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Diagnostic efficiency of digital photography and AI-assisted image interpretation in dental caries examination: An umbrella review

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ABSTRACT

Background: Dental caries, a prevalent oral health issue impacting all demographics globally, necessitates precise detection and evaluation for effective intervention and preventive strategies. Advances in scientific research and technology have facilitated the development of innovative applications that utilize Artificial Intelligence (AI) within the medical sciences. AI offers promising improvements in risk assessment and caries prediction. A comprehensive body of evidence assessing the diagnostic accuracy of AI for identifying Dental caries via digital intraoral photographs remains insufficient.

Aim and objectives: Thus, the aim is to consolidate evidence regarding the efficacy of photographic examination and subsequent image analysis, demonstrating that these methods offer comparable accuracy to traditional visual inspection in the diagnosis of Dental caries.

Methodology: Eight systematic reviews were obtained from Medline, Web of Science, Scopus, and EMBASE up to June 2024. These articles were screened at the title, abstract, and full-text levels, with the risk of bias evaluated using the Joanna Briggs Institute (JBI) assessment tool.

Results: AI-based dental caries detection from intraoral photographs showed sensitivities ranging from 67 % to 96 % and specificities from 75 % to 99.2 % with AUC values reported between 0.74 and 0.987 across modalities. The overall risk of bias was minimal.

Conclusion: Therefore, AI-assisted interpretation of digital photography can significantly aid in the early identification of Dental caries, thereby enhancing patient outcomes.

1. Introduction

Dental caries (DC) remains one of the most widespread chronic conditions worldwide, disproportionately affecting underserved communities and straining public health systems.[1] The unequal allocation of dental resources and practitioners further intensifies the challenges in accessing dental care.[2] Early identification of carious lesions, coupled with enhanced oral hygiene practices and preventive measures, can effectively halt the progression of lesions, shorten treatment times, and diminish related expenses.[3] Conventional diagnostic methods, largely dependent on visual and tactile inspection, are subjective and influenced by clinical expertise, thereby limiting consistency and reliability.[4] Digital intraoral photography has emerged as a promising alternative, offering high-resolution documentation, ease of image sharing, and potential for remote evaluation. By allowing standardized visualization of tooth surfaces, photographic methods can aid in early lesion detection and longitudinal monitoring.[5,6]

More recently, Artificial Intelligence (AI) algorithms have been integrated with digital photography to enhance diagnostic accuracy. Studies have shown the applicability and effectiveness of AI models in diverse dental fields, including Orthodontics, Restorative Dentistry, and Prosthodontics.[7–10]

Furthermore, AI-driven models for identifying Dental caries from images, whether taken with smartphones or traditional imaging devices,

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have been recognized as economically viable solutions.[11] These models frequently demonstrate enhanced accuracy in caries detection relative to trained professionals and significantly decrease the frequency of false-negative findings.[12,13] However, the deployment of AI technologies in the evaluation and treatment of Dental caries necessitates comprehensive validation to confirm their dependability and effectiveness in clinical settings.

Recent studies on diagnosing Dental caries through intraoral imaging, whether taken with mobile devices or conventional cameras, have yielded positive results when compared to standard visual-tactile clinical assessments.[14] A multitude of studies has examined the precision and diagnostic capabilities of this methodology, juxtaposing it with traditional clinical assessments.[15] Most of these studies provide narrative summaries without consolidating outcomes across multiple reviews. This lack of synthesis hampers the ability to judge diagnostic accuracy comprehensively. A more detailed understanding of the advantages and drawbacks of using digital photographs for caries detection can be gained by synthesizing the collective results from these investigations. In light of the increasing dependence on photographic techniques for caries diagnosis, this umbrella review aims to critically appraise and integrate evidence from existing systematic reviews on digital photography for caries detection. By consolidating available data, the review addresses a key knowledge gap and clarifies whether AI-assisted interpretation of digital intraoral images can serve as a dependable alternative or complement to conventional diagnostic methods.

2. Materials and methods

2.1. Review question

This comprehensive review was performed following PRISMA guidelines to address the subsequent research inquiry: "Is AI-assisted interpretation of digital intraoral images a reliable method for detecting Dental caries, and does it provide superior diagnostic efficacy compared with traditional clinical examination techniques?"

2.2. Inclusion criteria

The criteria for eligibility were established based on the following PICOS framework:

- **(P) Population:** Patients of any age undergoing diagnostic evaluation for Dental caries.
- **(I) Intervention:** Digital imaging modalities such as intraoral photographs, including those enhanced with AI algorithms.
- **(C) Comparison:** Conventional diagnostic standards (visual-tactile inspection or radiographs)
- **(O) Outcomes:** Diagnostic accuracy, sensitivity, specificity, and Area Under Curve (AUC).
- **(S) Study design:** Systematic reviews published up to June 2024, which followed PRISMA guidelines and incorporated observational or diagnostic accuracy studies, were deemed eligible.

