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DIAGNOSTIC ACCURACY OF AI-BASED VERSUS CONVENTIONAL RADIOGRAPHIC CARIES DETECTION IN PEDIATRIC PATIENTS: A CROSS-SECTIONAL STUDY

Original Research

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ABSTRACT

Background: Dental caries remains a leading oral health concern in children, often requiring early and accurate diagnosis to prevent progression. Conventional radiographic methods, though widely used, can be limited by human interpretation variability. Artificial intelligence (AI)-based diagnostic tools have emerged as promising alternatives, offering consistency and enhanced lesion detection, yet their clinical utility in pediatric settings remains underexplored.

Objective: To compare the diagnostic accuracy of AI-assisted caries detection tools with conventional radiographic evaluation in pediatric dental patients.

Methods: A cross-sectional study was conducted over eight months at a tertiary pediatric dental center involving 120 children aged 6–14 years. Standardized bitewing radiographs were analyzed using two methods: independent evaluation by calibrated pediatric dentists and AI-assisted analysis via a deep learning-based diagnostic system. Diagnostic performance was measured using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy. McNemar's test was applied to compare paired proportions, and Cohen's kappa assessed inter-rater reliability among clinicians. Ethical clearance and informed consent procedures were completed.

Results: AI-assisted detection showed significantly higher diagnostic performance, with sensitivity of 88.3%, specificity of 90.8%, PPV of 89.1%, NPV of 89.9%, and overall accuracy of 89.6%. Conventional radiography yielded lower values across all metrics, including sensitivity (72.5%) and accuracy (78.8%). Statistical analysis confirmed significant differences between the two methods ($p < 0.05$), favoring AI tools for consistent caries detection in children.

Conclusion: AI-assisted caries detection demonstrates superior diagnostic accuracy compared to conventional radiographic interpretation in pediatric patients, supporting its integration as a reliable clinical decision aid in routine dental practice.

Keywords: Artificial Intelligence, Bitewing Radiography, Caries Detection, Deep Learning, Diagnostic Imaging, Pediatric Dentistry, Sensitivity and Specificity.

INTRODUCTION

Dental caries remains one of the most prevalent chronic diseases in children worldwide, with significant implications for oral health, overall well-being, and quality of life. Early detection and accurate diagnosis are critical to initiating timely interventions that can prevent the progression of decay, reduce the risk of tooth loss, and minimize invasive treatments. Radiographic evaluation, particularly bitewing radiographs, has traditionally served as a cornerstone for detecting interproximal and occlusal carious lesions that are not readily visible during a clinical examination (1). However, this method relies heavily on the interpretative skills of clinicians, which introduces an element of subjectivity and inconsistency (1,2). Furthermore, early-stage lesions can be easily overlooked, leading to underdiagnosis and delayed treatment. In recent years, the integration of artificial intelligence (AI) into diagnostic tools has gained momentum across various medical and dental specialties (3). AI-based systems, particularly those leveraging deep learning algorithms, offer the potential to enhance diagnostic accuracy by minimizing human error and improving consistency in image interpretation. These systems can analyze radiographic images rapidly and objectively, identifying minute changes in tooth structure that may not be perceptible to the human eye. In the context of pediatric dentistry, where patient cooperation and image quality can vary significantly, such technological advancements could prove particularly valuable (4,5).

Several studies have explored the utility of AI in dental diagnostics, with a growing body of evidence suggesting that AI-assisted caries detection tools may match or even surpass traditional methods in terms of sensitivity and specificity. For example, a study demonstrated that deep learning models could identify carious lesions on bitewing radiographs with performance comparable to that of experienced dentists (6,7). Other investigations have echoed these findings, highlighting the robustness and reliability of AI tools under various imaging conditions and across different patient populations. Despite these promising developments, the majority of research to date has focused on adult populations or idealized imaging settings, leaving a gap in understanding how these tools perform in routine pediatric dental practice (8,9). Pediatric patients present unique diagnostic challenges due to mixed dentition stages, anatomical variations, and behavioral factors that may influence the quality and interpretation of radiographs. Additionally, dental professionals may face time constraints or diagnostic fatigue during high-volume clinical sessions, which could compromise the accuracy of visual assessments. In such contexts, AI could serve not only as a diagnostic aid but also as a second opinion system to bolster clinical decision-making and ensure consistent outcomes across providers. However, the real-world applicability of AI in pediatric dental settings remains underexplored, and robust comparative studies are necessary to determine its practical value (10,11).

