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STRENGTHENING HEALTH SECURITY THROUGH INTELLIGENT RISK DETECTION SYSTEMS IN PUBLIC HEALTHCARE SETTINGS

Abdullah*

***Corresponding Author: Abdullah**

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1. ABSTRACT

Background: Strengthening health security requires effective strategies for identifying and managing public health risks. As one of the most prevalent oral diseases globally, dental caries represents a significant burden on healthcare systems and serves as a key indicator of community health. The early detection of initial lesions is particularly critical to prevent disease progression and reduce treatment costs. However, conventional diagnostic methods, which rely on visual examination and radiography, are often limited by their subjectivity and time-consuming nature, reducing their effectiveness for large-scale screening in public healthcare settings. This challenge highlights the need for intelligent risk detection systems. Artificial intelligence (AI) offers a transformative solution, with the potential to shift disease diagnostics from a reactive to a proactive model, thereby enhancing population-wide health security. **Methods:** This review highlights how artificial intelligence is transforming the diagnostic process, using dentistry as a powerful example of its broader potential in public health. However, the study also identifies challenges and limitations, such as restricted sample sizes and variability in AI model architectures. Therefore, the findings suggest that further research is needed to validate and scale the application of AI in clinical settings. By enhancing diagnostic accuracy and efficiency, intelligent systems can serve as a vital component in strengthening health security and improving public health outcomes. **Results:** All included studies demonstrate that artificial intelligence models, particularly deep neural networks, achieve higher accuracy in diagnosing dental diseases from radiographic images. This finding is especially critical for the identification of proximal carious lesions, which are often missed during routine examinations. The results signify a major advancement in early disease detection capabilities, which is a cornerstone of effective health security systems. **Conclusions:** This review highlights how artificial intelligence is transforming the diagnostic process in dentistry. However, the study also reveals the problems and pitfalls of AI utilization, such as restricted sample sizes and potential differences in the architecture of AI models. Therefore, the findings suggest that more studies are needed to advance the application of AI in clinical settings, as it appears to enhance diagnostic accuracy and effectiveness.

KEYWORDS: Artificial intelligence, radiographic image analysis, proximal caries, diagnostic accuracy.

2. INTRODUCTION

Dental Caries is a prevalent and persistent disease that significantly impacts both individual health and healthcare systems.[1] Dental caries affects approximately three billion people in the world, which results in high financial costs and place a strain on healthcare.[2] Dental caries can lead to physical discomfort and distress, negatively impacting sleep, diet, social well-being, and self-esteem. These consequences, in turn, significantly impact overall quality of life.[3]

Early identification and management of dental caries preserve tooth structure and minimizing the need for recurrent and invasive interventions.[4] Conventional caries diagnosis techniques depend on visual inspection and radiography, which are subjective and susceptible to human errors.[5] This conventional diagnostic approach often fails to identify early lesions on surfaces that are difficult to assess, such as proximal surfaces.[2] Traditionally, bitewing radiographs are used to enhance the sensitivity of caries detection, especially in identifying cavities between teeth.[6]

The phrase "artificial intelligence" was first introduced in the 1950s to refer to the concept of creating computers that can performing tasks similar to those carried out by humans.[7] Basis of the data that is input, these machines are able to solve problems.[8] In medicine and dentistry, the advent of artificial intelligence has opened new horizons to improved diagnostic imaging, optimization of workflows, costs reduction, mitigation of manpower shortages, and fulfillment of goals set out by the World Health Organization for its Sustainable Development Goals.[7] AI applications are not a common sight in the dental field. However, advancement of these technologies has brought a positives changes in area such as robotic help, dental image diagnostic aid, caries identification, radiographic and pathological analysis as well as computerized record keeping.[9] Assessing proximal enamel caries is challenging and typically based on the clinician's knowledge that is derived from education and practice. Computer-aided image analysis systems that include the (AI) technology has been used in this case.[10]

In recent years, several studies applied deep learning algorithms together with convolutional neural networks (CNNs), for detection of caries on dental X-ray images.[11, 12, 13, 14, 15, 16, 17] Additionally, some studies have use the same deep learning (CNNs) to detect caries in images that obtained through near-infrared light transillumination research.[18,19]

