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ROLE OF AI IN PREDICTING CARDIOVASCULAR RISK USING ROUTINE DENTAL IMAGING: A SYSTEMATIC REVIEW

Systematic Review

Ramzan Ali[1]*, Zarina Naz[2]*, Shaikh Khalid Muhammad[3], Muhammad Zeeshan Ahmad[4], Muhammad Junaid Asif[5], Rimal Rashid[6].

[1]Lecturer, Department of Dental Technology, Khyber Medical University, Peshawar, Pakistan.

[2]MSN, MHPE Scholar, National University of Medical Sciences, Rawalpindi, Pakistan.

[3]MBBS, FCPS (Medicine), Professor of Medicine, CMC Teaching Hospital, Shaheed Mohtarma Benazir Bhutto Medical University, Larkana, Pakistan.

[4]Student, Department of Chemistry, Superior University, Lahore, Pakistan.

[5]Researcher, Artificial Intelligence Technology Centre (AITeC), National Centre for Physics (NCP), Islamabad, Pakistan.

[6]MBBS, MPH, Dow University Hospital, Karachi, Pakistan.

Corresponding Author: Ramzan Ali, Lecturer, Department of Dental Technology, Khyber Medical University, Peshawar, Pakistan, aaramzan.ali123@gmail.com

Zarina Naz, MSN, MHPE Scholar, National University of Medical Sciences, Rawalpindi, Pakistan, zarina_nazsalim@yahoo.com

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ABSTRACT

Background: Cardiovascular disease (CVD) remains the leading global cause of mortality, often progressing asymptomatically until advanced stages. Routine dental imaging, particularly panoramic radiographs, may incidentally capture vascular calcifications indicative of subclinical atherosclerosis. While artificial intelligence (AI) has shown potential in automating such detections, current evidence is fragmented, and no prior systematic review has synthesized its diagnostic value in this context.

Objective: This systematic review aimed to evaluate the accuracy and clinical utility of AI algorithms in identifying early cardiovascular risk indicators from routine dental radiographs in adult populations.

Methods: Following PRISMA guidelines, a systematic review was conducted using PubMed, Scopus, Web of Science, and the Cochrane Library to identify relevant studies published between 2019 and 2024. Eligible studies included cross-sectional and retrospective designs using AI models to detect cardiovascular risk markers via dental imaging. Data were extracted on study characteristics, AI model performance, and risk of bias, which was assessed using the Newcastle-Ottawa Scale. A narrative synthesis was conducted due to heterogeneity in model types and outcome measures.

Results: Eight studies comprising 788 to 3,200 participants were included. All employed deep learning-based AI algorithms, primarily convolutional neural networks, to detect markers such as carotid artery calcifications. Reported accuracies ranged from 82.5% to 95.3%, with AUC values up to 0.91. Most studies demonstrated moderate-to-high methodological quality. However, variability in model training and limited external validation restricted meta-analytic pooling.

Conclusion: AI algorithms show strong potential in identifying early cardiovascular risk using dental radiographs, offering a novel, non-invasive screening opportunity within dental care. Despite promising results, further prospective studies with standardized methodologies and external validation are essential to support clinical integration.

Keywords: Artificial Intelligence, Cardiovascular Risk, Dental Imaging, Panoramic Radiograph, Deep Learning, Systematic Review.

INTRODUCTION

Cardiovascular disease (CVD) remains the leading cause of morbidity and mortality worldwide, accounting for an estimated 17.9 million deaths annually, which represents 32% of all global deaths. Early detection and risk stratification are critical for timely intervention, yet many individuals remain undiagnosed until disease progression becomes symptomatic (1). Traditional cardiovascular screening tools, while valuable, often require specialized resources, infrastructure, and patient compliance with clinical visits, which may not always be feasible in general populations or low-resource settings (2). Consequently, there is increasing interest in leveraging routinely acquired health data from non-traditional sources for opportunistic screening. One such promising source is dental imaging, particularly panoramic and periapical radiographs, which are frequently performed during routine dental care (3). Dental radiographs can incidentally capture calcifications and changes in mandibular or carotid regions that may reflect early vascular pathology. These incidental findings have been correlated with subclinical atherosclerosis and may provide early indicators of cardiovascular risk. However, manual interpretation of such subtle markers requires trained specialists and is subject to interobserver variability (4,5). The integration of artificial intelligence (AI) offers a potential solution by automating the detection of radiographic signs linked to cardiovascular conditions with high consistency and efficiency. In recent years, AI-based algorithms—especially those utilizing deep learning and convolutional neural networks—have shown promise in medical image analysis, including identifying atherosclerotic changes, vascular calcifications, and mandibular bone density variations associated with systemic disease (6,7). However, despite the growing body of research, the clinical validity, reliability, and practical applicability of AI in analyzing dental images for cardiovascular risk prediction remain poorly defined. The literature is scattered, with studies varying widely in design, AI models used, sample size, and outcomes assessed. To date, no comprehensive synthesis of this evidence has been conducted to determine the true diagnostic and prognostic value of these systems in a clinical context (8,9).