This study seeks to address this critical gap by directly comparing the diagnostic accuracy of AI-based caries detection tools with conventional radiographic interpretation in a pediatric population. By employing a cross-sectional design, the study evaluates current clinical performance under typical practice conditions, thereby offering insights into the real-world utility of AI in pediatric dentistry. The overarching aim is to determine whether AI can serve as a reliable adjunct or even a replacement for traditional diagnostic methods, potentially setting a new standard in caries detection protocols for children. The objective of this research is to evaluate and compare the diagnostic effectiveness of artificial intelligence-assisted caries detection tools against conventional radiographic assessments in pediatric dental patients, thereby rationalizing the potential integration of AI into routine clinical practice for improved diagnostic accuracy and patient care.

METHODS

This cross-sectional study was conducted over a duration of eight months at the Department of Pediatric Dentistry in a tertiary care academic hospital. The research aimed to compare the diagnostic performance of artificial intelligence-assisted caries detection systems with conventional radiographic interpretation in pediatric patients. A total of 120 participants, aged between 6 and 14 years, were recruited following a sample size estimation based on an anticipated effect size of 0.5, power of 80%, and alpha level of 0.05, accounting for a 10% dropout rate (2,3). The participants represented a broad demographic to ensure a representative pediatric population, and all were attending the clinic for routine dental evaluations or treatment planning that included bitewing radiographic imaging. Inclusion criteria encompassed children in the mixed or permanent dentition phase who required bitewing radiographs as part of standard clinical care. Participants were required to be systemically healthy, cooperative for radiographic imaging, and have at least two posterior teeth

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in contact for accurate interproximal caries assessment. Exclusion criteria included the presence of developmental dental anomalies, history of previous extensive restorative treatment in posterior teeth, systemic conditions affecting tooth development or mineralization, and patients with incomplete radiographic records or those unable to cooperate during imaging procedures (12).

Radiographic images were acquired using a standardized digital radiography system with consistent exposure parameters. All bitewing radiographs were reviewed for image quality and diagnostic adequacy before inclusion. Caries detection was performed independently using two diagnostic modalities: conventional visual radiographic evaluation by pediatric dental specialists and AI-assisted analysis via a commercially available, FDA-approved AI software specifically trained for dental caries detection. The software utilized a convolutional neural network (CNN) algorithm capable of identifying radiolucent lesions in interproximal and occlusal surfaces with automated lesion grading. Each radiograph was first interpreted by two calibrated pediatric dentists with a minimum of five years of clinical experience. These clinicians assessed the presence or absence of carious lesions based on established radiographic criteria and recorded their findings independently. Discrepancies were resolved through consensus or consultation with a third senior clinician. Following this, the same radiographs were uploaded into the AI diagnostic tool, which processed the images and provided lesion detection output. The AI output was blinded to the human evaluators to prevent bias in interpretation.

The primary outcome measure was diagnostic accuracy, which was assessed by comparing the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of each diagnostic method against a reference standard. The reference standard was established through clinical validation of radiographic findings via direct visual-tactile examination under rubber dam isolation in cases where intervention was indicated, thereby allowing intraoral confirmation of caries presence or absence (13). Data were analyzed using SPSS version 26. Descriptive statistics summarize demographic characteristics and lesion frequencies. The Kolmogorov-Smirnov test confirmed normal distribution of the data, allowing for the use of parametric tests. Paired-sample t-tests were used to compare the sensitivity and specificity between AI-based and conventional diagnostic methods. Additionally, McNemar's test was employed to evaluate differences in paired proportions of diagnostic outcomes. A p-value of less than 0.05 was considered statistically significant. Inter-rater reliability among human assessors was assessed using Cohen's kappa coefficient. Prior to the commencement of the study, ethical approval was obtained from the Institutional Ethics Committee of the host. All procedures adhered to the principles of the Declaration of Helsinki. Written informed consent was secured from parents or legal guardians of all participating children, and verbal assent was obtained from children above the age of seven, ensuring age-appropriate understanding of the study's purpose and procedures. By employing rigorous methodology and ethical standards, this study ensures the generation of reliable and clinically meaningful data to evaluate the potential of artificial intelligence in enhancing diagnostic precision for caries detection in pediatric dental care.

