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Code Meets Care: AI's Role In Shaping Pediatric Oral Health

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Abstract
Artificial Intelligence (AI) has undergone a paradigm shift from rule-based algorithms to advanced machine learning and deep neural networks, enabling unprecedented capabilities in healthcare diagnostics, decision support, and personalized treatment planning. In pediatric dentistry, AI applications—ranging from caries risk assessment and age estimation to CBCT image analysis and behavior prediction—are increasingly aligning with evidence-based clinical protocols. These technologies promise enhanced diagnostic accuracy, reduced operator variability, and improved patient outcomes. However, their integration into routine pediatric dental practice faces significant challenges, including limited pediatric-specific datasets, algorithmic bias, ethical concerns, and infrastructural constraints. Simultaneously, the rapid adoption of digital tools and smart devices contributes to the growing burden of electronic waste (e-waste), raising sustainability and environmental health concerns. Addressing these dual imperatives—clinical efficacy and ecological responsibility—requires a strategic framework that promotes validated AI use, clinician training, and green technology practices within pediatric dentistry.
Keywords: *AI models, Pediatric Dentistry, Machine learning, Deep learning, Convolutional Neural Network, E-Waste, AI toolkit, AI approaches.*

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I. Introduction

Artificial Intelligence (AI) has rapidly advanced, enabling machines to replicate human intelligence through data analysis. With the rise of digital devices, AI efficiently processes vast datasets and performs complex tasks across industries such as robotics, finance, and smart systems. In healthcare and dentistry, AI is increasingly used for diagnostics, treatment planning, and digital support. This review article outlines AI's evolution, its applications & alignment with evidence-based pediatric dentistry, current implementation challenges, concept of E-waste and recommendations for use. [1,2]

AI An Overview

According to Stevenson (2010), Artificial Intelligence (AI) is defined as "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision making, and translation between languages[3].It encompasses the ability of machines to learn, reason, perceive, interpret, communicate, and make decisions—often equalling or surpassing human performance [4].

With the introduction of the first mechanical calculating machine by French mathematician and inventor Blaise Pascal[5] in 1642, Artificial intelligence was never far out of reach. Alan Turing in 1950 proposed that humans solve problems and make decisions by utilising available information and inference, machines also can do the same thing in his paper "Computing Machinery and Intelligence[2]. The term AI was first proposed in a 2-month workshop: Dartmouth Summer Research Project on Artificial Intelligence led by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon[6]. AI had two major developments:

1980 - Machine learning and expert system
2012 - Graphics processing unit (GPU)-implemented deep learning (DL) network with eight layers

In 2022 the launch of ChatGPT (Chat Generative Pre-trained Transformer) by OpenAI recieved extensive discussion as it is a text-generation model that can generate human-like responses based on text input[6].

The rise of machine learning and deep learning has marked a major milestone in the evolution of artificial intelligence. Deep learning is a specialized subset of machine learning, though not all machine learning techniques fall under deep learning. Machine learning focuses on creating algorithms and statistical models that can be trained to produce specific outcomes based on input data. This allows computers to learn from experience and improve their decision-making capabilities without the need for explicit programming[7].

Deep learning, in particular, utilizes neural networks inspired by the architecture of the human brain. These networks are capable of processing vast amounts of raw data—such as images, sounds, and text—and automatically identifying relevant features to generate predictions or decisions. A typical neural network consists of multiple layers: an input layer, one or more hidden layers, and an output layer. Information flows through these layers via a process called forward propagation, ultimately producing the desired output[7].

AI has two primary types: narrow AI and general AI. Narrow AI, often called weak AI, is designed to excel in specific tasks, such as language translation, image recognition or autonomous driving. It operates within well-defined bound aries and focuses on optimizing performance within those limitations. Conversely, artificial general intelligence, often referred to as strong AI, refers to AI systems with the capacity to understand, learn, and utilize knowledge across various tasks similar to human intelligence. Despite being a theoretical concept, general AI remains an active area of research and discovery[8]

AI In Healthcare

Despite being a relatively new technology, AI is increasingly being used in various medical specialties to diagnose diseases, interpret results, and help healthcare providers achieve positive patient outcomes. AI search in health care can be divided into two types virtual and robotic. The virtual type deals with mathematical algorithms and the robotic type supports the physical part of healthcare systems[9]

In dentistry AI has made notable strides in recent years. Clinically, AI applications are generally categorized into four main domains: diagnosis, decision-making, treatment planning, and outcome prediction.

