography (CBCT) images, cephalometrics, and intraoral photos. As for the application of AI in these pictures, it may assist in diagnosing dental caries, perapical conditions, periodontal bone loss, tooth impaction, cysts and tumors, fractures, and even landmarks. Heo et al. noted that AI was great potential for the area of oral and maxillofacial radiology with regards to picture classification, detection, segmentation, and diagnostic assistance [8].

AI can also be useful in the diagnosis and prognosis of oral cancers. Survival and treatment outcomes are better if oral cancer and potentially malignant oral conditions can be detected early. Predicting outcomes of oral cavity cancer, evaluating its prognosis and assisting with clinical decision making have been the fields of application of machine learning models. Adeoye et al. analysed machine learning prediction models of oral cavity cancer outcomes and emphasised the relevance of AI-based prediction models in risk stratification and outcomes assessment [9]. These tools can help facilitate early referral, risk stratification and personalized management but would need to be carefully validated for routine clinical use.

AI diagnostic software is not only used for specific diseases but is also being created to assist with overall dental diagnosis and assessment. De Angelis et al. assessed the diagnostic software for AI in dentistry and discussed its potential use for assisting with diagnosis in clinical practice [10]. Such systems can be used to help standardise interpretation, decrease human error and increase the speed of clinical evaluation. But although promising, AI should be seen as a tool to assist, not replace, dental practitioners.

It therefore means that this review will focus on evaluating the extent to which there have been efforts towards integrating AI applications within oral care, especially concerning surgeries, imaging, and diagnosis. It is all about using AI technology for detecting diseases, analysing radiography, surgery, restoration work, and decision-making processes. The topic under consideration will also highlight the limitations, ethical issues, and possible future directions towards adopting this technology within the dental industry. Based on this hypothesis, the main assumption is that through proper validation and collaboration, there are great chances of improving diagnosis processes and decision making.

2. Materials and Methods

2.1 Study Design

This study aimed to investigate the incorporation of AI in the field of oral health care with a particular focus on dental imaging, oral diagnostics and oral surgery and implantology. The choice of a review-based approach was made due to the wide range of AI technologies, clinical applications and study designs in the field of dentistry. The review was concentrated on machine

learning, deep learning, convolutional neural network, computer vision or artificial intelligence (AI) aided decision making systems applied in the fields of prosthodontics, restorative dentistry, implantology, endodontics, periodontics, oral surgery, and dental radiology.

2.2 Data Sources and Study Population

The data that were collected were from the previously published research articles related to oral healthcare, clinical studies, diagnostic accuracy studies, review papers, and experimental studies on the development of AI models. The following types of clinical or radiographic data were included in reviewed studies: dental radiographs, panoramic images, cone-beam computed tomography scans, intraoral photographs, digital impressions, patient records and clinical diagnostic datasets. Studies in populations of adult or pediatric dental patients were included when AI was used to diagnose, interpret an image, plan treatment, predict risk, and/or evaluate surgery.

Studies were selected if they related AI, machine learning, deep learning or computer vision to dentistry, and an outcome measurement was provided including accuracy, sensitivity, specificity, area under the curve, precision, recall, or F1 score. Studies that did not report relevant clinical or technical outcomes, lacked clear methodology, and/or had poor quality datasets, did not describe the AI system adequately, or were not related to dentistry were excluded.

2.3 AI System or Model Description

The reviewed studies applied various AI systems such as machine learning algorithms, deep learning models, convolutional neural networks, computer vision tools, artificial neural networks, and natural language processing systems. The most common applications of deep learning and CNN were on image-based diagnosis, including caries detection, periapical lesion identification, assessment of periodontal bone loss, CBCT segmentation, and recognition of anatomical landmarks.

Most of the studies used split datasets to test the performance of the models which were split between training, validation and testing datasets. Dental images and clinical records were usually labelled by experienced clinicians or specialists. Typical image pre-processing techniques included image resizing, image normalization, image segmentation, image contrast enhancement, noise reduction and data augmentation. Overall, the performance of the models was assessed in comparison to expert labelled standards or clinician evaluation.

