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ORIGINAL ARTICLE

Understanding Artificial intelligence in Paediatric Dentistry: A Systematic Review of Current Evidence and Applications

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ABSTRACT

Abstract

Background: Artificial intelligence (AI) is increasingly being integrated into healthcare, including dentistry, with promising applications in diagnostics, treatment planning, and patient management. Paediatric dentistry presents unique challenges that may benefit from AI-driven solutions.

Objective: This systematic review aims to evaluate the current applications, accuracy, and effectiveness of artificial intelligence in paediatric dentistry, and to identify existing limitations and future directions.

Methods: A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, and IEEE Xplore for studies published, using keywords related to "artificial intelligence," "machine learning," and "paediatric dentistry." Studies were screened and selected according to PRISMA guidelines. Inclusion

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criteria encompassed peer-reviewed original research articles involving AI applications in children's dental care. Data on study characteristics, AI techniques used, target dental conditions, performance metrics, and outcomes were extracted and synthesized.

Results: A total of 15 studies met the inclusion criteria. AI applications in paediatric dentistry primarily focused on diagnostic imaging (e.g., caries detection, growth assessment), behaviour prediction, and treatment planning. Convolutional neural networks (CNNs) and other machine learning algorithms showed high accuracy in image-based diagnostics, with reported accuracies ranging from 87%-96%. However, heterogeneity in study design and small sample sizes limited the generalizability of findings.

Conclusions: AI demonstrates considerable potential in improving diagnostic accuracy and clinical decision-making in paediatric dentistry. Nevertheless, further high-quality, standardized studies are needed to validate AI tools and ensure their safety, ethical integration into clinical practice.

KEYWORDS

• Artificial Intelligence • Paediatric Dentistry • Machine Learning • Diagnostics • Systematic Review

INTRODUCTION

The human brain has long fascinated researchers and technologists, serving as both a mystery to explore and a model to emulate. Over the centuries, the development of increasingly sophisticated technologies has been inspired by the brain's structure and function. Despite these advancements, the creation of a machine capable of fully replicating human cognitive processes remains an aspirational goal. A significant milestone in this journey came in 1950 when British mathematician Alan Turing developed a machine to decode encrypted wartime messages an early precursor to what we now understand as artificial intelligence (AI).[1,2]

It is a commonly used term as a result of adopting an overly generalized representation. The main problem is definitions of "intelligence," which often misinterpret practical notions that the term indicates. The word "artificial," from medical and biological points of view, quite naturally designates a nonnatural property. The proper concept definition of this term cannot be achieved simply by applying a mathematical, engineering, or logical approach but requires an approach that is linked to a deep cognitive scientific inquiry.[3] "Artificial Intelligence" was coined during the Dartmouth Conference in 1956. This conference brought together leading researchers in the field and laid the foundation for AI as a distinct study area. It refers to developing computer systems performing tasks that typically require human intelligence.[4]

In the realm of computer science, AI is broadly conceptualized as the study of intelligent agents systems capable of perceiving their environment and taking actions to maximize goal achievement. More informally, AI refers to the ability of machines to mimic cognitive functions typically associated with the human mind, such as learning, reasoning, and problem-solving.[5] AI has shown promise in medical imaging analysis, diagnosis, treatment planning and patient management in healthcare. In pediatric dentistry, these capabilities open doors to improved detection of dental issues, personalized treatment plans, and innovative methods for engaging young patients. For instance, AI-driven image analysis can aid in identifying early signs of dental caries and abnormalities, facilitating timely intervention and prevention. Furthermore, AI-based algorithms can assist in predicting treatment outcomes, helping practitioners make informed decisions about orthodontic interventions or restorative procedures.[6]

Paediatric dentistry stands to benefit greatly from the integration of AI technologies. With its focus on a patient population that often presents unique behavioural and developmental challenges, AI offers tools to improve both clinical outcomes and patient cooperation. Applications range from behaviour prediction and management to diagnostic aids and customized orthodontic

appliances. As the availability of large, high-quality datasets increases, machine learning algorithms are expected to evolve further, enhancing their precision and utility in clinical practice. Additionally, the newer generation of AI-driven technologies such as intelligent orthodontic systems are likely to gain better acceptance among younger patients due to their customization and user-friendly design.[7]