Among these, diagnostic use remains the most prevalent. AI-powered tools have shown the capacity to enhance diagnostic speed and accuracy, helping to ease the burden on dental practitioners. Consequently, dentists are increasingly relying on intelligent systems to aid in clinical decision-making. These technologies continue to evolve—becoming more dependable, precise, and adept at handling complex clinical tasks within dental settings[2], across branches of dentistry[10].

AI In Pediatric Dentistry

Early detection, timely management, and preventive strategies are pivotal to ensuring optimal oral health in children.[1] The integration of artificial intelligence (AI) into healthcare has facilitated the development of advanced programs that support clinicians in diagnosis, treatment planning, and outcome prediction.[2] In the context of global health challenges, oral diseases continue to affect a substantial pediatric population[5]. Addressing these conditions through early intervention remains central to promoting overall well-being. In recent years, AI has evolved rapidly, extending its influence into domains traditionally governed by human expertise. Although complex to define, AI broadly refers to machine-based algorithms capable of performing cognitive tasks such as reasoning, learning, and decision-making[6].

AI In Pediatric Developmental Milestone

Artificial Intelligence is transforming how pediatric developmental milestones are monitored, offering a more precise, efficient, and data-driven approach to assessing a child's growth. By integrating AI with clinical expertise, healthcare professionals can now evaluate developmental progress using diverse data sources such as medical records, parental input, wearable devices, and sensor-based technologies. This innovation enables early identification of potential delays and supports timely interventions, ultimately improving long-term outcomes.AI in pediatric developmental milestone tracking offers numerous benefits[10]:

- Objective and Standardized Assessment: AI eliminates human bias by automating milestone evaluation, replacing manual observation with consistent, data-driven analysis.
- Multisource Data Integration: It processes vast datasets—including medical histories, video recordings, and sensor inputs—to deliver accurate developmental assessments.
- Consistency and Reliability: Automated tracking ensures uniformity across assessments, reducing variability in interpretation and documentation.

- Early Detection of Delays: Continuous monitoring allows AI to flag subtle deviations from typical developmental trajectories, enabling prompt intervention.
- Insightful Pattern Recognition: AI identifies trends and correlations that may be overlooked by human observers, offering valuable clinical insights.
- Personalized Guidance: Based on individual developmental profiles, AI recommends targeted activities and interventions to support optimal growth.
- Enhanced Parental Engagement: Parents receive actionable feedback and can actively participate in their child's developmental journey, fostering collaboration with clinicians.
- Remote Monitoring via Telehealth: AI-powered platforms facilitate virtual assessments, benefiting families in rural or underserved regions by saving time and resources.
- Support for Research and Evidence-Based Practice: Aggregated data from AI systems can uncover developmental patterns and inform future research, contributing to improved pediatric care protocols[10].

Steps In Pediatric Developmental Milestone Tracking

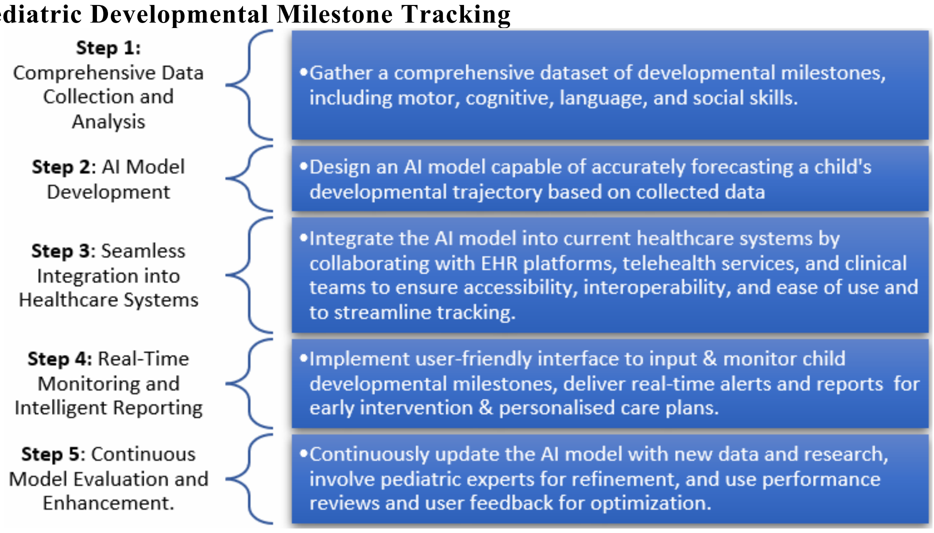

Figure 1 :Structured overview of AI in Developmental milestone tracking [10]