Previous studies have documented several findings that demonstrate the ability of AI algorithms to be utilized with a significant degree of efficiency in the diagnosis and assessment of dental caries. Although, early models of computer analytic system for caries diagnosis which is known as the Logicon caries Detector was not useful in identifying carious lesions in the 1990s.[10] Recent pilot study has shown that the newly developed AI application, AssistDent, improved on the performance of third-year dental students by a significant margin in the diagnosis of proximal enamel-only caries in bitewings.[10] In addition, a study carried out by Lee et al. and published in 2021 explored the application of artificial intelligence in the detection of first dental caries lesions using dental images.[20] To summarize, the study showed promising results, especially for the early interventions. These results illustrate an increasing interest regarding the utilization of AI technology to enhance the identification and evaluation of caries.

This systematic review aims to give a broad-based analysis and discuss the state of current research into the use of machine intelligence algorithms in detecting proximal caries from dental images. The study conducts a thorough examination, evaluation, and synthesis of current research studies to assess the effectiveness, accuracy, and reliability of algorithms driven by AI in diagnosing proximal caries, as compared to traditional methods. The article aims to provide a literature review on the current and future applications of AI technology in improving the accuracy of detecting and diagnosing proximal caries in dentistry. In contrast to previous studies, this systematic review offers a detailed discussion on the developments in the application of AI for proximal caries diagnosis in the past decade, as well as an assessment of their strengths and shortcomings. While prior studies tend to emphasize only one set of diagnostic tools, our paper strictly compares AI-based methods with other diagnostic tools and demonstrates enhanced diagnostic performance. In addition, we coordinate ourselves with several areas of the existing literature that lack adequate information on how AI can be applied in clinical practice, thus creating a sound and comprehensive framework to evaluate its effectiveness when conducive to promoting reasonable approaches to dentistry and its integrated advancement.

3. MATERIALS AND METHODS

This systematic review was conducted in accordance with the guidelines established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Fig. 1) (Supplementary Material 1). Acquisition of clearance from an institutional review board was unnecessary due to the nature of the study.

3.1 zA PICO investigation question focuses

For the purpose of screening the qualified studies, the PICO question was defined as follows: "What is the current evidence on the effectiveness of artificial intelligence in radiographic image analysis for the detection of proximal dental caries?" 1-Population: patients receiving dental radiographic imaging for proximal caries; 2-Intervention: radiographic image analysis assisted by artificial intelligence 3-comparison: The artificial intelligence approaches versus radiographic image processing for proximal caries;4- Outcomes: Accuracy of proximal caries detection, reliability, and diagnostic efficiency.

3.2 search strategy

We searched for all of the articles that have been published in the past ten years that relate to artificial intelligence and dental proximal caries detection. These publications were found in PubMed, the Cochrane Library, Web of Science, and Google Scholar. The investigation included grey literature including conference proceedings and industry reports and organizational publications about dental AI technologies. According to the search technique (Supplementary material 1&2), all of the publications that were pertinent to the investigation were found.

3.3 .Criteria for eligibility

The following criteria must be met by studies in order for them to be considered for inclusion in the systematic review: a) Research articles that investigate the application of intelligence in the process of interpreting dental radiographic pictures; b) Clinical trials, observational studies, and comparative analyses that are related to this topic; c) Articles written in the English language. The decision to include only English-language articles was made primarily to manage the scope of the review and ensure the feasibility of thorough data extraction and synthesis within the available timeframe and resources. This limitation may have introduced publication bias, and future research could explore expanding the language scope to mitigate this; d) Recent research that have been carried out within the past ten years. The next criteria were used to exclude studies from consideration; a) articles that are not written in English; b) Studies that are not specifically relevant to radiographic imaging; and c) Studies that have been published for more than ten years.

3.4 Study Selection

The titles and abstracts of the relevant papers were reviewed by two reviewers, namely AG and RA, in order to decide whether or not they were eligible for consideration. Following that, the complete texts of all publications that had the potential to fulfill the requirements were retrieved and subjected to a comprehensive evaluation in order to ascertain which studies satisfied all of the criteria that were set for inclusion. Any disagreements found were resolved by discussion with a third reviewer (EA) and a final list of articles to be included in this review was compiled.