The primary research question guiding this systematic review is: In adults undergoing routine dental imaging (Population), how accurately do artificial intelligence algorithms (Intervention), compared to traditional or no screening methods (Comparison), identify early signs or risk factors of cardiovascular disease (Outcome)? The objective is to systematically review and evaluate the diagnostic performance, accuracy metrics, and potential clinical utility of AI models trained on dental radiographs for cardiovascular risk assessment. This review will consider both observational studies and interventional studies that investigate AI-based cardiovascular risk detection using dental imaging, including cross-sectional, retrospective, and prospective designs. Only peer-reviewed articles published from 2019 to 2024 will be included to ensure relevance and reflect technological advances in AI. No geographical limitations will be imposed, enabling a global perspective on the issue. By synthesizing the current evidence base, this review aims to clarify the potential of AI as a transformative tool in preventive cardiology through dental practice. It will provide updated insights for clinicians, radiologists, and dental professionals on the viability of incorporating AI-assisted cardiovascular risk screening into dental workflows. The review will be conducted in accordance with PRISMA guidelines and the Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy to ensure methodological rigor and transparency.

METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological transparency and reproducibility. A comprehensive literature search was performed across four major electronic databases: PubMed, Scopus, Web of Science, and the Cochrane Library. The search strategy combined medical subject headings (MeSH) and free-text terms using Boolean operators. The keywords included combinations of “Artificial Intelligence” OR “AI” AND “Dental Imaging” OR “Panoramic Radiograph” OR “Dental Radiograph” AND “Cardiovascular Risk” OR “Atherosclerosis” OR “Carotid Artery Calcification.” The search was limited to human studies published in English from January 2019 to March 2024. Additionally, reference lists of selected articles were manually screened to identify any relevant studies not captured through database searches. Studies were included if they met the following eligibility criteria: (1) original peer-reviewed research articles; (2) observational studies, cross-sectional studies, retrospective cohort studies, and prospective diagnostic studies; (3) adult participants (≥18 years) undergoing routine dental imaging; (4) implementation of AI-based algorithms for the detection or prediction of cardiovascular risk indicators (e.g., vascular calcifications, mandibular bone changes); and (5) outcomes involving diagnostic accuracy, sensitivity, specificity, or predictive value for cardiovascular conditions. Studies were excluded if they were case reports, reviews, non-human or in vitro studies, conference abstracts, editorials, or articles not available in English. Studies focusing solely on dental disease without cardiovascular endpoints were also excluded (10,11). Two independent reviewers screened titles and abstracts using EndNote X9 for reference management. Full texts of potentially relevant studies were then retrieved and assessed against the inclusion criteria. Disagreements were resolved by consensus or by involving a third reviewer. The study selection process was documented using a PRISMA flow diagram to illustrate the number of records identified, screened, excluded, and included.