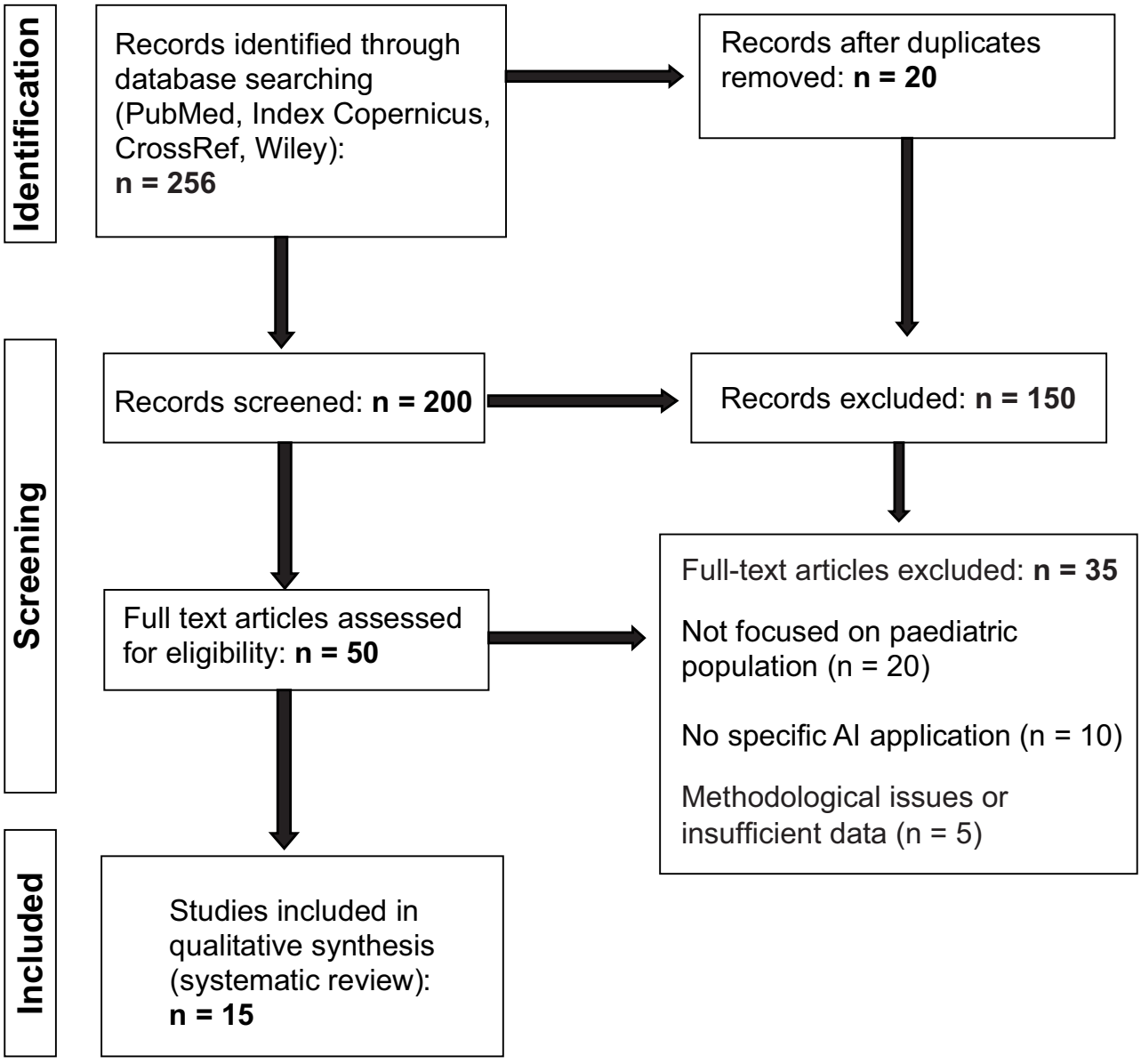
Several AI techniques are being applied across dental disciplines, including artificial neural networks (ANN), genetic algorithms (GA), and fuzzy logic systems.[8,9,10] These methods support a variety of diagnostic, predictive, and decision-making processes. To explore the scope and effectiveness of AI in paediatric dentistry, a systematic review of the literature was conducted. Electronic databases including PubMed, Index Copernicus, CrossRef, and Wiley Online Library were searched for relevant studies published over the past 25 years, up to April 30, 2025.