3.5 Data Extraction

For the synthesis presented in Table 1, we extracted data from each of the selected papers using the following variables: authors, year of publication, country where the study was conducted, journal or conference where the article was published, study design (e.g., RCT, cohort, cross-sectional), sample size, age range of participants, study setting (e.g., clinical, academic), algorithm architecture, imaging modality (e.g., panoramic radiographs, bitewing radiographs), statistical tests applied, specific intervention or technique evaluated, comparison group or method used, primary outcomes measured, key findings, and the authors' conclusions or suggestions for future research. The complete extraction process results in comprehensive data collection from each study which advances the quality level and enhances the reliability of our systematic review. We systematically arrange these variables to create detailed knowledge of all included studies which enhances the understanding of research activities within this field.

3.6 Risk of bias (quality) assessment.

All included reports underwent a systematic review using the critical appraisal skills program checklist, which evaluated the quality of each one. Regarding application and time, the tool is simple to use and has a satisfactory level of validity. The three authors independently evaluated the study’s quality. Any discrepancies between the two reviewing authors were discussed in order to resolve them, and the third author was brought in to resolve disputes when necessary.

3.7 .Analysis of the data

A meta-analysis was not possible since the data extraction revealed high heterogeneity among the studies. Rather than that, the data was organized into a table, and a descriptive summary was developed in order to communicate the characteristics of the research as well as the findings.

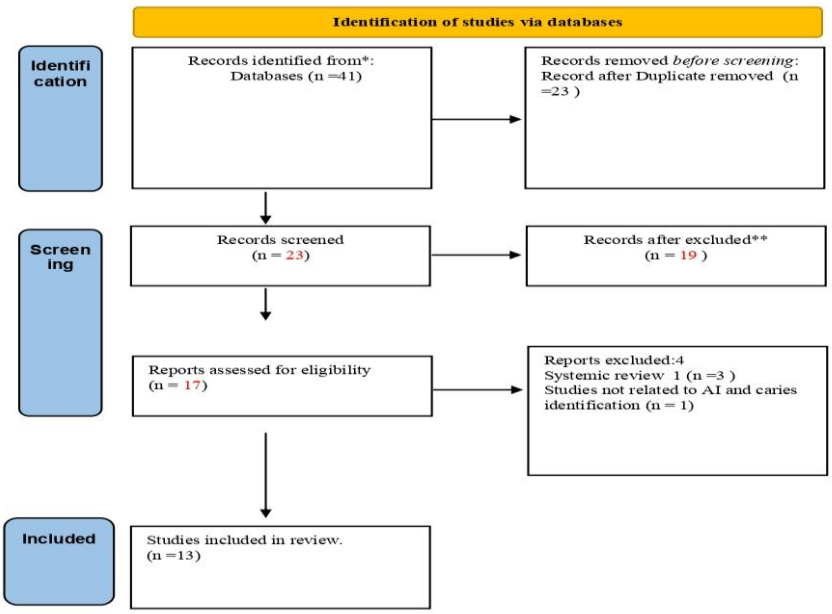

Fig.1.

Table.1: Data extraction table.