2.3. Exclusion criteria

- Narrative or scoping reviews, case reports, case series, and RCT-only reviews.
- Ex vivo or laboratory-based imaging studies without human subjects.
- Reviews without explicit methodology or without diagnostic accuracy outcomes.

2.4. Type of the study

This umbrella review encompassed systematic reviews of observational studies that analyzed the diagnostic accuracy of digital photographs in contrast to conventional clinical assessments for the identification of Dental caries. The protocol for this study can be reviewed on the International Prospective Register of Systematic Reviews (PROSPERO) database, referenced under the registration number CRD42024570469.

2.5. Search strategy for article identification

An electronic search for systematic reviews was conducted by two independent researchers (S.S. and R.S.) using the following databases: Medline (via PubMed), Web of Science, Scopus, EMBASE, and Google Scholar, with articles published up to June 2024. The specific search strategies for each database are outlined in Table 1. The search was limited to English-language publications, with no additional restrictions applied.

2.6. Screening of articles

To compile the articles, duplicates were identified and removed based on title, author, and publication year after merging results from different databases. Two reviewers (S.S. and R.S.) independently assessed the titles and abstracts. Studies not conforming to the predefined PICO criteria were excluded by mutual consensus of the reviewers. Any disputes regarding article selection were addressed through discussion and, if necessary, with the input of a third and fourth reviewer (M.K & R.K). Following this, each reviewer individually evaluated the full texts of the remaining articles, with any disagreements resolved through further discussion. Finally, eight review articles were included in this research.

2.7. Data extraction

Data from studies meeting the inclusion criteria were extracted by two reviewers (S.S and R.S) by the Joanna Briggs Institute (JBI) guidelines for umbrella reviews.[16] The extraction focused on several parameters: (a) author and year of publication, (b) type of study, (c) research setting, (d) range of years covered, (e) number of studies reviewed, (f) sample size, (g) sources of information, (h) characteristics of the study group, (i) characteristics of the control group, (j) tools used for appraisal, (k) outcomes measured, (l) results and findings, (m) significance of the results, and (n) heterogeneity of the studies. These details have been organized and presented in Tables 2 and 3.

Table 1
Search strategy for the study.

Database	Search string	Nos.
Medline (PubMed)	(((((dental caries[MeSH Terms]) OR (caries, dental [MeSH Terms])) OR (caries, cervical[MeSH Terms])) OR (caries, root[MeSH Terms])) OR (caries susceptibility, dental[MeSH Terms])) AND (((dental photography [MeSH Terms]) OR (intraoral photographies[MeSH Terms])) OR (intraoral photography[MeSH Terms]))	3
Web of Science	TS=("Dental caries") AND (TS=("dental photography")) OR TS=("dental images")	6
Scopus	((TITLE-ABS-KEY ("dental caries") OR TITLE-ABS-KEY ("caries detection"))) AND ((TITLE-ABS-KEY ("dental photography") OR TITLE-ABS-KEY ("smartphone application") OR TITLE-ABS-KEY ("dental images")))	5
Embase	('dental caries'/exp OR 'caries' OR 'caries, dental' OR 'cariogenesis' OR 'carious dentine' OR 'carious teeth' OR 'dental caries' OR 'dental caries susceptibility' OR 'dental decay' OR 'dental fissure' OR 'dental fissures' OR 'fissure, tooth' OR 'root caries' OR 'tooth caries' OR 'tooth decay' OR 'tooth fissure') AND ('medical photography'/exp OR 'dental photography' OR 'medical photography' OR 'photography, dental' OR 'photography, medical')	4
Google Scholar	("Dental Caries" OR "Cervical Caries" OR "Root Caries" OR "Dental Caries Susceptibility") AND ("Dental Photography" OR "Intraoral Photography")	14

Table 2
General characteristics of included systematic reviews.

S. No	Author, year	Study type	Study setting	Range of years	No of studies	Subjects (n)	Sources searched	Study group	Control group	Appraisal instrument
1	Inês Meurer, M. et al. 2015[31]	Systematic review	Australia	1998–2014	10	845	PubMed, Embase, Scopus	Digital photographs	Visual examination	QUADAS-2
2	Estai, M. et al. 2016[32]	Systematic review	Australia	Till 2016	10	270	Medline, Embase, Scopus	Tele Dentistry	Histologic and visual examination	QUADAS-2
3	Thanh, M. T. G. et al. 2021[19]	Systematic review and Meta-analysis	Vietnam	2011–2018	12	2010	PubMed, Cochrane	Digital photographs, Visual inspection, fluorescence methods	Histologic and visual examination	QUADAS-2
4	Khanagar, S. B. et al. 2022[22]	Systematic review	Saudi Arabia	2000–2022	34	818	PubMed, Google Scholar, Scopus, Web of Science, Embase, Cochrane, Saudi Digital Library	AI application for detection, diagnosis, and prediction of Dental caries	Expert opinions, reference standards/ models	QUADAS-2
5	Mohammad-Rahimi, H. et al. 2022[21]	Systematic review	Germany	2010–2021	42	–	PubMed, Google Scholar, Scopus, Embase, and Repository (ArXiv)	Deep learning (NN)	Reference test	QUADAS-2
6	Toledo, L. et al. 2022[33]	Systematic review	Brazil	2008–2020	15	–	PubMed, Scopus, Embase, Web of Science, Open Grey, IADR annals	Non-logistic regression ML algorithm	Expert's judgment, clinical/ histological examination	QUADAS-2
7	Priyank, H. et al. 2023[20]	Systematic review and Meta-analysis	India	2013–2023	8	787	PubMed, Embase, Cochrane, Scopus, Web of Science, CINAHL, PsycINFO	Digital photographs	Clinical examination	New Castle-Ottawa Scale
8	Moharrami, M. et al. 2024[34]	Systematic review	Canada	2019–2022	19	12600	Medline, EMBASE, Scopus	Digital photographs	Tactile/visual examination	Modified QUADAS-2