Data were extracted using a standardized data extraction form. Extracted variables included author name, publication year, study design, country of origin, population characteristics, type of dental imaging, AI model used, diagnostic outcomes, validation methods, and performance metrics such as accuracy, sensitivity, specificity, and area under the curve (AUC). The risk of bias in individual studies was assessed using the Newcastle-Ottawa Scale (NOS) for observational studies, evaluating three domains: selection of study groups, comparability, and outcome assessment (12,13). Each study was independently reviewed by two authors, and discrepancies were resolved through discussion. Items such as selection bias, performance bias, and reporting bias were specifically examined to determine study quality. Given the heterogeneity in AI models, study designs, and outcome measures, a narrative synthesis approach was employed. The review qualitatively synthesized findings across studies, focusing on the diagnostic performance of AI in identifying cardiovascular risk indicators on dental radiographs. Where possible, comparative insights into model types, imaging modalities, and population characteristics were highlighted to identify emerging trends and potential clinical applicability. The review synthesized data from eight eligible studies that met all inclusion criteria. These include recent advances in deep learning and convolutional neural networks applied to panoramic and periapical dental radiographs for the detection of carotid artery calcifications, mandibular cortical erosion, and other surrogate markers of cardiovascular risk. These studies varied in model architecture and population demographics but collectively offered insights into the diagnostic potential of AI in opportunistic screening during dental evaluations.

RESULTS

A total of 483 articles were identified through the initial database search, with an additional 12 studies obtained through manual screening of references. After removing duplicates, 426 articles remained for title and abstract screening. Of these, 68 full-text articles were assessed for eligibility. Following thorough evaluation based on the predefined inclusion and exclusion criteria, 8 studies were ultimately included in the final systematic review. The selection process adhered to PRISMA guidelines and is visually summarized using the PRISMA flow diagram, detailing records screened, excluded, and reasons for exclusion at each stage. The included studies comprised seven cross-sectional studies and one retrospective cohort study, published between 2020 and 2023. Sample sizes varied considerably, ranging from 134 to 3,200 participants, with the majority of populations consisting of adults undergoing routine dental panoramic radiographs. Across studies, AI models—primarily deep learning architectures including convolutional neural networks (CNNs)—were trained and validated to detect surrogate markers of cardiovascular risk, such as carotid artery calcifications, mandibular cortical erosion, and reduced bone density. Demographic information was reported in most studies, indicating a balanced representation of male and female participants aged 40 years and older, a group considered to be at higher risk for subclinical atherosclerosis. Risk of bias assessment using the Newcastle-Ottawa Scale revealed moderate to high methodological quality across the studies. Most studies demonstrated adequate selection of participants and appropriate ascertainment of exposure and outcomes.

However, several studies showed potential detection bias due to lack of blinding during outcome assessment and variable reporting of validation procedures. Reporting bias was minimal, though some articles lacked complete descriptions of exclusion criteria or failed to account for potential confounding variables. The primary outcomes across studies focused on the diagnostic accuracy of AI models in detecting early cardiovascular risk markers. Reported accuracies ranged from 82.5% to 95.3%, with sensitivities between 80% and 92% and specificities ranging from 78% to 94%. For instance, a study reported a CNN model with an AUC of 0.91 in identifying carotid artery calcifications from panoramic radiographs, while another demonstrated an AUC of 0.89 for predicting overall cardiovascular risk factors using similar imaging modalities (14,15). A study further validated their model on an external dataset, reporting consistent diagnostic performance (AUC = 0.87), indicating potential for generalizability (16). Statistical significance was confirmed in most studies, with p-values <0.05 and confidence intervals showing narrow ranges around effect estimates. Although heterogeneity in model types and outcome metrics precluded a meta-analysis, the consistency in high diagnostic performance across studies suggests a promising role for AI in non-invasive cardiovascular risk detection via dental imaging (17). These findings support further research into clinical translation and integration into dental practice workflows.

Table:1 Summary of Included Studies

Author (Year)	Study Design	Sample Size	Imaging Modality	AI Model Used	Primary Outcome
Yoon SJ (2020)	Cross-sectional	2,487	Panoramic Radiograph	CNN	Detection of carotid artery calcification
Kwon Y (2021)	Cross-sectional	1,122	Panoramic Radiograph	Deep CNN	Cardiovascular risk prediction
Kim J (2023)	Cross-sectional	1,004	Panoramic Radiograph	Deep learning ensemble	AI detection accuracy of vascular lesions
Alotaibi N (2023)	Systematic review base	3,200	Panoramic Radiograph	Multiple CNN models	Diagnostic value comparison
Bukhari S (2022)	Cross-sectional	984	Dental X-ray	Hybrid AI system	Predictive performance
Zhang J (2021)	Retrospective cohort	635	Dental Radiograph	CNN	Early vascular calcification detection
Park WJ (2022)	Cross-sectional	788	Panoramic Radiograph	Transfer learning-based CNN	CAD risk prediction model performance
Rahman MM (2023)	Cross-sectional	1,318	Panoramic Radiograph	Multi-layer neural network	Validation of predictive algorithm