Authors	Year	Country	Journal or conference	Study Design	Sample Size	Age	Study Setting	Algorithm Architecture	Modality	Statistical Test	Intervention	Comparison	Outcome	Result	Authors Suggestions /Conclusions
Xiaotong Chen et al.(1)	2020	China	BMC Oral Health	Randomized Controlled Trial (RCT)	160 Radiographs	NA	Peking University School and Hospital of Stomatology in Beijing	Faster R-CNN	Bitewing Radiographs	McNemar's χ2 and McNemar Bowker tests ($p < 0.05$)	Deep Neural Network for detecting proximal carious lesions on bitewings	Comparing with assessments by dental postgraduate students	Evaluation of the Faster R-CNN model's efficacy in identifying proximal surface carious lesions	The Faster R-CNN model demonstrated superior accuracy(0.87), sensitivity(0.72), specificity(93), PPV (0.77), , NPV (0.91)and F1-score (0.74) relative to evaluations conducted by dentistry students. In contrast with students, accuracy, sensititvty , specificity, PPV , NPV and F1 score were 0.82 0.47 0.94 0.73 0.84 and 0.57	The research indicates the efficacy of convolutional neural networks, namely Faster R-CNN, in identifying interproximal caries on bitewing x-rays with elevated sensitivity and specificity, advising the verification of AI-generated diagnoses to prevent overtreatment.
Burak Dayı et al(21).	2023	Turkey	MDPI Diagnostic	Retrospective Study Design	504 Panoramic X-rays	14-80	Inonu University Faculty of Dentistry's Department of Oral and Maxillofacial Radiology	Dental Caries Detection Network (DCDNet)	Panoramic Radiographs	Comparison between proposed DCDNet network with other models	TensorFlow-Keras library in Python environment	NA	Effectiveness of DCDNet design in dental caries segmentation	The ResNet50-DCDNet architecture exhibited the superior performance in F1-score metrics(62,89), whereas the VGG16-DCDNet network recorded the lowest F1-score.	Future research should expand datasets, integrate clinical examination data, and address challenges like tooth superposition in panoramic radiographs for better AI-based caries detection systems.
Changgyun Kim et al.(22)	2022	Korea	JMIR Medical Informatics	Development Study Design	10,000 Panoramic Images	Various	NA	Fast R-CNN, ResNet, Inception Models	Panoramic Images	NA	Developing a model using artificial intelligence to detect tooth-related diseases in real time on panoramic images	Traditional diagnostic methods for tooth-related diseases	Precision in diagnosing five tooth pathologies utilizing the AI system	The Fast R-CNN model had an accuracy exceeding 90% in diagnosing five tooth-related diseases.	Future research could address class imbalance in the dataset, explore strategies like data augmentation or transfer learning, and expand AI models to predict overall oral health conditions for enhanced relevance.

Hugh Devlin et al.(4)	2021	England	British Dental Journal	Randomized Controlled Trial	23 Dentists	NA	University of Manchester Dental School, University of Manchester Foundation NHS Trust	AssistDent Enamel-only Proximal Caries Assessment	Bitewing Radiography	T-tests (p < 0.01)	AssistDent software for detection of enamel-only proximal caries	Comparing the ability of dentists with and without AssistDent	Enhancement in the identification of enamel-only proximal caries by AssistDent	AssistDent achieved a significant improvement in the mean true positive rate (75.8%) versus the control arm (44.3%), with a p-value < 0.01. Conversely, the true negative rate decreased from 96.3% to 85.4%. Odds ratios indicated a 71% increase in the detection of enamel-only proximal caries with AssistDent, while indicating an 11% decrease in the correct identification of healthy surfaces.	Improving sensitivity in identifying enamel-only inter-proximal caries is recommended through learning, audits, and AI-assisted detection methods.
Lars Schropp et al.(10)	2023	Denmark	European Journal of Dental Education		74 Dental Students	NA	Department of Dentistry and Oral Health, Aarhus University, Denmark	AssistDent®	Bitewing Radiographs	T-tests, paired t-tests	AI software (AssistDent®) for detecting dental caries	NA	Concordance between experimental and control groups for the detection of dental caries	Participants in the test-group showed significant growth in positive agreement between sessions 1 (mean 41.6, SD 16.5) and session 2 (mean 57.7, SD 21.6; p < .001)., while those in the control group maintained their positive agreement level. However, their negative agreement score improved significantly from session 1 (mean 86.0, SD 8.5) to session 2 (mean 89.4, SD 7.8; p < .001).	Refinement of AI caries diagnostic programs for accuracy, minimizing false positives, and user-friendly interfaces is recommended. Also, integrating AI training into dental curricula prepares students for future advancements and optimizes the use of AI in dental education and practice.