2.4 Clinical Application Areas

2.4.1 AI in Dental Imaging

The applications of AI in dental imaging were examined with respect to intraoral radiographs, panoramic radiographs, cephalometric images, three-dimensional cone beam computed tomography (CBCT) scans, and intraoral photographs. The systems were primarily used to diagnosis dental caries, periapical lesions, periodontal bone loss, root fractures, impacted teeth, cysts, tumors and anatomical landmarks. AI proved to be highly beneficial, especially in the segmentation of teeth, alveolar bone, mandibular canal, maxillary sinus, and pathological structures in CBCT imaging. The following applications can be used for diagnosis, implant planning, endodontic evaluation, orthodontic assessment, and surgical risk assessment.

2.4.2 AI in Oral Diagnostics

The role of AI in oral diagnostics was evaluated for caries detection, periodontal disease classification, endodontic diagnosis, evaluation of oral mucosal lesions and oral cancer screening. AI systems, which use images, were evaluated for their capacity to detect suspicious lesions, disease severity, differentiate between benign and potentially malignant lesions, and assist with early referral decisions. AI was used in periodontal and endodontics for evaluating bone loss, disease progression, periapical pathology, the root canal morphology, and the complexity of the treatment. The tools were regarded as supportive aids for diagnosis and clinical decision making which were more consistent.

2.4.3 AI in Oral and Implant Surgery

AI algorithms and applications in oral and implant surgery were discussed regarding to implant site assessment, anatomical risk identification, surgical guide planning, and prediction of complications. The bone quality and quantity, the localization of the mandibular canal, the evaluation of the distance between the maxilla and the sinus and aiding safe implant placement were assessed using AI-assisted systems. In the field of robotic-assisted surgery, dynamic navigation, and predicting complications like nerve damage, peri-implant issues, slow healing and implant failure, AI demonstrated promise.

2.5 Outcome Measures

The main outcome measures evaluated in this review were the diagnostic accuracy, sensitivity, specificity, area under the receiver operating characteristic curve, precision, recall, F1 score, and agreement between AI outputs and expert diagnosis. These were applied to assess the performance of AI-based systems in diagnosing diseases, identifying abnormalities, categorising clinical conditions and aiding diagnosis.

The secondary outcomes measured included time taken to diagnose or plan treatment, interobserver agreement, consistency of clinical decision making, decrease in the number of diagnostic errors, and patient safety. The clinical value of AI as a decision-support tool in various clinical workflows including prosthodontic, restorative, surgical, diagnostic, endodontic and periodontal care was also considered.

2.6 Statistical Analysis

This was a review study and therefore no new statistical analysis of patient level data was undertaken. However, the results of the statistics reported in the studies included have been summarized in a narrative form. Where available, reported values for accuracy, sensitivity, specificity, AUC, precision, recall, F1 score, confidence intervals and interobserver reliability were

extracted. Studies that compared the performance of AI with clinician assessment compared the two by diagnostic agreement and p values reported by the original authors, with $p < 0.05$ deemed statistically significant.

2.7 Ethical Considerations

This is a review of literature published previously, it did not require the recruitment of new patients, new data collection nor clinical intervention, so ethical approval was not a requirement. But ethical aspects on AI in oral health care were considered, such as privacy and anonymization of clinical data, protection of privacy of clinical data, algorithmic bias, transparency and professional accountability.

AI should not replace clinical expertise but be employed as a supporting tool. Diagnosis and therapy should be left to competent dental personnel based on the final diagnosis with due consideration of patient safety, informed consent, confidentiality and responsible clinical implementation.

3. Results

3.1 Characteristics of the Reviewed Studies

The literature reviewed showed that AI has been applied in the various fields of oral health including dental imaging, oral diagnostics, and oral and implant surgery. The majority of the studies in the present review were based on radiographic images, cone-beam computed tomography (CBCT) scans, intraoral photographs, digital impressions, clinical records or diagnostic datasets. Most of the applications used AI had most of them based on machine learning, deep learning, convolutional neural networks, artificial neural networks, and computer vision systems, fitting in with the methodological focus of this review.