AI In Behavioural Management

The disciplines of behavioral science and AI have a deep historical relationship. Early mechanistic views held that human behavior is based on fixed rules, which could allow for simulation via AI. It can support behavior change by facilitating personalized recommendations and experiences. In general, personalized interventions work better than generic ones and are more likely to prompt sustained behavior change over time. This is likely because people perceive personalized interventions as more relevant. Personalization can also encourage the initiation and sustenance of new behaviors via motivational pathways[11].

AI for child behavior management uses the information and abilities they gained during dental school. Pediatric dentists are essential in diagnosing and treating dental conditions affecting children. However, modifying the child's behavior is frequently necessary to treat these illnesses safely and efficiently. It requires a range of interactions, with a focus on teaching and communication, between the patient, parent, dental team, and dentist. The objectives include reducing fear and anxiety and promoting awareness of the value of preserving optimal oral health and the steps required [12].

Table 1: Traditional methods vs AI based innovations in Behavioural Management

Aspect	Traditional Methods	AI-Based Innovations
Approach to Behavior	Dentist-led strategies like *tell-show-do*, modeling, and verbal reassurance	AI systems use personalized engagement, predictive behavior modeling, and virtual interfaces
Engagement Tools	Physical demonstrations, non-digital distractions, clinician interaction	AR/VR platforms, gamified apps, virtual reality exposure therapy (VRET), and smart behavior monitoring tools
Anxiety Reduction	Sedation, parental presence, voice control, familiarity through repeated visits	VRET, immersive environments, and emotion-aware systems reduce fear non-invasively
Customization	Dependent on clinician's intuition and experience	AI adjusts content based on patient profiles, anxiety levels, and prior responses
Outcome Consistency	Varies by practitioner skill and patient mood	Provides repeatable, measurable outcomes with data-driven insights
Education & Empowerment	Relies on posters, storytelling, dental models	AI uses interactive games, apps, videos, and augmented learning tools to improve understanding
Ethical	Minimal technological concerns; focus on	Raises concerns about data privacy, screen overuse, and

Considerations	consent and trust	reduced human connection
Clinical Integration	Already integrated into standard care	Requires equipment, technical support, and training; not universally accessible yet

AI In Diagnosis And Treatment Planning

The use of AI in dentistry has expanded significantly, encompassing a broad spectrum of applications, ranging from diagnostic radiology to complex procedural planning. The capability of AI systems to emulate the pattern recognition skills of human radiologists has dramatically enhanced diagnostic accuracy and efficiency. The ability of AI to automate the quantification, analysis, and visualisation of dental imaging has revolutionised traditional practices, offering new insights into tooth growth, decay, bone structure, and soft tissue conditions. Furthermore, the potential of AI to develop personalized treatment plans, analyse dental images for disease detection, and design dental resto rations through computer-aided design (CAD) systems under scores its transformative impact on dental healthcare[7].

Artificial Intelligence (AI) is transforming pediatric dentistry by introducing powerful, child-focused innovations. It significantly improves how patient data is collected, structured, and used—ultimately enhancing the quality and personalization of dental care for children and adolescents. In this specialized area, AI has become a valuable asset, offering targeted support that aligns with the unique needs of young patients and modernizing pediatric dental practice[12].

Table 2: AI contributions in Diagnosis and treatment planning[12]

Domain	AI Contribution	Benefits for Paediatric Care
Data Management	Organizes dental records and histories	Enables fast, tailored treatment planning for each child
Automation	Uses chatbots for scheduling, billing, and communication	Eases clinic workload and enhances parent experience
Diagnosis Support	Analyzes X-rays and intraoral images	Increases accuracy in detecting caries and oral conditions
Decision Support	Recommends treatments based on patient data	Facilitates informed, individualized care planning
Education Tools	Develops child-friendly educational resources	Improves understanding and engagement from children and their parents
Predictive Analytics	Identifies risk patterns (e.g., caries, malocclusion)	Enables early, preventive interventions tailored to paediatric needs
Remote Monitoring	Tracks oral hygiene via smart toothbrushes or devices	Encourages proactive responses from both caregivers and clinicians
Research and Development	Analyses paediatric clinical trial data	Speeds up development of age-specific dental treatments
Engagement	Offers interactive digital platforms	Promotes collaboration among children, parents, and dental care teams