#QUADAS-2 - Quality Assessment of Diagnostic Accuracy Studies, NN-Neural Network, ML-Machine Learning, AI-Artificial Intelligence.

2.8. Risk of Bias

The risk of bias (ROB) for each study was independently assessed by two reviewers using the JBI critical appraisal tool for systematic reviews (Fig. 2).[17] Discrepancies in their assessments were addressed with the input of a third reviewer (M.K) to ensure consensus. The visualization of this risk of bias was performed using the RoBvis tool.[18]

3. Results

3.1. Study selection and its characteristics

The study selection process was carried out independently by two authors (S.S & R.S). This involved an initial screening of titles and abstracts, followed by a detailed evaluation of full texts according to set inclusion and exclusion criteria. Ultimately, data extraction was conducted on eight articles (Fig. 1). According to the JBI methodological guidelines, the data were systematically organized and presented in Tables 2 and 3 Table 3 offers a consolidated overview of the outcome measures derived from the included studies. The research predominantly investigated the diagnostic accuracy of digital photographs, focusing on metrics such as sensitivity and specificity. Notably, a significant number of these studies utilized artificial intelligence for detecting Dental caries.

3.2. The primary outcome of the study

A total of eight systematic reviews met the inclusion criteria (Fig. 1). These reviews assessed the diagnostic accuracy of digital photography, with or without AI integration, for detecting dental caries compared with traditional diagnostic methods. Two reviews (Thanh et al., 2021[19]; Priyank et al., 2023[20]) conducted quantitative meta-analyses, while six provided narrative syntheses. Reported sensitivity and specificity values varied across modalities. Intraoral photographs demonstrated sensitivities ranging from 67 % to 96 % and specificities from 75 % to 99.2 % with AUC values reported between 0.74 and 0.987.[21] Tele-dentistry approaches using photographic images yielded diagnostic accuracy comparable to traditional visual inspection.[22]

3.3. Risk of Bias

The JBI critical appraisal tool was employed to assess the risk of bias (ROB)[17] in the individual systematic review studies, and its visualization was generated using the risk of bias visualization (RoBvis) tool.[18] This assessment utilized 11 criteria, categorized on a nominal scale into four distinct options: yes (present), no (absent), unclear, and not applicable. Out of the eight reviews examined, most criteria were thoroughly addressed in all studies. The only criterion not applicable was the evaluation of publication bias, as some studies included predominantly qualitative evidence synthesis. Therefore, the overall risk of bias across the included reviews is considered to be minimal (Fig. 2).

4. Discussion

This review examines systematic reviews of observational studies that explore the diagnostic performance of digital photography in detecting Dental caries. Findings confirm that digital images can achieve diagnostic accuracy comparable to traditional visual examination, with the added benefits of standardized documentation and potential for remote assessment. Accurate diagnosis of dental caries is central to effective clinical management, yet conventional methods primarily visual inspection and tactile probing are subjective and highly dependent on clinician expertise and clinical conditions.[23,24]

Digital photography offers clear advantages in early lesion detection,

Table 3
Inference from included studies.