F. Schwendicke et al.(2)	2021	Germany	Journal of Dental Research	Retrospective Study Design	Randomized Controlled Trial	12 Years	German Dental Clinics	U-Net	Bitewing Radiographs	Markov Simulation Model	U-Net for caries detection	Standard method for caries detection	Cost-effectiveness assessment of U-Net for proximal caries identification	The AI system showed higher accuracy than dentists, with a sensitivity of 0.75 and specificity of 0.83. In the base-case scenario, AI led to tooth retention for a mean of 64 years and lower costs of 298 euros, compared to conventional assessments without AI, which resulted in tooth retention of 62 years and costs of 322 euros. The AI system's specificity was not significantly lower than dentists' at 0.91.	Prospective randomized studies should validate findings in real-world practice settings, assess the impact of AI on treatment decisions, and evaluate cost-effectiveness. Future research should explore dentists' acceptance of AI detections and their treatment decisions in affecting patient outcomes and healthcare costs.
Bingzhi Chen et al[23]	2024	China	The Thirty-Eighth AAAI Conference on Artificial Intelligence (AAAI-24)	Development and validation o	6,000 panoramic dental X-ray images with 13,783 annotated instances of dental caries.	18 to 45 45 to 80	NA	Faster R-CNN.	Panoramic dental X-rays	Average Precision (AP)	Development and application of the FPCL algorithm.	The FPCL algorithm was compared with various baseline object detection methods, including SSD, RetinaNet, DETR, EfficientDet, FCOS, YOLOv7, YOLOv8, YOLOX, and Conditional-DETR.	The FPCL algorithm demonstrated superior performance compared to baseline methods in detecting dental caries across various sizes and appearances, as measured by AP.	Experiments on CariesXrays demonstrate that FPCL significantly outperforms several state-of-the-art object detection methods in terms of average precision (AP), achieving a 7.7% improvement over top-performing CNN-based methods and a 6% improvement over transformer-based methods.	the FPCL framework offers improved accuracy and efficiency in detecting dental caries compared to existing methods. The creation of a large-scale, publicly available dataset (CariesXrays) is highlighted as a significant contribution to the field. They suggest future work could focus on expanding the approach to other oral health concerns and improving telemedicine applications.
Amr Ahmed Azhari et al[24]	2023	Saudi Arabia	Digital Health	Comparative effectiveness	771 bitewing radiographs	Adult and	King Abdulaziz	Ensemble U-Nets with	Bitewing radiographs	Intersection over Union	Development and	Various deep learning	The effectiveness	Adult Bitewings: For	Deep learning models can

				study evaluating deep learning models for caries detection	(554 adult, 217 pediatric)	pediatric	University Dental Hospital	ResNet50, ResNext101, and Vgg19 encoders		(IoU), F1-score	application of deep learning models for caries detection	models (U-Net with different encoders)	of the model to detection dental caries	zero, primary, moderate, and advanced caries, the model obtained IoU scores of 98%, 23%, 19%, and 51%, respectively. Pediatric Bitewings: For zero, primary, moderate, and advanced caries, the model obtained IoU scores of 97%, 8%, 17%, and 25%, respectively. Advanced caries detection: In both the adult and pediatric groups, advanced caries was shown to be more correctly diagnosed than primary caries ($p<0.05$).	accurately detect advanced caries; further research needed to improve early-stage caries detection and address class imbalance issues; integration with clinical practice guidelines is recommended.
Arman Haghanifar et al[25]	2020	Canada	arXiv preprint	Development	470 Panoramic X-ray images (240 labeled for classification)	NA	University of Saskatchewan	Ensemble transfer learning with a Capsule Network (CapsNet) classifier	Panoramic dental X-rays	Accuracy, Recall (for mild and severe caries), F0.5-score	Development and testing of PaXNet (proposed model)	Existing deep learning models for caries detection (implicitly mentioned in related work)	Caries detection in Panoramic X-ray images	86.05% accuracy on the test set; 69.44% recall for mild caries, 90.52% for severe caries; F0.5-score of 0.78	PaXNet demonstrates acceptable performance and improved speed; more robust model needed for mild caries detection; future work should focus on larger datasets and enhanced model architectures.
Shuaa S. Alharbi et al[26]	2023	Saudi Arabia	Applied Sciences	Comparative effectiveness study	1500 panoramic dental X-ray images	NA	Qassim University	U-Net, U-Net++, U-Net3+	Panoramic dental X-rays	IoU, Dice coefficient, Accuracy	Application of U-Net, U-Net++, and U-Net3+ to detect dental cavities	Different U-Net architectures	Caries detection accuracy	U-Net3+ achieved 95% accuracy in testing.	U-Net3+ outperforms other U-Net versions; future research should explore larger datasets and more sophisticated architectures to address challenges in image quality and annotation.