AI In Oral Health Assessment

Oral health is generally not given much emphasis by humans, and not even the majority of people receive an annual oral examination. This is particularly valid in developing and poor nations. To address these issues, the WHO created an oral health questionnaire for both adults and children. A research team's goal was to develop oral health evaluation toolkits that could accurately predict the children's oral health status index (COHSI) and referral for treatment needs (RFTN) by utilizing Machine learning[13].

Some oral hygiene toolkit /technology of importance include Patient-Reported Outcome Measurement Information System {PROMIS} framework, short form questionnaire tool kit by wang et al., Internet of things (IoT) Technology. These offer a ground-breaking chance to transform early preventive and education approaches, encouraging proactive dental hygiene. They can completely change the way dental care is provided and encourage lifelong practices for the best possible oral hygiene through real-time data collection, sophisticated analytics, and tailored interventions[12].

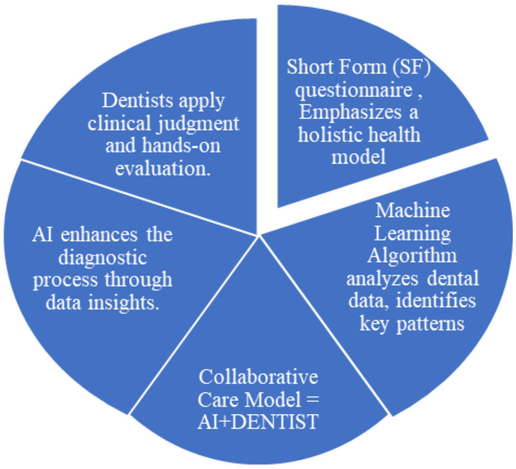

Figure 2: Steps for assessing child's oral health[12]

Dentists, parents, and even children might utilize the ML-based toolkit findings to determine whether a patient needs dental treatment and to determine their current oral health status. To effectively address the need for clinical AI solutions, dental education must also promote digital literacy among future dental professionals[14].

AI In Tooth Detection And Anomalies

AI's influence extends to precise tooth numbering and charting, enhancing the accuracy of patient records and treatment planning. In one study, tooth detection and numbering using CNN on periapical radiographic images, achieved an impressive accuracy of 98.67%, providing valuable insights into precise tooth localization. AI's capabilities also play a crucial role in prognosis prediction, providing valuable insights into individual tooth health[15].

Dental pathology detection and tooth type categorization are crucial yet often error-prone and time-consuming tasks in dental diagnostics. In dental image processing, the application of deep learning holds considerable promise for improving the diagnostic accuracy and treatment planning, allowing complex tasks such as tooth recognition, categorization, and segmentation to be executed with unprecedented precision[16].

In recent years, with the ease of accessing data and the development of computers with faster processing power, artificial intelligence (AI) technologies have advanced, and expert systems have evolved into data-oriented AI applications. In particular, the increase in the successful performance of deep learning methods, especially in image-based diagnostic tasks. Unlike traditional machine learning methods, deep learning can learn features like image, audio, and video processing to natural language processing, simultaneously by automatically extracting features from raw data symbols instead of learning with rules. In addition to these flexible structures, prediction accuracy can increase according to the size of the data[17].

A notable advancement in pediatric dentistry was achieved with the creation of an AI model which can accurately identify dental defects, tooth count, and eruption patterns through radiographic analysis—marking a first-of-its-kind innovation in the field[12].