S. No	Author, year	Appraisal result	Outcome assessed	Results	Significance	Heterogeneity
1	Inês Meurer, M. et al. 2015[31]	The study exhibited a high risk of bias in the case selection (19 %) and reference standard domains (50 %). The index test, time, and flow domains showed varying degrees of uncertainty, with a notable percentage of studies considered unclear or having low applicability.	Sensitivity, Specificity	Image analysis was superior in three studies, with comparable accuracy in the remaining six. For enamel defects, three studies favored image analysis, two favored visual inspection, and three found both methods comparable. Overall, photographic and visual inspection techniques were at least comparable in most studies.	Insignificant	–
2	Estai, M. et al. 2016[32]	Among the 10 studies assessed, eight were found to have a high risk of bias, with the remaining two presenting an unclear risk.	Sensitivity, Specificity	Photographic examination demonstrated acceptable diagnostic performance compared to visual inspection, with sensitivity ranging from 43 % to 100 % and specificity from 52 % to 100 %.	Insignificant	–
3	Thanh, M. T. G. et al. 2021[19]	The study showed a significant risk of bias, particularly in case selection (75 %) and reference standard (58 %) domains. The index test domain exhibited a balanced distribution of high, low, and unclear risks.	Sensitivity, specificity	Among twelve articles, three used visual photographic examination, ten used fluorescence methods, and five utilized visual inspection for initial caries detection. Visual inspection and fluorescence methods demonstrated higher pooled sensitivities and specificities compared to photographic examination. Specifically, visual inspection yielded a sensitivity of 80 % and a specificity of 75 %, While Photographic examination showed a sensitivity of 67 % and a specificity of 79 %. Additionally, Fluorescence methods achieved a sensitivity of 80 % and a specificity of 80 %.	Significant	72 %–98 %
4	Khanagar, S. B. et al. 2022[22]	Good quality, with a moderate to low risk of bias	Sensitivity, Specificity	AI models for detecting and diagnosing dental caries (DC) have shown excellent performance, potentially enhancing diagnostic accuracy, treatment quality, and patient outcomes.	Insignificant	–
5	Mohammad-Rahimi, H. et al. 2022[21]	The study revealed that 26.2 % of included studies had a low risk of bias across all domains. The reference standard domain was the most challenging, with less than half classified as low risk.	Sensitivity, Specificity	The accuracy of caries classification models varied, i.e., 71 %–96 % on intra-oral photographs, 82 %–99.2 % on peri-apical radiographs, 87.6 %–95.4 % on bitewing radiographs, 68.0 %–78.0 % on near-infrared trans-illumination images, 88.7 %–95.2 % on optical coherence tomography images, and 86.1 %–96.1 % on panoramic radiographs. While the results were promising, the quality of studies and reporting was generally low.	Insignificant	–
6	Toledo, L. et al. 2022[33]	Out of the 10 assessed studies, two diagnostic studies and two prognostic studies were rated as high quality.	Sensitivity, Specificity	Machine learning algorithms, as demonstrated by intra-oral photographs, showed promise in dental caries diagnosis and prognosis prediction; however, the evidence's general applicability was limited due to the high prevalence of bias. AUC values ranged from 0.74 to 0.987.	Insignificant	–
7	Priyank, H. et al. 2023[20]	Good quality, with a moderate to low risk of bias	Sensitivity, Specificity	With the four studies in quantitative analysis, there is no significant difference between clinical and digital photography (tele-dentistry) based examinations ($p = 0.09$). A mean difference of 0.64 (95 % CI: 0.10; 1.38) suggested that both examinations were on par with each other for the detection of dental caries.	Insignificant	64 %
8	Moharrami, M. et al. 2024[34]	Out of 19 studies, 6 showed a low risk of bias, and others had a moderate to high risk of bias.	Sensitivity, Specificity	AI models show promise for caries detection from oral photographs, suggesting the potential for using smartphone cameras in various settings.	Insignificant	–

#AUC-Area Under Curve, CI-Confidence Interval, AI-Artificial Intelligence.

especially at sites less accessible to direct inspection. Images can be stored, re-evaluated, and shared with other professionals, enhancing diagnostic consistency and also enables the tracking of lesion progression over time, serving as a valuable resource for both clinical applications and research purposes.[25–28] However, digital photography cannot replicate the tactile feedback provided by conventional methods, which is crucial for identifying cavitated lesions and assessing their depth.[29] Moreover, the reliability of digital images depends on various factors such as image quality, lighting conditions, focus, and viewing angle, which can impact diagnostic accuracy.[30]

In their systematic review, Inês Meurer et al. (2015)[31] found that most studies reported digital photography as performing at least on par with conventional assessment techniques for common Dental issues. In another systematic review by Estai et al. (2016),[32] ten studies assessed photographic examination. They found it to deliver a diagnostic performance deemed acceptable when compared to visual inspection, with sensitivity ranging from 43 % to 100 % and specificity ranging from 52 % to 100 %. Thanh, M. T. G. et al. (2021)[19] systematically reviewed twelve articles, among which three employed visual photographic techniques, ten used fluorescence methods, and five relied on visual inspection for initial caries detection. The findings indicated that visual inspection and fluorescence methods generally outperformed photographic examination in terms of pooled sensitivities and specificities. This difference may be attributed to fluorescence's ability to identify demineralization not visible in conventional or photographic inspection. Specifically, visual inspection achieved a sensitivity of 80 % and a