The studies were all different types of studies such as diagnostic accuracy studies, studies about the development of AI models, clinical investigations, reviews-based studies. Most of the AI models were tested with datasets that were annotated by experts or reference standards established by clinicians. The typical results reported were accuracy, sensitivity, specificity, area under the curve, precision, recall, F1 score, and agreement between AI-generated results and expert diagnosis. The summary of the general characteristic of the reviewed studies can be seen in Table 1.

Table 1. General characteristics of reviewed studies on artificial intelligence in oral healthcare

Study category	Data source/modality	AI approach	Dental application	Outcome measures
Diagnostic accuracy studies	Radiographs, CBCT, intraoral images	CNN, deep learning	Caries, periodontal bone loss, oral lesions	Accuracy, sensitivity, specificity, AUC
AI model development studies	Expert-labelled datasets	Machine learning, neural networks	Disease classification, segmentation	Precision, recall, F1 score
Clinical investigations	Patient records, images, digital impressions	Decision-support systems	Diagnosis, treatment planning	Diagnostic agreement, time efficiency
Review-based studies	Published literature	Mixed AI methods	Imaging, diagnostics, surgery, restorative dentistry	Narrative synthesis

3.2 Results of AI in Dental Imaging

In the field of dental imaging, AI demonstrated promising applications in detecting and interpreting prevalent oral and maxillofacial diseases. AI systems were often applied in intraoral and panoramic radiographs for identification of dental caries, periapical lesions, periodontal bone loss, impacted teeth, root fractures, cystic lesions, tumors and anatomical landmarks. These systems have shown some benefit in supporting the radiographer's interpretation and in minimising the variation between clinicians.

AI proved beneficial in the segmentation of teeth, alveolar bone, mandibular canal, maxillary sinus and pathological structures when used in cone-beam computed tomography imaging. The results indicate that AI could help the clinician with more complex interpretation of 3D images, particularly in implant planning, endodontic assessment, orthodontic assessment, and surgical risk evaluation. In summary, AI-powered imaging solutions contributed to more accurate, uniform, and timely image evaluations. The major AI applications in dental and maxillofacial imaging are presented in Table 2.

Table 2. Summary of AI applications in dental and maxillofacial imaging

Imaging modality	AI application	Detected/segmented features	Clinical relevance
Intraoral radiographs	Disease detection	Caries, periapical lesions, periodontal bone loss	Early diagnosis and routine screening
Panoramic radiographs	Detection/classification	Impacted teeth, bone loss, cysts, tumors	Broad diagnostic assessment

CBCT	Segmentation and anatomical mapping	Teeth, alveolar bone, mandibular canal, maxillary sinus	Implant planning and surgical risk reduction
Intraoral photographs	Lesion recognition	Oral mucosal lesions, suspicious lesions	Screening and referral support
Cephalometric images	Landmark identification	Craniofacial landmarks	Orthodontic and surgical planning

3.3 Results of AI in Oral Diagnostics

The studies reviewed demonstrated the relevant use of AI in oral health diagnosis. The use of AI systems was prevalent across various clinical scenarios, such as caries detection, periodontal disease assessment, endodontics diagnosis, oral mucosal lesion evaluation, and oral cancer screening. The image-based AI tools detected suspicious lesions, severity classification, and even were able to help differentiate between benign and potentially malignant lesions. Table 3 illustrates the clinical uses and results of using AI in oral diagnostics and implant surgery.

Table 3. Clinical applications and outcomes of AI in oral diagnostics and implant surgery

Clinical area	AI-supported task	Main outcome	Clinical benefit
Caries diagnosis	Image-based detection	Improved lesion identification	Early intervention
Periodontology	Bone-loss assessment and disease classification	Better diagnostic consistency	Reduced subjectivity
Endodontics	Periapical lesion and canal morphology detection	Improved treatment assessment	Better planning of complex cases
Oral cancer screening	Mucosal image analysis	Identification of suspicious lesions	Early referral support
Implant surgery	Bone and anatomical risk assessment	Safer implant positioning	Reduced surgical complications
Oral surgery	Surgical guide planning and risk prediction	Improved preoperative planning	Personalized treatment planning