Table 3: Comparative Table: Manual vs. AI-Based Approaches in Pediatric Dental Anomaly and Tooth Identification[18]

Diagnostic Area	Traditional (Manual) Approach	AI-Driven Approach
Tooth Segmentation	Done visually by clinicians using radiographs or intraoral exams	Deep learning models (e.g., CNN) segment teeth with precision from radiographic or photographic images
Mesiodens Detection	Identified manually via clinical signs or panoramic imaging	Detected early using single-model deep learning algorithms
Tooth Counting (Deciduous Teeth)	Counted during physical exams or via manual review of radiographs	Automatically counted using CNN-based analysis on dental images using Faster R-CNN integrated with the GoogleNet Inception v2 architecture
Ectopic Eruption Identification	Diagnosed over time through routine observation and radiographs	Accurately identified through AI models trained on first molar eruption patterns
Cephalometric Landmark Tracing	Manually traced on X-rays or digital cephalograms by orthodontists	AI systems (e.g., R-CNN) pinpoint landmarks faster and with greater consistency than manual methods

AI In Chronological Age Assessment

Recently, owing to the increased computation power and the evolving algorithm, artificial intelligence (AI)-assisted approaches have been introduced into the field of DA assessment. The reported results retrieved from either machine learning (ML) or the convolutional neural network (CNN) have shown their abilities to come up with more accurate estimations. AI-assisted modalities were able to lift off the long-standing dilemma resulting from population diversities in DA assessment after establishing the AI-assisted standard that successfully overcame the population-related limitations observed with traditional methods[19].

Recent AI advancements now combine digital pantomographs with specific tooth and bone features, enhancing age estimation accuracy for children aged 4 to 15 and marking a significant shift from conventional techniques[12,16].

A novel AI-based method was developed using tooth and bone markers to estimate chronological age with exceptional precision, significantly outperforming manual assessments and achieving near-complete metric accuracy. Updated dental maturity scores were tailored to the target population, enhancing cultural specificity and enabling more accurate age estimation across ethnic groups. Machine learning models detected age prediction and Convolutional neural networks (CNNs) detected age delays in both genders. The approach also enabled reliable age estimation in cases of incomplete dentition by integrating both qualitative and quantitative data, thereby improving accuracy through the use of diverse anatomical markers[12].

AI In The Detection Of Dental Plaque

AI offers potential for ongoing monitoring of oral hygiene status. Advances in machine learning and deep neural networks have accelerated the development of computer vision technologies. In particular, image processing techniques have played an important role in analyzing medical images in a wide variety of ways. Among image processing techniques, image segmentation is the classification of each pixel in an image. Each pixel of an image with similar characteristics is divided into meaningful regions[20].

By capturing changes in plaque accumulation, it empowers dental professionals to deliver personalized oral care guidance and tailor preventive interventions to each child's needs. One of the key strengths of the AI system lies in its ability to rapidly process and analyze a large volume of dental images. This accelerates clinical workflows, enabling more frequent and comprehensive evaluations. By facilitating early detection and tracking of plaque over time, the model supports proactive implementation of preventive strategies[16].

Table 4: Comparative Table: Manual vs. AI-Based Approaches in the detection of dental plaque[16]

Aspect	Traditional Methods	AI-Based Approaches
Detection Techniques	Visual inspection, dental explorer, disclosing agents, or autofluorescence	Deep learning models (e.g., CNN, YOLOv7) analyse intraoral images for automated plaque detection
Tools / Input	Explorers, dye-based solutions (often leave stains and taste unpleasant)	Digital intraoral images, mobile apps, web platforms, real-time detection systems
Accuracy	Varies by clinician skill; can miss early/subtle deposits	Yüksel et al. (2023): 82% accuracy, 84% sensitivity; Lee et al. (2024): best real-time performance with YOLOv7
Patient Experience	May involve discomfort or unpleasant taste; not always child-friendly	Non-invasive, visually engaging, especially useful in children through image-guided analysis
Outcome Consistency	Subjective; results can vary with fatigue, experience, and technique	Consistent and reproducible results once trained; reduces diagnostic variability
Processing Speed	Time-consuming, especially with charting and revealing solutions	Fast and scalable; real-time plaque identification possible (e.g., Lee et al.)
Data Management	Manual recording or charting	Platforms can store, organize, and manage patient data with AI-generated findings
Key Studies & Tools	Explorer/Disclosing Agents (traditional benchmarks)	You et al.: CNN-based detection using 886 images – Yüksel et al.: DL model with high performance – Lee et al.: YOLOv7 with app integration for real-time and remote assessment
Limitations	Aesthetic issues from dyes; subjective accuracy; limited sensitivity	Dependent on image quality; some AI models are opaque in decision-making; require validation and retraining

AI In Early Childhood Caries

The application of Artificial Intelligence (AI) in pediatric dentistry has introduced ground-breaking opportunities, particularly in alleviating the global impact of early childhood caries (ECC)—a widespread yet preventable oral health concern. ECC affects millions of children across the globe, contributing to substantial health, developmental, and economic burdens[21].