DISCUSSION

This systematic review found that artificial intelligence algorithms applied to routine dental radiographs demonstrate strong potential for identifying early signs of cardiovascular risk. Across the eight included studies, AI models—particularly those based on deep learning architectures—consistently achieved high diagnostic accuracy, sensitivity, and specificity in detecting surrogate cardiovascular markers such as carotid artery calcifications and mandibular bone changes. Reported accuracies exceeded 82% in most cases, with some models achieving AUC values above 0.90, underscoring the robust diagnostic capability of these systems (17-20). Collectively, the strength of evidence supports the feasibility of integrating AI-driven analysis into dental workflows as an adjunct tool for opportunistic cardiovascular screening. These findings align well with previous studies that have explored the diagnostic utility of dental imaging in systemic disease detection. Earlier research demonstrated correlations between carotid artery calcifications visualized on panoramic radiographs and increased cardiovascular risk, but diagnostic accuracy relied heavily on subjective radiographic interpretation (21,22). The introduction of AI significantly enhances objectivity and standardization, mitigating the variability observed in manual assessment. Notably, the present review builds on the work of a study, who conducted a broader systematic review focused on the diagnostic value of dental radiographs but did not exclusively assess AI models. By focusing specifically on AI applications, the current review provides more targeted insights into algorithm performance and validation strategies (23,24). A major strength of this review lies in its methodological rigor, including a comprehensive search across four major databases and strict adherence to PRISMA guidelines. All included studies underwent independent quality assessment using the Newcastle-Ottawa Scale, with most demonstrating moderate to high quality. The review also focused on recent literature (2019–2024), ensuring that only the most up-to-date AI technologies and methodologies were considered. Additionally, the synthesis included diverse study populations and imaging modalities, contributing to the generalizability of findings across various clinical settings.

Nevertheless, several limitations warrant consideration. First, most included studies were cross-sectional, limiting conclusions regarding causality or long-term predictive value. Second, the sample sizes of several studies were modest, potentially reducing statistical power and increasing the risk of type II errors. Third, variability in AI models, training datasets, and validation protocols introduced

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heterogeneity, which precluded formal meta-analysis. Moreover, publication bias remains a concern, as studies with negative findings may be underreported, and the inclusion was limited to English-language publications, possibly excluding relevant international work. Finally, while internal validation was common, external validation using geographically or demographically distinct populations was limited, affecting the broader applicability of the models. Despite these limitations, the clinical and research implications of these findings are noteworthy. Incorporating AI analysis of dental radiographs into routine dental care could facilitate early cardiovascular risk identification, particularly in asymptomatic individuals who may not undergo regular medical screening. This offers a unique opportunity to bridge the gap between dental and medical practice, transforming dental clinics into strategic points for public health intervention. For future research, there is a need for larger prospective cohort studies, external validation of AI algorithms, and standardized reporting of AI model performance metrics. Investigating the integration of such tools into clinical decision-making workflows and their impact on patient outcomes would also be valuable.

CONCLUSION

This systematic review highlights the promising role of artificial intelligence in detecting early cardiovascular risk markers through routine dental radiographs, with multiple high-quality studies demonstrating consistently strong diagnostic performance across diverse populations and imaging modalities. The integration of AI, particularly deep learning algorithms, into dental settings offers a novel, non-invasive avenue for opportunistic cardiovascular screening, potentially enabling earlier intervention in asymptomatic individuals. While the evidence is encouraging, variability in study design and limited external validation underscore the need for further large-scale, prospective research to establish clinical applicability and generalizability. Nonetheless, the findings support the growing reliability of AI as an adjunct diagnostic tool, paving the way for more interconnected dental and medical care models focused on preventive health.

AUTHOR CONTRIBUTION

Author	Contribution
Ramzan Ali*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Zarina Naz*	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Shaikh Khalid Muhammad	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Zeeshan Ahmad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Junaid Asif	Designed the experiments, Analyzed the data Prepared the table & drafted the work
] Rimal Rashid	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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