Ángel García-Cañasa et al[27]	2022	Spain	Caries research	Diagnostic accuracy study	300 bitewing radiographs	16-85 years (mean 43)	Private dental clinic	Deep Convolutional Neural Network (CNN) - Denti.Ai software	Bitewing radiographs	Accuracy(A), Sensitivity(S), Specificity(E), PPV, NPV, PLR, NLR, AUC	Use of Denti.Ai software for caries detection	Clinical-visual examination and instrumental cavity access (gold standard)	Diagnostic accuracy of detecting interproximal caries lesions	Model 2 showed best performance in differentiating between healthy and decayed teeth. Model 2: A=82%, S=69.8%, E=85.4%, PPV=57.2%, NPV=91%, PLR=4.78, NLR=0.35, AUC=0.777;	AI software provides good diagnostic reliability for detecting caries; model 2 (≥25% confidence threshold) performed best; limitations of the software regarding severity classification and dealing with image artifacts are noted; AI should be used as a tool to assist, not replace, clinicians.
Maneesha Das et al[28]	2024	India	Journal of Pharmacy and Bioallied Sciences	Randomized controlled trial (RCT)	200 patients (400 intraoral radiographs)	18-65 years	Multiple dental care settings	Deep learning algorithms (AI-based software)	bitewing and periapical)	Sensitivity, Specificity, Overall Accuracy	AI-based software vs. human interpretation	Diagnostic accuracy of dental caries detection by dentist interpretation	Sensitivity, specificity, and overall accuracy of AI software vs. human interpretation in detecting dental caries	AI software: Sensitivity 88%, Specificity 91%, Overall Accuracy 89%; Human Interpretation: Sensitivity 84%, Specificity 88%, Overall Accuracy 86%. AI software consistently met or exceeded predefined benchmarks.	AI-based software is a valuable tool for diagnosing dental caries from intraoral radiographs; performance comparable to or exceeding that of experienced human dentists; highlights AI's potential as an adjunctive diagnostic tool.
Javier Pérez de Frutos et al[29]	2024	Norway	BMC Oral Health	Evaluation study (using five-fold cross-validation)	13,887 bitewing x-rays (197 in consensus test set)	19-94 years (mean 51.8)	HUNT4 Oral Health Study on the prevalence of periodontitis in a Norwegian population	RetinaNet (ResNet50), YOLOv5 (M size), EfficientDet (D0 and D1)	Bitewing X-rays	Mean Average Precision (mAP), Mean F1-score (mF1), Mean False Negative Rate (mFNR)	Training and testing of three deep learning object detection models for caries detection	Performance of AI models vs. human dental clinicians (six annotators)	Accuracy of proximal caries detection in bitewing x-rays	YOLOv5 model showed largest improvement over human annotators: mAP = 0.647, mF1 = 0.548, mFNR = 0.149. Other models also outperformed annotators.	Deep learning models have potential to assist in caries diagnosis; further research needed to address challenges in image artifacts.

4. RESULT

The systematic review synthesized findings from studies focusing on the application of artificial intelligence (AI) in dental diagnosis. Studies investigated various AI models, including deep neural networks (DNNs) such as Faster R-CNN, DCDNet, and U-Net, across different dental imaging modalities to improve diagnostic accuracy and efficiency. The review included RCTs and retrospective studies. The interventions were AI algorithms for the detection of proximal carious lesions, tooth-related diseases, and enamel-only proximal caries, compared with traditional diagnostic methods or human expertise.