AI enables consistent and unbiased diagnostic capabilities, minimizing human error and subjectivity, and can even forecast the progression of caries by evaluating key risk indicators such as age, nutrition, and oral hygiene practices. Recent innovations in AI have shown remarkable promise in facilitating early detection of ECC by harnessing diverse datasets. Machine learning (ML), through algorithms that identify intrinsic statistical patterns and data structures, can extrapolate previously unknown insights[22].

AI-driven systems can segment dental structures, detect carious lesions, and produce predictive analytics. Within pediatric dentistry, these tools are instrumental in diagnosing common conditions like dental cavities by interpreting radiographic and intraoral imagery, while also contributing to patient education initiatives for children[17].

Models utilizing dental radiographs and intraoral photographs have demonstrated impressive accuracy in identifying caries, and predictive algorithms assist in recognizing high-risk populations by analyzing demographic data, behavioral patterns, and genetic predispositions. AI-integrated smartphone applications, such as AI Caries, equip caregivers with accessible tools for home-based caries screening, thereby improving reach and promoting preventive strategies[21].

AI In Pediatric Restorative Dentistry

Artificial Intelligence (AI) is revolutionizing pediatric restorative dentistry by enhancing diagnostic accuracy, procedural efficiency, and esthetic outcomes. With its transformative capabilities, AI offers powerful solutions across diagnosis, prognosis, and treatment planning. Conventional restorative approaches often encounter challenges such as variability in clinician expertise, limited resources, and the inherently subjective nature of clinical decision-making—all of which can result in inconsistent patient care. These limitations highlight the value of AI-driven systems, which deliver consistent, data-informed, and highly precise support throughout the restorative process[15].

Also at the forefront is AI-integrated CAD/CAM technology, which enables rapid, accurate design and fabrication of restorations tailored to a child's dental anatomy. This not only shortens treatment time—vital for young patients—but also enhances comfort and clinical outcomes. Additionally, deep learning models analyze dental radiographs to extract fine anatomical details, aiding in conservative caries removal and minimally invasive tooth preparation[16].

Within dental biomaterials research, machine learning models enable the analysis of extensive datasets to pinpoint materials with superior durability, biocompatibility, and esthetic properties—driving the development of next-generation restorative solutions[15].

AI empowers clinicians to make more informed decisions regarding the prioritization of restorative procedures by predicting treatment outcomes. Advanced AI models can distinguish between different types of dental restorations by analysing gray-scale values in dental radiographs. Moreover, the integration of complex algorithms—such as neural networks and decision tree models—has notably enhanced the precision of dental shade matching[23].

AI is emerging as a transformative force, revolutionizing both clinical and administrative domains with exceptional efficiency. Administratively, it automates appointment scheduling, ensures precise record-keeping, and delivers personalized treatment reminders—optimizing workflow management, especially in pediatric care settings. Clinically, AI powered by Convolutional Neural Networks (CNNs) demonstrates remarkable proficiency in the early detection of complex oral health conditions, enabling timely interventions and promoting cost-effective treatment strategies[15].

AI In Local Anesthesia

Artificial Intelligence (AI) is markedly improving the precision and safety of local anaesthesia administration in paediatric dentistry. AI-assisted pain management, combined with the use of 4D goggles and virtual reality technologies for effective behaviour modulation, can be seamlessly integrated into chairside procedures to enhance patient comfort and cooperation[15].

By processing and improving sonographic images, AI algorithms increase the clarity and visibility of anatomical structures, helping clinicians accurately identify target injection sites. This enhanced imaging facilitates more precise anesthesia delivery, reducing the likelihood of complications.

Beyond clinical accuracy, AI-guided anaesthesia improves the overall patient experience. With more targeted injections, patients often experience less discomfort, quicker recovery, and fewer side effects. This contributes to greater confidence in the procedure's safety and effectiveness, ultimately fostering a more positive attitude toward dental visits—especially important in young patients[16].

AI In Interceptive Orthodontics

In interceptive orthodontics, AI-powered tools are revolutionizing treatment planning by enabling precise analysis of cephalometric radiographs and 3D scans, leading to optimized treatment outcomes. For instance, machine learning algorithms have been developed to predict tooth movement trajectories and suggest personalized treatment plans for patients undergoing appliance therapy[15].