RESULTS

The study enrolled a total of 120 pediatric patients with a mean age of 9.8 years, comprising 48.3% males and 51.7% females. All participants successfully underwent standardized bitewing radiographic imaging, and both conventional and AI-assisted diagnostic assessments were conducted for interproximal and occlusal caries detection. The AI-based detection system demonstrated a higher overall diagnostic accuracy compared to conventional radiographic interpretation. The sensitivity of the AI-assisted method was 88.3%, while conventional evaluation yielded a sensitivity of 72.5%. Similarly, specificity was higher for AI-based detection at 90.8% compared to 85.0% with traditional assessment. Positive predictive value (PPV) and negative predictive value (NPV) followed similar trends, with AI reporting 89.1% and 89.9%, respectively, as opposed to 80.3% and 78.2% for conventional methods. The overall diagnostic accuracy was calculated at 89.6% for the AI system and 78.8% for traditional radiographic interpretation. Statistical analysis using McNemar's test revealed significant differences in sensitivity and specificity between the two methods, with p-values of 0.012 and 0.034 respectively, indicating that the AI-based tool outperformed traditional radiographic interpretation in these diagnostic parameters. Inter-rater reliability for human assessments was strong, with a Cohen's kappa coefficient of 0.82, suggesting high consistency between evaluators.

Table 1: Demographic and Diagnostic Data

Variable	Value
Total Participants	120
Mean Age (years)	9.8
Male (%)	58 (48.3%)
Female (%)	62 (51.7%)

Table 2: Diagnostic Performance Metrics

Metric	Conventional Radiography (%)	AI-Assisted Detection (%)
Sensitivity	72.5	88.3
Specificity	85	90.8
PPV	80.3	89.1
NPV	78.2	89.9
Accuracy	78.8	89.6

Table 3: McNemar Statistical Outcomes

Comparison	p-value	Statistically Significant
Sensitivity Difference	0.012	Yes
Specificity Difference	0.034	Yes