Most of the reviewed studies comparing the diagnostic performance of AI models against traditional methods or human experts showed the better overall performance of the AI models.[1,2] Faster R-CNN outperformed others in proximal carious lesion detection for accuracy, sensitivity, specificity, PPV, and F1-score compared to dental postgraduate students.[1] Equally, the DCDNet architecture was much better than all other models, with the best mean F1 score in segmenting dental caries.[22] AssistDent AI software significantly increased the sensitivity of the dental expert in detecting enamel-only proximal caries, though it reduced specificity.[4] No statistically significant difference in positive agreement was seen between the test and control groups regarding the detection of dental caries using artificial intelligence (AI) software by dental care students.[4] The clinical application of FPCL provided more precise results for diagnosing dental caries through 6,000 panoramic dental X-ray images yet Ensemble U-Nets proved best at identifying advanced caries from bitewing radiographs.[23,24] The detection model PaXNet provided 86.05% accurate outcomes and U-Net3+ delivered 95% precise results for both panoramic X-ray image evaluation and dental cavity detection.[25,26] The diagnostic accuracy rate achieved by Denti.Ai software reached 82% for the detection of interproximal caries lesions.[27] AI-based software developed by Maneesha Das et al (2024) recorded 88% sensitivity together with 91% specificity for dental caries detection.[28] Finally, YOLOv5 significantly improved accuracy in detecting proximal caries compared to human annotators.[29]

Based on the analysis of the findings, a consistent pattern toward improved results of diagnostic systems that are integrated with artificial intelligence compared to traditional models was identified.[1,2] Some limitations discovered from the studies included enrolled participants' small sample size, study design bias, and variations in the AI model architecture, and the training dataset. Furthermore, some issues associated with the generalizability and practical applicability of the developed AI systems in dental practice were recognized. The conclusions reinforce the possibilities of utilizing AI in the field of dental diagnosis and propound the opportunities for the enhancement of correct patient treatment. Nevertheless, more studies are needed to tackle the methodological issues and to provide a proper cross-validation of AI models to make them practical and integrated into the clinical practice. In other words, the systematic review focuses on the fact that the findings are highly consistent with the conclusion that the approach is indeed superior.

5. DISCUSSION

It has been ascertained that the use of AI when applied to dental diagnosis resulted in positive results in other studies. Erasing conventional detection from the diagnostic process and bringing in artificial intelligence models like Faster R-CNN and Fast R-CNN yields an enhanced level of accuracy at diagnosing such diseases. For instance, when using Faster R-CNN model, the sensitivity and specificity obtained in detecting proximal carious lesions were significantly higher than those obtained from dental students who have used them with little experience. As described by Burak Dayı et al. (2023) the Dental Caries Detection Network (DCDNet) using panoramic radiographs achieved higher performance than different models in the segmentation of caries for F1-score.[21] This is a clear indication that with the advancement in AI technology, an broad range of dental diseases can be diagnosed using artificial intelligence. The detection capabilities in real time that were presented in the study conducted by Changgyun Kim et al. (2022) reveal that it is feasible to include artificial intelligence in clinical practices as a tool that would help diagnose patients instantly.[22] The proposed algorithm of this research separately yielded more than 90% efficiency for identifying five different diseases associated with the teeth.[22]

The literature reviews that have been conducted in the past have suggested that artificial intelligence has the ability to enhance the diagnosis of images and, as such, the present review is in concurrence with the previous reviews. As for the second major category of techniques, our review is more targeted to the employment of AI in dental radiographs, where it was found that higher performance is achieved using models that include the Faster R-CNN and DCDNet.[1,21] However, our focus on specific studies that can be deemed as reliable indicates several strengths of AI application in dental diagnostics, such as AI for detecting caries progress and for diagnosing diseases on panoramic radiographs in real time. This is even though numerous medical fields have proven that AI provided positive results with solving numerous problems.