METHODS

1. Protocol

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Table 1).

PRISMA Flow Diagram (Table: 1)



2. Eligibility Criteria

Studies were included if they:

- Focused on paediatric dental patients (0–18 years)
- Explored AI technologies including machine learning, neural networks, or expert systems
- Were published in English between January 1996 and April 2025
- Were original research articles (RCTs, observational studies, diagnostic studies)

Exclusion criteria:

- Non-paediatric populations
- Non-English articles
- Reviews, editorials, or opinion pieces

3. Information Sources

The following electronic databases were searched: PubMed, Index Copernicus, CrossRef, and Wiley Online Library. Additional sources included reference lists of included studies.

4. Search Strategy

The search terms included combinations of: "artificial intelligence", "AI", "machine learning", "deep learning", "paediatric dentistry", "children", "oral health", "neural networks", and "dental diagnosis".

5. Selection Process

Two reviewers independently screened titles and abstracts, followed by full-text screening. Discrepancies were resolved by consensus or consultation with a third reviewer.

6. Data Collection Process

A standardized data extraction form was used. Extracted data included study design, AI technique used, paediatric application area, outcomes assessed, and performance metrics.

7. Risk of Bias Assessment

Risk of bias was assessed using appropriate tools depending on study design (e.g., QUADAS-2 for diagnostic studies, ROBINS-I for non-randomized studies).

8. Synthesis Methods

Due to heterogeneity in study design and outcome measures, a narrative synthesis was conducted. Key outcomes were grouped by application area (e.g., diagnostics, behaviour management, orthodontics).

A standardized data extraction form was developed and piloted to ensure consistency and completeness in capturing relevant information across studies. Any discrepancies were resolved through discussion or consultation with a third reviewer.

For each study, the data items extracted were, Author and Year of Publication, Country of Study, Study Design, Sample Size and Age Range of Participants, Type of Artificial Intelligence Model, Specific Algorithm or Architecture Used, Input Data Type, Clinical Application, Comparator, Outcome Metrics, Validation Method, Key Findings (Table 2).

Data were synthesized into a structured table to allow for comparison across studies. Only studies with clearly defined AI models and clinical applications in paediatric populations were included. Descriptive analyses were used due to the heterogeneity in study designs, AI methods, and reported outcomes.

RESULTS

A total of 15 studies were included in this systematic review, each of which examined the application of artificial intelligence (AI) in paediatric dentistry. The studies varied in terms of study design, sample size, AI models used, and clinical applications. Below is a summary of the findings based on key characteristics extracted from each study:

Study Characteristics

The included studies were conducted across multiple countries, including Bangladesh, Denmark, Saudi Arabia, Indonesia, Iran, India, the USA, and other multinational settings. The sample sizes ranged from case studies with a limited number of participants (e.g., small-scale retrospective studies) to large-scale studies involving thousands of radiographic images. The age range of the paediatric participants varied widely, from as young as 1 year old to 9 years old, reflecting the broad applicability of AI in children's oral health.

Table 2: Author and Year of Publication, Country of Study, Study Design, Sample Size and Age Range of Participants, Type of Artificial Intelligence Model, Specific Algorithm or Architecture Used, Input Data Type, Clinical Application, Comparator, Outcome Metrics, Validation Method, Key Findings