AI was used for the diagnosis of periodontal disease, including the evaluation of alveolar bone loss, the classification of the severity of the disease, and the prediction of disease progression. In endodontics, AI systems aided in the diagnosis of periapical lesions, identification of root canal morphology, treatment planning complexity, and assessment of complex root canals. In endodontics, AI systems were used in diagnosis of periapical lesions and identification of root canal morphology, treatment planning complexity and complex root canals. Overall, the findings indicate that AI has the potential to enhance diagnostic uniformity and provide a valuable decision-making aid, especially in conjunction with the experience of a clinician.

3.4 Results of AI in Oral and Implant Surgery

The most common applications of AI in oral and implant surgeries included treatment planning, evaluation of implant sites, assessing potential risks in the oral cavity, and predicting surgery complications. For bone quality and quantity, proximity to the maxilla sinus, location of the mandibular canal and assisting safe implant placement, AI assisted tools proved to be useful.

The study has also demonstrated evidence of AI tools supporting surgical guide planning, dynamic navigation and surgical workflows in robotic surgeries. Furthermore, AI predictive models showed promise in risk prediction for complications like nerve injury, peri-implant complications, delayed healing, and implant failure. The results suggest that AI could enhance the accuracy of surgical procedures, minimize complications, and aid in personalized treatment planning for procedures involving implants and oral surgery.

3.5 Diagnostic and Predictive Performance Outcomes

In the examined studies, the ability of AI was primarily evaluated by measuring the diagnostic accuracy, sensitivity, specificity, area under the receiver operating characteristic curve, precision, recall, F1 score, and agreement with the expert diagnosis. Overall, the performance of AI models in the diagnosis and prediction of caries, lesion identification, assessment of periodontal bone loss, and segmentation of CBCT images was promising.

AI systems demonstrated potential to decrease the time to diagnosis and enhance uniformity in clinical interpretation as well. Research validation studies found that AI can aid clinicians in a variety of ways, such as quickly analysing preliminary data, identifying areas of concern, and enhancing diagnostic accuracy. The performance was however different based on the dataset's quality, imaging modality, accuracy with which the datasets are annotated, the model design, and the method they are validated. There are several key performance indicators that are commonly used for the diagnosis and prediction of AI systems, as summarized in Figure 1.

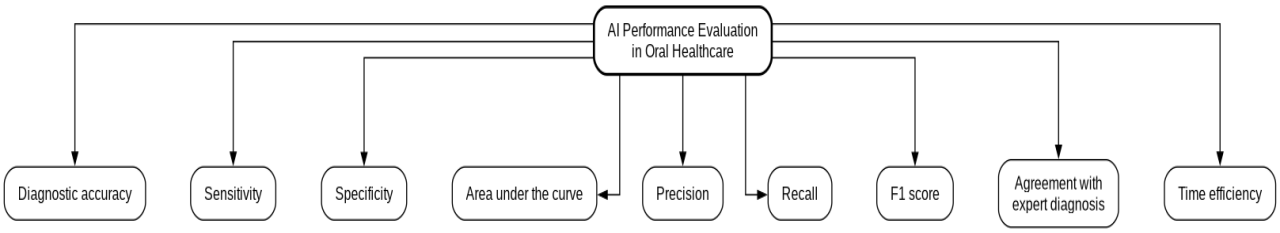

Figure 1. Performance evaluation framework for artificial intelligence systems in oral healthcare

3.6 Clinical Utility of AI in Oral Healthcare

The reviewed results indicate that AI has potential practical applications as an assistive device in oral health care. Additionally, AI can help automate the interpretation of radiographic findings, potentially leading to faster diagnosis and more accurate identification of subtle changes in dental imaging. AI can help with the early identification of disease in diagnostics and better consistency in diagnosing oral conditions. AI can enhance the precision of pre-surgical planning, anatomical evaluation, and risk assessment in oral and implant surgeries.