One of the most researched tasks is automated lateral cephalogram landmark detection. As the eventual aim of landmark detection is to derive clinically useful diagnoses (e.g., classification of growth types) that help guide treatment decisions, end-to end AI applications have been developed to directly classify lateral cephalograms based on clinically relevant diagnoses. Moreover, AI can help not only to diagnose growth findings but also to detect contraindications for appliance therapy, like the presence of active carious lesions, apical lesions, or periodontal bone loss[24].

AI–AR (Artificial Intelligence-Augmented reality) synergy enables the design of highly personalized appliances by analyzing large datasets and simulating treatment outcomes in real time. This approach is especially appealing to younger patients due to its aesthetic focus and interactivity. Remote monitoring capabilities via AR-enabled apps further enhance care delivery, allowing patients to send progress images and receive virtual guidance—minimizing clinic visits without compromising quality[16].

AI In Oral Health Education

As part of a pediatric oral health awareness initiative, QR code scanning stations can be strategically placed in dental clinics, schools, and healthcare centers to promote early screening and education. These QR codes would link directly to a pediatric dental app that functions as a comprehensive tool for assessing child oral health using AI-powered dental scans. The app can generate instant screening reports, monitor disease progression, and provide tailored follow-up reminders and post-operative instructions[8].

To support daily oral hygiene, the app can offer personalized guidance, brushing tutor videos for pre-schoolers, and interactive games that teach proper techniques in a fun and engaging way. Enhancing the dental clinic experience, the app can collect feedback, facilitate appointment scheduling, and deliver educational content to both parents and children. For behavioural modification, it can include dentist-child cartoons and story-based animations that help reduce anxiety and improve cooperation during dental visits.

In cases of dental trauma, the app must provide immediate first-aid instructions, including how to handle an avulsed tooth—advising storage in milk, saline, or saliva—and guiding caregivers on urgent steps to take before reaching a paediatric dentist. This integrated approach not only improves access to care but also empowers communities with the knowledge and tools needed to support children's oral health from an early age[25].

Other Applications Of Ai In Pediatric Dentistry

AI facilitates early and remote screening for dental caries and oral cancers using intraoral photographs and autofluorescence probes, enabling disease prevention, accurate diagnosis, and effective triaging of high-risk and low-risk populations without the need for trained personnel.

In forensic dentistry, AI estimates age from radiographs and performs facial reconstruction via lateral cephalograms, enhancing remote workflows.

AI interprets digital radiographs and CBCT scans to detect caries, assess bone loss, measure root canal length with exceptional precision, and evaluate the morphology of roots and canal systems in endodontics.

High-resolution biopsy images can be captured and remotely analysed by AI-assisted pathologists, while AI also aids in decision-making for restorative procedures such as fillings, prostheses, orthodontic planning, and treatment simulations.

Tools like Dental Monitoring allow remote observation of tooth movement and appliance fit, while AI-driven systems send reminders for appointments, medications, and payments, thereby enhancing patient compliance and support.

Feedback mechanisms powered by AI include adaptive form-based questionnaires for patient satisfaction, emotion recognition via convolutional neural networks (CNNs) to assess engagement, predictive models analysing no-show patterns to forecast future visits, and social media crawling—such as on Twitter—to extract insights into patient experiences.

Additionally, CNNs can detect and classify pit and fissure sealants from intraoral photographs, and Quantitative Light-Induced Fluorescence (QLF) technology can assess microleakage in sealants by measuring maximum fluorescence loss, offering a non-invasive and precise evaluation method[26].

Artificial Intelligence (AI) is reshaping tele dentistry by enhancing remote screening, diagnosis, triaging, record-keeping, and patient monitoring through smart devices. This streamlines routine care, allowing dental professionals to prioritize complex cases. Importantly, AI extends dental services to underserved areas, promoting broader access and equity. By supporting a shift toward preventive, personalized care, AI also benefits from integrated, multi-channel feedback systems that continuously evaluate and improve the quality of remote dental services[19].