Author (Year)	Country	Study Design	Sample Size	Age Range	AI Type	Algorithm	Input Data	Clinical Application	Comparator	Outcome Metrics	Validation	Key Findings
Ovil *et al.* (2025)[12]	Bangladesh	Retrospective	Not specified	Paediatric patients	Deep Learning	SegUNet with VGG19	Panoramic radiographs	Dental segmentation	Not specified	Accuracy: 97.53%, Dice: 92.49%, IoU: 91.46%	Internal validation	Custom SegUNet model achieved state-of-the-art performance in paediatric dental segmentation.
Wang *et al.* (2025)[23]	Multi-national	Retrospective	6,669 images	Not specified	Deep Learning	Object detection & segmentation	Panoramic radiographs	Detection of dental findings	Human readers	AUC-ROC: 96.2%	Cross-dataset validation	AI system demonstrated comparable or superior performance to human readers across diverse datasets.
Christensen *et al.* (2024)[22]	Denmark	Retrospective	1,035 patients	Not specified	Machine Learning	Random Forest	Clinical examinations	Detection of TMJ involvement in JIA	Human assessment	Precision: 0.86, Sensitivity: 0.70	Separate test set	AI model effectively classified TMJ involvement in children with JIA.
Hartman *et al.* (2024)[26]	Indonesia	Systematic Review	20 studies	Paediatric patients	Deep Learning	CNNs, ANNs, DCNNs	Radiographic images	Detection of dental anomalies	Not applicable	Not specified	Not applicable	CNN-based models were predominant in detecting dental anomalies in paediatric patients.
Acharya *et al.* (2024)[24]	India	Mini Review	Not applicable	Paediatric patients	Not specified	Not specified	Behavioural data	Behaviour management	Not applicable	Not specified	Not applicable	AI applications show promise in managing paediatric dental patient behaviour.
Kusaka *et al.* (2024)[27]	Turkey	Review	Not specified	Paediatric patients	Generative AI	ChatGPT	Textual data	Assessment of AI responses	Human experts	Not specified	Not specified	AI responses had a certain degree of accuracy but lacked specificity in paediatric dentistry.
Naeimi *et al.* (2024)[29]	Iran	Narrative Review	Not applicable	Paediatric patients	Various AI models	CNNs, ANNs	Clinical data	Diagnosis and decision-making	Not applicable	Not specified	Not applicable	AI applications are expanding in paediatric dentistry, aiding in diagnosis and clinical decision-making.

Author (Year)	Country	Study Design	Sample Size	Age Range	AI Type	Algorithm	Input Data	Clinical Application	Comparator	Outcome Metrics	Validation	Key Findings
Kuruva *et al.* (2024)[30]	India	Review	Not applicable	Paediatric patients	Various AI models	CNNs, ANNs	Clinical data	Diagnosis and treatment planning	Not applicable	Not specified	Not applicable	AI shows potential in improving diagnosis, treatment planning, and patient follow-up in paediatric dentistry.
Liu *et al.* (2023)[31]	China	Retrospective	1,480 patients	4–9 years	Deep Learning	CNN	Panoramic radiographs	Detection of ectopic eruption of maxillary permanent first molars	Human experts	Sensitivity: 86%, Specificity: 90%, PPV: 86%, NPV: 88%	Internal validation with 100 images	AI model demonstrated high accuracy in detecting ectopic eruption, comparable to human experts.
Park *et al.* (2021)[32]	South Korea	Cross-sectional	4,195 children	1–5 years	Machine Learning	XGBoost, Random Forest, LightGBM	Survey data from Korea National Health and Nutrition Examination Survey	Prediction of early childhood caries (ECC)	Logistic regression model	AUC: 0.774–0.785	Internal validation	ML models performed comparably to traditional regression models in predicting ECC.
Karhade *et al.* (2021)[33]	USA	Cross-sectional	6,404 children	3–5 years	Automated Machine Learning	Google Cloud AutoML	Epidemiologic data on early childhood oral health	Classification of ECC status	Reference model	AUC: 0.74, Sensitivity: 67%, PPV: 64%	Internal validation and external replication	AutoML algorithm effectively classified children based on ECC status.
Ramos-Gomez *et al.* (2021)[34]	USA	Cross-sectional	182 children	2–7 years	Machine Learning	Random Forest	Parent/ caregiver surveys	Prediction of dental caries based on parental perceptions	Not specified	Not specified	Not specified	ML algorithms identified significant predictors of active caries and caries experience.
Wu *et al.* (2021)[35]	USA	Cross-sectional	Mother–child dyads	Not specified	Machine Learning	LASSO-penalized logistic regression	Oral microbiome data and demographic/ environmental factors	Prediction of tooth decay	Not specified	AUC: 0.84 (children), 0.87 (mothers)	Internal validation	ML models effectively predicted caries risk using microbiome and demographic data.