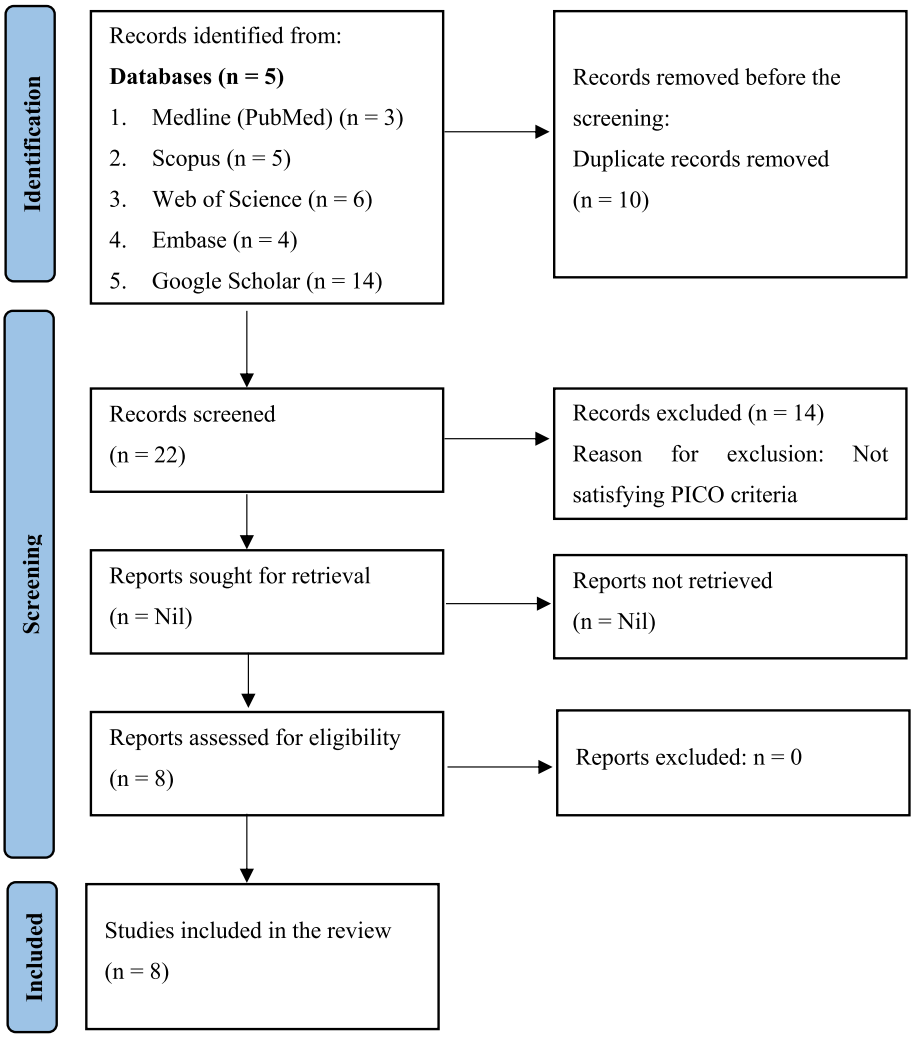

Fig. 1. PRISMA flow chart of the study selection process.

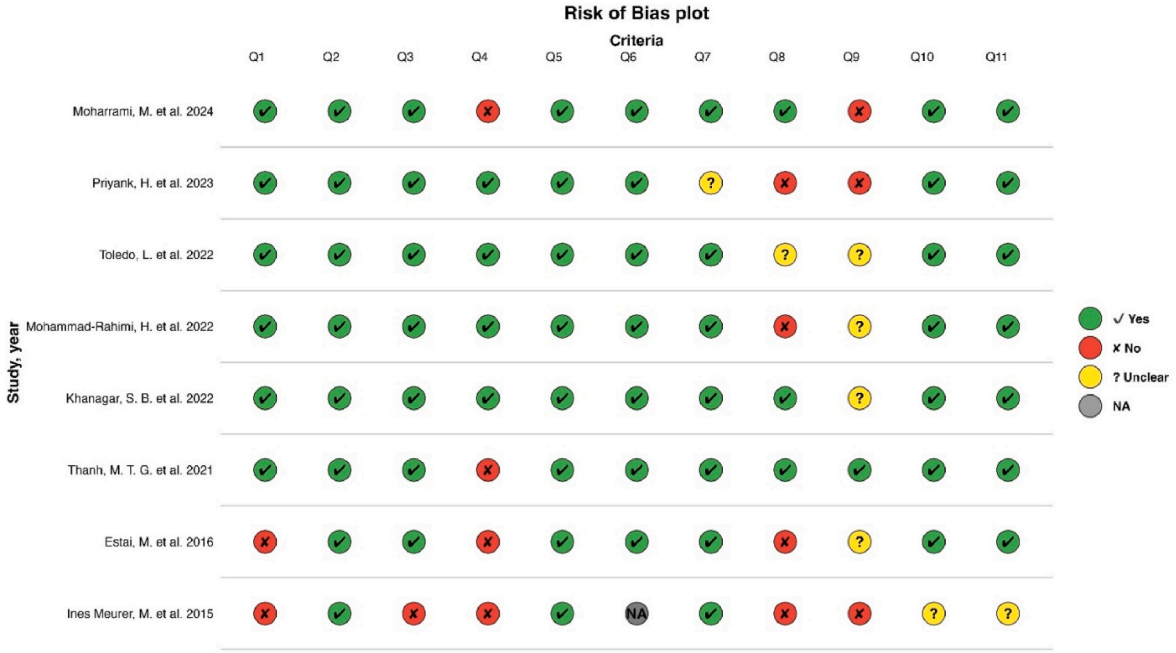

Fig. 2. Risk of bias of included studies.

specificity of 75 %. Photographic examination had a sensitivity of 67 % and a specificity of 79 %, while fluorescence methods exhibited a sensitivity of 80 % and a specificity of 80 %.