Table 5: Advantages And Disadvantages Of Ai In Pediatric Dentistry[16]

Aspect	Advantages	Disadvantages
Early Detection	Identifies Subtle Delays In Speech, Motor, And Social Behaviors For Timely Care	May Lack Emotional Connection Needed To Build Rapport With Children
Diagnostic Accuracy	Enhances Precision Via Large-Scale, Data-Driven Analysis	Relies On Pediatric-Specific Datasets, Which Are Time-Consuming To Develop
Customized	Generates Individualized Care Plans Based On	Raises Ethical Concerns Around Privacy,

Interventions	Developmental/Dental Profiles	Consent, And Algorithmic Transparency
Operational Efficiency	Automates Routine Tasks Like Image Analysis And Scheduling	Requires Clinician Training And May Disrupt Existing Workflows
Preventive Potential	Predicts Risks (E.G., Caries, Malocclusion) For Proactive Treatment	Smaller Practices May Struggle With Adoption Due To Limited Resources
Patient Engagement	Uses Interactive Tools To Improve Communication With Children And Caregivers	Involves Sensitive Data, Increasing Privacy And Consent Risks
Cost & Accessibility	Optimizes Resources, Reduces Delays, Improves Long-Term Outcomes	High Initial Investment In Software, Hardware, And Integration Infrastructure
Data Quality & Integrity	Supports Accurate Assessments Via Standardized Analysis	Poor Data Input Can Lead To Misdiagnosis Or Ineffective Interventions
Treatment Planning	Provides Tailored Suggestions Based On Ai Interpretation Of Clinical Data	Requires Frequent Updates And Regulatory Compliance
Data Management & Security	Streamlines Recordkeeping And Supports Evidence-Based Decisions	Demands Stringent Protection Of Sensitive Pediatric Data
Infrastructure Equity	Offers Scalable Solutions For Underserved Populations	May Be Inaccessible In Low-Resource Or Rural Settings

AI's Hidden Footprint: A Rare But Rising Concern

While most conversations around AI focus on ethics, bias, or automation, E-Waste is quietly becoming one of its most tangible environmental consequences.

- Hardware dependency: Generative AI models rely on high-performance computing**-** GPUs, TPUs, CPUs, memory modules, and storage devices. These components have short lifespans (2–5 years), leading to frequent upgrades and disposal.
- Data centers & carbon load: AI-driven data centers consume vast energy and require constant cooling and hardware refreshes. This contributes not only to e-waste but also to **carbon emissions and water usage**, compounding the environmental burden.

AI AS A SOLUTION TO E-WASTE: Ironically, AI also offers tools to combat the very problem it contributes to:

- Smart Waste Management: AI can automate **sorting and recycling**, identifying reusable components and hazardous materials. It supports **predictive maintenance**, extending device lifespans and reducing premature disposal.
- Circular Economy Enabler: AI helps track material flows, optimize logistics, and design **modular, upgradeable electronics**. It can guide **eco-design** strategies for future devices, making them easier to repair and recycle.

Despite its significance, this topic remains niche because:

- Sustainability discussions in AI often focus on energy and emissions, not hardware turnover.
- E-waste is seen as a hardware issue, while AI is viewed as software-driven.
- There's limited cross-disciplinary dialogue between AI developers, environmental scientists, and policymakers[27,28]**.**

II. Conclusion

The adoption of Artificial Intelligence (AI) and machine learning is accelerating across pediatric dentistry, offering innovative solutions to longstanding clinical challenges. By streamlining complex procedures and delivering consistent, data-driven outcomes, AI enhances both efficiency and quality of care.

However, AI systems often require sophisticated infrastructure and substantial initial investment. While their integration into pediatric dentistry is still emerging, rapid advances in research are driving continuous progress.

Artificial Intelligence offers transformative potential and following reccomendations can be considered to ensure effective integration:

- Ensure Data Integrity: Use accurate, diverse data and safeguard privacy.
- Foster Collaboration: Engage clinicians, AI experts, and caregivers.
- Support Personalization: Tailor systems to individual developmental trajectories.
- Promote Transparency: Make AI decisions explainable and clinician-friendly.
- Enable Continuous Improvement: Use real-world feedback for ongoing refinement.
- Prioritize Ethics: Uphold informed consent, fairness, and human-centered care[14]

Crucially, human expertise remains indispensable. Regardless of how advanced AI becomes, the empathy, clinical judgment, and hands-on skills of dental professionals are vital—especially in treating children. AI should therefore be embraced not as a replacement, but as a powerful complement to human-centered care[16].

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