Based on the results of AI models, it can be claimed that the use of AI models in decision-making processes and dental care in particular will have a positive impact on the increase in the effectiveness of diagnosis and treatment. Thus, if AI tools are integrated into routine dental practice, this could enhance the early detection of dental diseases. This means that dentists would not have to perform many invasive procedures, as they would be treating diseases at their early stages. The AssistDent system is an artificial intelligence technology that has been shown to enhance dentists' ability to diagnose enamel-only proximal caries.[4] Consequently, AI has the potential to aid in preventative dentistry within general practice environments. At the same time, to prevent their overuse, it is essential to have the balance where the sensitivity is higher while the risk of false-positive results is low. Bingzhi Chen et al. (2024) demonstrated performance development and validation of a new algorithm FPCL through its application to 6,000 panoramic dental X-ray images.[23] The proposed algorithm showed better performance at detecting dental caries than other baseline methods with substantial average precision (AP) scores reaching.[23] The research by Amr Ahmed Azhari et al. (2023) demonstrated that ensemble U-Nets delivered top accuracy rates in advanced caries detection from bitewing radiographs while demanding future investigations to focus on early-stage caries screening and class imbalance management.[24] Researchers from Arman Haghanifar et al. (2020) developed PaXNet resulting in an 86.05% accuracy rate to detect caries in panoramic X-ray images.[25] The investigators reported the necessity for a better model dedicated to diagnosing mild caries.[25] Shuaa S. Alharbi et al. (2023) determined U-Net3+ as the best U-Net architecture because it achieved 95% accurate cavity detection.[26] Future work should analyze bigger datasets through advanced algorithms to tackle the problems associated with image quality and annotation according to the researchers.[26] The diagnostic accuracy of Denti.Ai software reached 82% when detecting interproximal caries lesions according to Ángel García-Cañasa et al. (2022).[27] The authors pointed out strength and functional limits which included the identification of severity grades as well as image artifact management thus supporting AI technology as a tool for assisting healthcare providers.[27] The study by Maneesha Das et al. (2024) proved that AI-based software surpassed human dental interpretations of caries diagnosis with sensitivity at 88% and specificity at 91%.[28] The data demonstrates that AI technologies have strong potential to function as diagnostic assistants in dental practices.[28] The research by Javier Pérez de Frutos et al. (2024) showed that YOLOv5 yielded better detection accuracy for proximal caries than human professionals.[29] Deep learning models show great potential for improving dental diagnostics because of their outcomes expressed in.[29]

One of the advantages of our scholarly review is the coverage of numerous artificial intelligence models and the use of artificial intelligence models in dentistry. However, there are some limitations, like variations in study design, sample size and type, and the AI algorithms used in studies. For instance, in the research carried out by Burak Dayı et al. (2023) and F. Schwendicke et al. (2020), the authors noted that there was a dearth of data balance, and there was a limited amount of datasets.[21,19] This is because diseases with a smaller sample size can affect the performance of AI models, which highlights the significance of having large and balanced datasets. Moreover, while the sensitiveness of the AI models has improved, the specificity is normally reduced, thus, leading to higher levels of false positives. The research by Lars Schropp and colleagues in 2023 shows that the integration of AI tools into everyday practice remains problematic.[10] In the study done by Agrawal P et al. (2022), it was found that there was no considerable difference in positive agreement between the students who used AI and those who did not use it prescribing the need to fine-tune AI tools and ensure that they are seamlessly integrated into clinical practice.[9]

A more rigorous focus should be placed on enhancing the models' sensitivity and specificity of artificial intelligence models. This should be achieved through the use of a larger assortment of datasets, data augmentation, and some form of training such as transfer learning. As for the future research, it was suggested that prospective randomized studies should be performed to establish these results in the clinical practice investigating the consequences of using AI in treatment choices, patients' outcomes, and health care.

6. CONCLUSION

This study highlighted AI as a potential method that could enhance the precision of dental caries diagnosis. While the available evidence generally supports the effectiveness of these models in carrying out this task, further research is required to determine their therapeutic usefulness and address any existing shortcomings. Additional progress and incorporation could establish AI as a transformative force in dentistry diagnostics and enhance patient care. These challenges would require additional improvement and investigation, focusing particularly on issues such as imbalanced data, false positive results, and the incorporation of clinical aspects. To fully harness the advantages of AI in dentistry, it is crucial to focus on refining AI models, validating their cost-effectiveness in real-world scenarios, and integrating AI training into dental education.

7. List of Abbreviations

AI: Artificial intelligence
CNNs: Convolutional neural networks
RCT: Randomized Controlled Trial
PPV: Positive Predictive Value
NPV: Negative Predictive Value
DCDNet: Dental Caries Detection Network
AP: Average Precision
IoU: Intersection over Union
SD: Standard Deviation
FPCL: Fast Proximal Caries Lesion

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