Khanagar, S. B. et al. (2022)[22] conducted a comprehensive review of 34 studies, revealing that artificial intelligence (AI) models excel in the identification of Dental caries. Their findings suggest that these AI systems can significantly enhance diagnostic accuracy, improve treatment quality, and improve patient outcomes while also helping identify individuals at elevated risk for Dental caries. Toledo, L. et al. (2022)[33] reviewed ten studies and found that machine learning algorithms applied to intra-oral photographs showed potential for effective caries diagnosis and prognosis. However, they noted that the generalizability of these findings was restricted due to prevalent biases, with AUC values ranging from 0.74 to 0.987.

In their 2023 analysis, Priyank, H. et al.[20] compared clinical examination with digital photography (teledentistry) across four studies and found no significant difference in their efficacy for caries detection ($p = 0.09$). The mean difference of 0.64 (95 % CI: 0.10; 1.38) indicated that both methods performed comparably in identifying Dental caries. Moharrami, M. et al. (2024)[34] evaluated the effectiveness of AI models in detecting Dental caries from oral photographs through a review of 19 studies. They concluded that AI models hold substantial promise for advancing caries detection capabilities using photographic images.

Several AI tools are now available for caries detection using digital photography—platforms like Diagnocat,[35] DentalXrai Pro,[36] and Denti. AI® and Overjet Dental AI[37] leverage deep learning to analyze intraoral images for carious lesions. Research-based tools, such as Caries Detect AI and experimental CNN models, have also demonstrated high accuracy in classifying lesions from smartphone images. Thus, AI models applied to digital photographs show strong promise in increasing diagnostic accuracy. However, their emphasis in the literature sometimes overshadows the primary role of photography itself. While AI tools can augment image-based diagnostics, the foundation remains the acquisition of high-quality, standardized intraoral photographs. Thus, digital photography stands as a clinically valuable adjunct to traditional methods. While not a complete substitute for tactile inspection or radiography, it can complement them, especially in telehealth and community-based care settings.

5. Limitations

The review is constrained by several factors, including the inclusion of only eight systematic reviews, of which just two involved meta-analyses. This limitation may restrict the broader applicability of the findings. Additionally, the diverse methodologies, sample sizes, and study durations among the included reviews could contribute to variability in the results. Additionally, we have conducted only a qualitative assessment rather than a quantitative one due to the heterogeneity among the studies. The potential overlap of primary studies across included systematic reviews was not systematically analyzed due to limited reporting in the reviews. This overlap may have influenced the summary findings. In addition, the quality of the included systematic reviews varied considerably. While some studies were appraised as having high methodological quality, others exhibited a high or unclear risk of bias in key domains, such as case selection, reference standards, and index testing procedures. This variability may affect the reliability of the synthesized findings. Also, substantial heterogeneity was observed across the included reviews in terms of diagnostic tools (e.g., smartphones, intraoral cameras, AI-based models), study settings (clinical vs. laboratory), and target populations (children vs. adults, high-risk vs. general populations). However, due to the narrative nature of most reviews and lack of consistent reporting, this heterogeneity could not be formally quantified using statistical measures such as I^2 or subgroup analyses. Further, the use of different critical appraisal instruments such as QUADAS-2, Newcastle-Ottawa Scale, and modified versions further complicates direct comparisons across studies. These tools differ in their scope and evaluation criteria, making it challenging to establish uniform benchmarks for methodological rigor. Collectively, these factors may limit the generalizability of our conclusions and should be considered when interpreting the diagnostic performance of digital photography for detecting dental caries. Furthermore, as the umbrella review exclusively included systematic reviews based on observational studies, the overall level of evidence remains moderate to low. The inherent limitations of observational designs, such as potential confounding and selection bias, may influence the strength of conclusions derived and the resulting evidence should be interpreted cautiously.

Despite these constraints, the review indicates that digital photography is a promising diagnostic tool for identifying Dental caries. It provides distinct benefits over traditional visual examinations, such as superior image clarity, enhanced record-keeping and monitoring capabilities, the ability to facilitate remote consultations and collaborative assessments, improved patient education and engagement, a non-invasive and comfortable approach, greater consistency and standardization, increased time efficiency, and a reduction in diagnostic errors.