AI was also identified to be pertinent to prosthodontic and restorative workflows, including digital impressions, CAD/CAM-based design, treatment planning, assessment of the restorations, and decision making on materials. While AI shows great promise, it is best suited as a clinical decision support tool, rather than a standalone diagnostic or treatment planning tool. The AI-assisted diagnostic and treatment planning process for the clinician is shown in Figure 2.

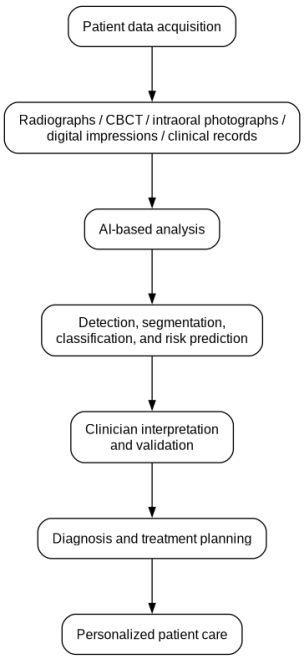

Figure 2. AI-assisted workflow for diagnosis, treatment planning, and clinical decision support in oral healthcare

The literature reviewed is consistent with the evolving importance of AI in oral health care. In the dental field, AI showed significant promise in areas such as dental imaging, oral diagnostics, surgical planning, and clinical decision-making, all of which can greatly benefit dental care. In the dental domain, AI's potential is evident in various applications like dental imaging, oral diagnostics, surgical planning, and clinical decision-making, which can all make substantial contributions to dental care. But the findings reveal that AI's implementation must be done judiciously, with proper validation, ethical application, clinician oversight, and patient safety precautions.

4. Discussion

From the results obtained through this review, artificial intelligence is becoming one of the enabling technologies in oral healthcare, particularly in dental imaging, oral diagnostics, and oral and implant surgery. AI systems have shown their ability to identify dental caries, periapical lesions, periodontal bone loss, oral mucosal pathology, and anatomy from both radiographic and clinical images. Dentists apply AI in dental diagnostics to help them in the identification of dental and maxillofacial diseases from the analysis of CBCT images, thereby saving time during diagnosis.

Artificial intelligence has been successfully applied clinically in dental diagnostics, assisting dentists in the identification of diseases and maxillofacial conditions from CBCT images in addition to improving the efficiency of imaging [11]. Moreover, AI-enabled caries diagnosis has been found to increase diagnostic accuracy and guide clinical decision-making in avoidance and restorative dentistry [13]. The findings show that the application of AI can improve the uniformity of diagnoses, reduce interpretation times and enable physicians to make better and personalized clinical decisions.

In avoidance and restorative dentistry, artificial intelligence is also important since digital workflows, imaging and treatment planning are becoming part of routine clinical procedures. AI technologies can help in caries detection, failure of restoration evaluation, planning of prosthetics, smile design, material selection, as well as prediction of treatment outcomes [13]. Additionally, deep learning technologies are proving to show great potential when it comes to oral diagnostics where detection and classification of cancerous lesions in the mouth are involved [14]. In terms of clinical significance, early detection of oral disease could contribute to good prognosis, timely treatment, and effective treatment plans.

The findings of this review align with the findings of recent systematic reviews that found good performance in radiographic detection of caries lesions and other oral pathologies when AI is used. There have been reports of the use of AI in radiographic systems to help detect carious lesions in various imaging modalities, but the results are dependent on the image quality,

characteristics of the data sets, accuracy of the annotations, and methods of validation [15]. Moreover, with the recent advances in CAD/CAM, AI has been increasingly used in the restorative workflows, such as in prosthesis design, occlusal analysis, fabrication of restorations and decision making related to materials [16]. The discovery underscores the growing significance of AI in medical care, going beyond diagnostics to treatment planning, digital manufacturing, and optimizing clinical workflows.

In prosthodontics and restorative dentistry, AI has a relevant application, since the treatment planning, precision and reproducibility are key points in these specialties. Restorative dental applications comprise of diagnosis of caries, detection of margins when preparing the tooth, restoration design, fracture identification and evaluation of failure of the restoration [17]. AI is also increasingly being used in the field of dentistry for various other applications, such as interpretation of dental X-rays, disease prediction, robotic assistance, digital impressions, clinical decision support, etc. [18]. AI should thus be considered as a multi-specialty tool, which can be used for various dental specialties such as prosthodontics, restorative dentistry, endodontics, periodontics, implantology, oral surgery and dental radiology.