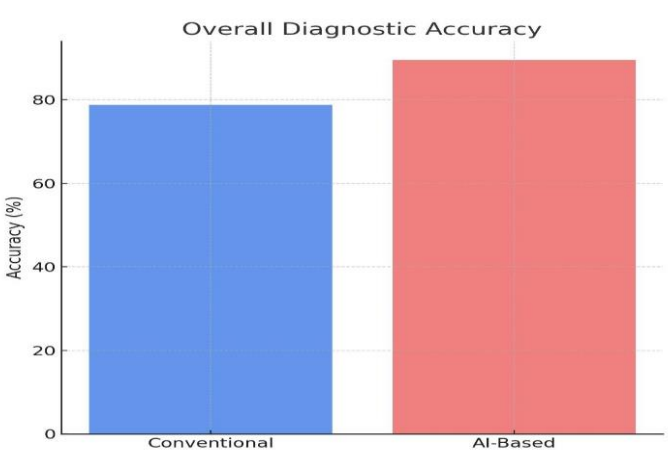

Figure 1 Overall Diagnostic Accuracy

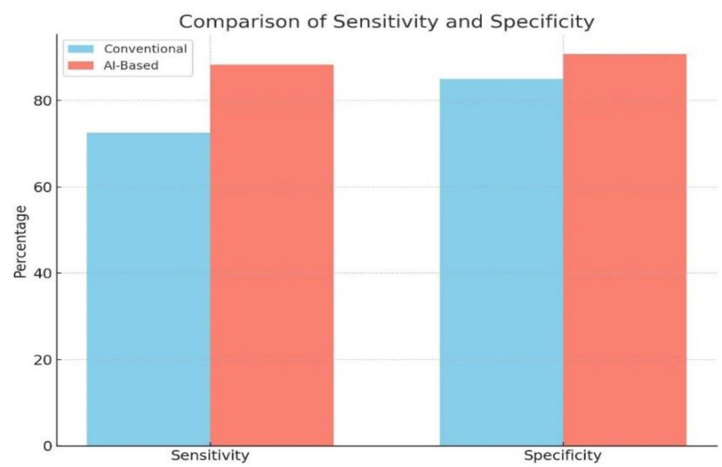

Figure 2 Comparison of Sensitivity and Specificity

DISCUSSION

The findings of this study provide compelling evidence supporting the superiority of AI-assisted diagnostic tools over conventional radiographic interpretation in detecting dental caries in pediatric patients. The significantly higher sensitivity and specificity achieved by the AI model are consistent with prior research that has demonstrated the clinical robustness of deep learning algorithms in dental image analysis. In particular, studies have shown that, convolutional neural networks (CNNs) applied to bitewing radiographs are capable of detecting and segmenting carious lesions with a high degree of precision, often exceeding the performance of experienced clinicians (14-17). The present study's outcome aligns with the broader shift in pediatric dentistry towards leveraging artificial intelligence to mitigate diagnostic inconsistencies and improve early lesion detection. A study highlighted the effectiveness of AI in pediatric applications, with reported diagnostic accuracies as high as 99% in some cases for caries identification (18). This is particularly important in pediatric populations, where early and accurate diagnosis can significantly impact long-term oral health outcomes and reduce the need for invasive interventions (19). A critical strength of this study is its real-world cross-sectional design, using a representative pediatric sample and incorporating both clinician and AI interpretations under typical clinical conditions. This design enhances the external validity and applicability of the findings. Furthermore, the blinded methodology and use of clinical validation as a reference standard provide methodological rigor, reducing the risk of assessment bias. The statistical significance observed in both sensitivity and specificity, validated by McNemar's test, underlines the robustness of the observed performance gap between the two diagnostic approaches.

Nonetheless, limitations of the study should be acknowledged. Firstly, although the sample size was statistically adequate, it may still limit the generalizability of findings to broader pediatric populations, particularly those with more diverse socioeconomic or geographic

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backgrounds. Secondly, the AI system used was based on 2D radiographic analysis, which inherently lacks the depth and detail of 3D imaging modalities. As noted in a study AI performance may vary across different tooth types and anatomical locations, with limitations particularly noted in premolars due to structural complexity and overlapping tissues on 2D images (20,21). Another challenge lies in the interpretability and user trust in AI tools. Despite superior technical performance, some clinicians remain hesitant to rely entirely on automated systems. However, recent studies suggest that, AI-assisted visualization can actually enhance patient understanding and confidence in diagnoses, especially when color overlays or heatmaps are used to highlight lesion areas (22,23). This dual benefit of improved diagnostic accuracy and enhanced communication may further support the integration of AI into pediatric dental practice. Future research should explore AI integration into multi-modal diagnostic systems, potentially combining 2D and 3D imaging with clinical data to further refine diagnostic predictions. Moreover, longitudinal studies assessing outcomes following AI-guided diagnosis and treatment planning would offer insights into the long-term benefits and limitations of such technologies. Finally, considerations around ethical deployment, data security, and practitioner training remain critical as AI becomes more embedded in clinical settings. In conclusion, this study confirms the diagnostic advantage of AI-assisted systems over conventional radiographic interpretation for caries detection in children, reinforcing the potential for these tools to enhance clinical decision-making and improve pediatric oral health outcomes.

CONCLUSION

This study demonstrated that AI-assisted caries detection significantly outperforms conventional radiographic evaluation in terms of diagnostic accuracy, sensitivity, and specificity in pediatric dental patients. The findings underscore the potential of integrating AI tools into routine clinical practice to enhance diagnostic consistency, reduce human error, and support early intervention strategies, ultimately improving pediatric oral health outcomes.

AUTHOR CONTRIBUTION

Author	Contribution
Ayesha Ikram Malik*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Adeel-ur-Rehman	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
Saad Umar	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Zubair	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Zainab Sajjad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ali Ghaffar	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Muhammad Jalil	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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