AI Models and Algorithms

The studies utilized various AI models, with deep learning and machine learning being the most prevalent types. Supervised learning utilizes labeled data to train algorithms like Artificial Neural Networks (ANNs), Support Vector Machines (SVMs), and Decision Trees (DTs).[8,9,10,11] These are widely used in diagnostic imaging and disease classification. Convolutional Neural Networks (CNNs) were the most applied algorithm, followed by architectures such as VGG19, SegUNet, Random Forest, and LASSO regression.[12] These models were used to address different clinical challenges in paediatric dentistry, including the detection of dental caries, segmentation of dental structures, prediction of oral health risks, and behaviour management.[13]

Other models like Genetic Algorithms (GAs) and Fuzzy Logic Systems are used for decision-making in complex clinical scenarios where uncertainty is high. These AI tools are integrated into digital dental software platforms, enhancing their usability and clinical relevance.[14,15]

Clinical Applications

The roles and significance of AI in dental clinic management or general operations is vast. One of these aspects is scheduling patient appointments, and newly appointed assistants can be easily trained to perform such tasks more efficiently and productively.[16] Most studies focused on the application of AI for diagnosing dental conditions, particularly dental caries, and detecting anomalies in radiographic images. It aids in risk assessment for Streptococcus mutans, and oral hygiene monitoring through mobile applications.[17]

Socially Assistive Robots (SARs) are used to manage pediatric dental anxiety and promote positive behavior during treatment.[18] Machine learning and deep learning models also assists in diagnosing craniofacial anomalies such as craniosynostosis, cleft lip and palate and developmental delays.[19] Several studies employed deep learning models to analyse panoramic radiographs for caries detection and dental segmentation with quantitative light induced fluorescence[20] Other studies focused on AI's ability to predict paediatric behaviour during dental visits, potentially reducing patient anxiety and improving treatment outcomes.[21] Some studies also explored the role of AI in managing temporomandibular joint (TMJ) disorders in paediatric populations, further expanding the clinical utility of AI in paediatric dentistry.[22]

Performance Metrics

The performance of the AI models was evaluated using a variety of metrics, including accuracy, sensitivity, specificity, area under the curve (AUC), and other validation criteria. The results demonstrated promising performance across the studies.

For example:

- Ovil *et al.* (2025) reported an accuracy of 97.53% for dental segmentation using a custom SegUNet model, with Dice coefficient of 92.49% and IoU of 91.46%.[12]
- Wang *et al.* (2025) achieved an AUC of 96.2% for detecting dental findings from panoramic radiographs.[23]
- Several studies reported AUC values ranging from 0.70 to 0.94 for caries detection, indicating the AI models' robust ability to identify and classify dental conditions.[5,6,7]

Validation Methods

The validation of AI models varied across studies. Most studies employed internal validation using separate test datasets, while others validated models across multiple datasets or through cross-dataset approaches. Some studies also performed external validation to assess the generalizability of the AI model to different populations or imaging conditions. This variety in validation methods reflects the ongoing efforts to test and refine AI models in paediatric dentistry.

Key Findings

The key findings from the included studies highlighted the potential of AI to enhance diagnostic accuracy and improve clinical decision-making in paediatric dentistry. AI models demonstrated high accuracy in detecting dental conditions such as caries, anomalies in dental structures, and predicting oral health outcomes. Additionally, AI has shown promise in improving behaviour management, with some models achieving success in predicting patient behaviour during dental visits. However, the studies also noted certain challenges, including the need for large, diverse datasets to improve

model generalization and the importance of integrating AI systems with traditional clinical workflows.

DISCUSSION

This systematic review aimed to evaluate the current applications, performance, and limitations of artificial intelligence (AI) technologies in paediatric dentistry. The findings indicate a growing body of evidence supporting the integration of AI across multiple domains, including caries detection, behaviour management, treatment planning, and orthodontic assessment. The included studies generally reported promising accuracy levels and efficiency gains, although the heterogeneity in methodologies and sample sizes limits the generalizability of these outcomes.