AI has shown promise in various areas of oral and implant surgery, such as enhancing anatomical evaluations and preoperative planning. The automated segmentation tools of CBCT can be helpful in locating clinically important structures such as the mandibular incisive canal, which is important for implant placement, surgical planning and avoiding neurovascular complications [19]. These technologies could provide a more accurate depiction of the surgeon to assess bone quantity, bone quality, position of the mandibular canal, and proximity of the maxillary sinus. This means that AI-driven planning can help to improve the accuracy of implant placement, minimize surgical risks, and ensure more predictable results.

AI also plays a critical role in diagnosing oral mucosal diseases. Image-based AI has been tested for classifying cancerous lesions of the oral cavity against normal mucosa, which could help with early diagnosis and patient referral [20]. In periodontal disease, AI has proven to be helpful in assessing the amount of bone loss and the disease's severity, making interpretations of radiographic images more objective and consistent in periodontal diagnostics [21]. AI algorithms have also been utilized for caries and periapical periodontitis diagnosis to improve treatment planning for endodontic and restoration treatments [22]. Together, these findings show how AI can be a helpful tool for detecting disease early on and improving diagnostic confidence in various aspects of oral healthcare.

While there are many potentials, there are also several limitations. The use of small and single-centre datasets in many AI models can restrict the applicability of the created models to a broader population or/and different clinical environments. Variations in imaging equipment, image quality, disease prevalence, annotation methods, or diagnostic criteria may impact the performance of AI. While randomized clinical trials have indicated that AI has significant potentials in caries detection, additional validation in a clinical setting is required before wide-scale application [24]. Similarly, AI applications using CBCT have huge potentials, but they require substantial training sets, independent verification, and adequate clinical oversight [24].

Future research should be multi-centre, large-scale, and prospective, and AI applications should be validated on various populations, imaging modalities, and clinical environments. More attention should be paid to explaining AI, reporting the development and use of the model, standardizing datasets, and evaluating long-term clinical outcomes. While AI could serve as a helpful decision-making aid, it should not be used as a replacement for clinical skills but rather enhance them. AI can become a beneficial part of modern dentistry practice; however, with adequate validation, ethical concerns, and professional supervision, in imaging, diagnostics, prosthodontics, restorative dentistry, and surgical planning.

5. Conclusion

Overall, AI holds great promise for revolutionizing oral health care, with its ability to enhance diagnostic accuracy, imaging interpretation, treatment planning, and clinical decision making. The results of this review show that AI can be of great benefit in dental imaging, for instance, in the detection of caries, periapical lesions, periodontal bone loss, impacted teeth, oral lesions and anatomical structures. AI enhances workflows in CBCT by aiding in the segmentation of various clinically relevant structures, including teeth, alveolar bone, mandibular canal, and the maxillary sinus, which enhances implant planning and facilitates improved assessment of surgical risks. AI also aids in oral diagnosis with the support of early disease detection, periodontal classification, endodontic assessment and oral cancer screening. AI tools can be used in oral and implant surgery to enhance the accuracy of pre-surgical planning, anatomical analysis, creation of surgical guides, and identification and prediction of complications like nerve damage, implant problems, delayed healing, and implant failure. The review also emphasizes the potential of AI in prosthodontic and restorative dentistry, such as in digital impression taking, CAD/CAM, diagnostic assessment of the restoration, design of the prosthetic, and decision-making regarding materials. While there are benefits to AI, it should not replace dental care providers. It is most useful as a decision support tool to help with efficiency, consistency and patient specific care, and is best used in conjunction with clinical skills. Looking forward, external validation, multicentre studies, explainable AI, standardized data sets, ethical data use and responsibilities of the professionals should be considered for implementation. AI has the potential to be an asset in today's dental practice when used responsibly and under clinical supervision.

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