The integration of AI-assisted digital photography into dental diagnostics provides notable public health benefits by facilitating precise and early detection of dental caries, thereby reducing the need for extensive restorative procedures. Its application in teledentistry enhances diagnostic reach in underserved areas,[38] promotes equitable access to oral healthcare, and contributes valuable data for population-level monitoring and public health strategy development.

6. Conclusion

Digital photography has emerged as a transformative diagnostic tool in the realm of Dental caries detection, delivering exceptionally detailed images that permit an in-depth examination of Dental tissues. This imaging technique is particularly adept at uncovering early-stage carious lesions and enables continuous tracking of their progression over time. Its non-invasive nature, combined with advanced capabilities for clinical documentation and remote consultation, enhances its role in Dental diagnostics. By providing precise and reliable imagery, digital photography significantly advances early intervention and management of Dental caries, leading to better patient outcomes and more effective Dental care.

Patient consent for publication

Not applicable.

Patient and public involvement

This research was conducted, reported, and disseminated without direct engagement or input from patients or the general public.

Ethical approval

Not applicable. The protocol for this study can be reviewed on the International Prospective Register of Systematic Reviews (PROSPERO) database, referenced under the registration number CRD42024570469.

Credit author contribution statement

Madan Kumar P.D: Conceptualization, Methodology, Investigation, Data curation, Writing-Original Draft, Writing and Editing, Critical revision, and supervision.

Sasidharan Sivakumar: Methodology, Data curation, Writing and Editing, Critical revision, and supervision.

Rajeshwari S: Conceptualization, Methodology, Investigation, Data curation, Writing-Original Draft, Writing-Review and Editing.

Lavanya C: Conceptualization, Methodology, Investigation, Writing and Editing, Critical revision, and supervision.

Ranganathan K: Conceptualization, Methodology, Investigation, Writing and Editing, Critical revision, and supervision.

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Declaration of competing interest

The authors state that they have no financial or personal relationships that could have influenced the work presented in this paper.

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Data availability

Data can be obtained through a reasonable request process.