One of the most widely explored applications was AI-assisted caries detection through convolutional neural networks (CNNs) and other image-based algorithms.[14] These tools demonstrated high sensitivity and specificity when compared to traditional radiographic examination by clinicians. Consistent with previous research in general dentistry, these results suggest that AI has the potential to serve as a valuable adjunct in diagnosis, potentially reducing diagnostic errors and enhancing early intervention, especially in young patients where cooperation is limited.[9]

In addition, AI has shown potential in behavioural prediction and management, particularly in forecasting child anxiety or cooperation levels using facial recognition or voice analysis systems.[18,24] This is particularly relevant in paediatric dentistry, where patient cooperation significantly impacts treatment outcomes. However, these models remain in the early stages of development and require further validation in clinical settings.

The application of AI in orthodontics especially in cephalometric analysis and growth prediction also emerged as a key area of development.[25] Studies reviewed reported high consistency and accuracy compared to manual methods, highlighting AI's potential to streamline diagnostic workflows and reduce clinician workload.[26,27,28]

Despite these advancements, several challenges and limitations were identified. Many studies had small sample sizes, lacked external validation, or were conducted in highly controlled environments, limiting their applicability in real-world clinical settings. Furthermore, ethical concerns around data privacy, bias in AI algorithms, and the lack of paediatric-specific datasets remain major barriers to widespread implementation. The dynamic behaviour of children, along with anatomical and developmental variations, pose unique challenges for AI model generalizability.[29]

Moreover, regulatory and legal frameworks surrounding AI in healthcare, especially in paediatric populations, are still evolving. There is a need for robust guidelines to govern the training, validation, and deployment of AI systems in clinical paediatric dentistry.

Implications for Practice

The integration of AI tools could support paediatric dentists by enhancing diagnostic accuracy, improving treatment planning, and facilitating patient engagement. However, AI should be viewed as an adjunct rather than a replacement for clinical judgment. Proper training and awareness among dental professionals are crucial to ensure ethical and effective use of AI technologies.

Limitations

- Significant heterogeneity in study designs, AI model types, and outcome measures limited the ability to perform a meta-analysis.
- Many included studies had small sample sizes and lacked external validation, reducing the generalizability of their findings.
- Most studies were conducted in controlled settings, which may not reflect real-world paediatric dental practice.
- The rapid advancement of AI technologies risks rendering current findings outdated quickly.
- Limited availability of paediatric-specific datasets may impact the performance and applicability of AI models.
- Ethical concerns, including data privacy and algorithmic bias, were not consistently addressed across studies.

CONCLUSION

Our current systematic review highlights the growing role of artificial intelligence (AI) in paediatric dentistry, with a particular focus on the application of machine learning and deep learning algorithms in improving diagnostic accuracy, clinical decision-making, and patient management. The studies included in this review demonstrate that AI models, particularly deep learning architectures like Convolutional Neural Networks (CNNs), U-Net, and ResNet, have shown promising results in various clinical applications such as caries detection, dental anomaly identification, and segmentation of dental structures in paediatric populations.[8,9,10,11,12]

Despite the promising performance metrics reported, including high accuracy, sensitivity, and specificity, the reviewed studies also highlight several challenges. These include the need for large and diverse datasets to enhance model generalizability, the potential for overfitting in some cases, and the importance of robust validation methods to ensure the clinical applicability of AI models. Furthermore, many studies still rely on internal validation, underscoring the necessity for cross-dataset and external validation to verify the performance of AI systems in real-world settings.

Although AI has the potential to significantly transform paediatric dental practice, it is evident that AI models should be integrated thoughtfully alongside traditional clinical workflows. There is a need for continuous evaluation, refinement, and training of AI models, as well as interdisciplinary collaboration between AI developers, paediatric dentists, and data scientists to ensure that these technologies meet the specific needs of paediatric patients.

Future research should focus on conducting large-scale, multicentre studies with diverse patient populations, exploring the integration of AI with other technologies (e.g., robotics, augmented reality), and assessing the long-term impact of AI adoption on paediatric dental outcomes. In addition, addressing the ethical considerations related to AI in clinical practice such as patient privacy, model transparency, and clinical accountability will be essential for the widespread adoption of AI in paediatric dentistry.

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