References

1. Peres MA, Macpherson LM, Weyant RJ, et al. Oral diseases: a global public health challenge. *Lancet*. 2019 Jul 20;394(10194):249–260.
2. Northridge ME, Kumar A, Kaur R. Disparities in access to oral health care. *Annu Rev Publ Health*. 2020 Apr 1;41(1):513–535.
3. Abdelaziz M. Detection, diagnosis, and monitoring of early caries: the future of individualized dental care. *Diagnostics*. 2023 Dec 12;13(24):3649.
4. Macey R, Walsh T, Riley P, et al, Cochrane Oral Health Group. Visual or visual-tactile examination to detect and inform the diagnosis of enamel caries. *Cochrane Database Syst Rev*. 1996 Sep 1;2021(12).
5. Akyıldız E, Özalp N. Diagnosis of early dental caries by traditional, contemporary and developing imaging methods. *Euro Annal Dental Sci*. 2022;49(1):38–45.
6. Liu F, Li Y, Shi X, Wang Y, Yu T. *Basic images of dental clinical photography. Dental Digital Photography: From Dental Clinical Photography to Digital Smile Design*. 2019: 109–160.
7. Ahmed N, Abbasi MS, Zuberi F, et al. Artificial intelligence techniques: analysis, application, and outcome in dentistry—a systematic review. *BioMed Res Int*. 2021; 2021(1), 9751564.
8. Marwaha J. Artificial intelligence in conservative dentistry and endodontics: a game-changer. *J Conserv Dent Endod*. 2023 Sep 1;26(5):514–518.
9. Singh S. Artificial Intelligence–A reality or myth. *J Conserv Dent Endod*. 2023 Nov 1; 26(6):609.
10. Singh S, Asthana G. Artificial intelligence……. A futuristic tool for advanced endodontics. *J Conserv Dent Endod*. 2024 May 1;27(5):447–448.
11. Anil S, Porwal P, Porwal A. Transforming dental caries diagnosis through artificial intelligence-based techniques. *Cureus*. 2023 Jul;15(7).
12. Ayhan B, Ayan E, Bayraktar Y. A novel deep learning-based perspective for tooth numbering and caries detection. *Clin Oral Invest*. 2024 Feb 27;28(3):178.
13. Ghaffari M, Zhu Y, Shrestha A. A review of advancements of artificial intelligence in dentistry. *Dentistry Rev*. 2024 Mar 13, 100081.
14. Xiong Y, Zhang H, Zhou S, et al. Simultaneous detection of dental caries and fissure sealant in intraoral photos by deep learning: a pilot study. *BMC Oral Health*. 2024 May 12;24(1):553.
15. Duong DL, Kabir MH, Kuo RF. Automated caries detection with smartphone color photography using machine learning. *Health Inf J*. 2021 Apr;27(2), 14604582211007530.
16. Aromataris Edoardo, Fernandez Ritin S, Godfrey Christina, Holly Cheryl, Khalil Hanan, Tungpunkom Patraporn. *Methodology for JBI Umbrella Reviews*. 2014. Faculty of Science, Medicine, and Health - Papers: part A. 3344.
17. Aromataris E, Fernandez R, Godfrey C, Holly C, Khalil H, Tungpunkom P. Chapter 10: Umbrella reviews. In: Aromataris E, Munn Z, eds. *JBI Manual for Evidence Synthesis*. JBI; 2020.
18. Sasidharan S, Gowardhan S. JBI RoB visualisation tool [Internet]. Version 1. Available from: https://sasidharan.shinyapps.io/JBI_RoBvis_tool/; 2024.
19. Thanh MT, Van Toan N, Toan DT, et al. Diagnostic value of fluorescence methods, visual inspection and photographic visual examination in initial caries lesion: a systematic review and meta-analysis. *Dent J*. 2021 Mar 6;9(3):30.
20. Priyank H, Verma A, Khan DU, Rai NP, Kalburgi V, Singh S. Comparative evaluation of dental caries score between teledentistry examination and clinical examination: a systematic review and meta-analysis. *Cureus*. 2023 Jul;15(7).
21. Mohammad-Rahimi H, Motamedian SR, Rohban MH, et al. Deep learning for caries detection: a systematic review. *J Dent*. 2022 Jul 1;122, 104115.
22. Khanagar SB, Alfouzan K, Awawdeh M, Alkadi L, Albalawi F, Alfadley A. Application and performance of artificial intelligence technology in detection, diagnosis, and prediction of dental caries (DC)—A systematic review. *Diagnostics*. 2022 Apr 26;12 (5):1083.
23. Baelum V, Hintze H, Wenzel A, Danielsen B, Nyvad B. Implications of caries diagnostic strategies for clinical management decisions. *Community Dent Oral Epidemiol*. 2012 Jun;40(3):257–266.
24. Diniz MB, Rodrigues JA, Lussi A. Traditional and novel caries detection methods. *Contemp Approach Dental Caries*. 2012 Mar 14;6:105–128.
25. Kühnisch J, Meyer O, Hesenius M, Hickel R, Gruhn V. Caries detection on intraoral images using artificial intelligence. *J Dent Res*. 2022 Feb;101(2):158–165.
26. Christensen GJ. Important clinical uses for digital photography. *J Am Dent Assoc*. 2005 Jan 1;136(1):77–79.
27. Schierz O, Hirsch C, Krey KF, Ganss C, Kämmerer PW, Schlenz MA. Digital dentistry and its impact on oral health-related quality of life. *J Evid Base Dent Pract*. 2023 Oct 15, 101946.
28. Al Saffan AD. Current approaches to diagnosis of early proximal carious lesion: a literature review. *Cureus*. 2023 Aug;15(8).
29. Chan EK, Wah YY, Lam WY, Chu CH, Yu OY. Use of digital diagnostic aids for initial caries detection: a review. *Dent J*. 2023 Sep 28;11(10):232.
30. Saincher R, Kumar S, Gopalkrishna P, Maithri M, Sherigar P. Comparison of color accuracy and picture quality of digital SLR, point and shoot and mobile cameras used for dental intraoral photography–A pilot study. *Heliyon*. 2022 Apr 1;8(4), e09262.
31. Inês Meurer M, Caffery LJ, Bradford NK, Smith AC. Accuracy of dental images for the diagnosis of dental caries and enamel defects in children and adolescents: a systematic review. *J Telemed Telecare*. 2015 Dec;21(8):449–458.
32. Estai M, Bunt S, Kanagasingam Y, Kruger E, Tennant M. Diagnostic accuracy of teledentistry in the detection of dental caries: a systematic review. *J Evid Base Dent Pract*. 2016 Sep 1;16(3):161–172.
33. Reyes LT, Knorst JK, Ortiz FR, Ardenghi TM. Machine learning in the diagnosis and prognostic prediction of dental caries: a systematic review. *Caries Res*. 2022 May 30; 56(3):161–170.
34. Moharrami M, Farmer J, Singhal S, et al. Detecting dental caries on oral photographs using artificial intelligence: a systematic review. *Oral Dis*. 2024 May;30(4): 1765–1783.
35. Kwiatek J, Leśna M, Piskórz W, Kaczewiak J. Comparison of the diagnostic accuracy of an AI-based system for dental caries detection and clinical evaluation conducted by dentists. *J Clin Med*. 2025 Feb 26;14(5):1566.
36. Mertens S, Krois J, Cantu AG, Arsiwala LT, Schwendicke F. Artificial intelligence for caries detection: randomized trial. *J Dent*. 2021 Dec 1;115, 103849.
37. Lal A, Nooruddin A, Umer F. Concerns regarding deployment of AI-based applications in dentistry–a review. *BDJ open*. 2025 Mar 25;11(1):27.
38. Goffin G, Carter N, Sari Widyarman A, et al. Role of teledentistry in enabling improved oral care outcomes. *Br Dent J*. 2024 Feb 9;236(3):162–168.