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EDITORIAL

Artificial intelligence in Dentistry: Clinical Impact and future perspectives

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Keywords: Artificial intelligence; dentistry; digital dentistry; digital smile design; matching learning; dental implants; prosthodontics.

ABSTRACT

Artificial intelligence (AI) has shifted from being a promise to becoming a tangible reality across dental domains imaging diagnostics, orthodontics, endodontics, periodontics, implantology, prosthodontics, and digital lab workflows offering AI-augmented workflows that promise precision, predictability, and equity. Yet, the gap between "laboratory accuracy" and real-world clinical effectiveness persists. This editorial synthesizes current advances, limitations, and future directions for responsible adoption.

Key words
Artificial intelligence; dentistry; digital dentistry; digital smile design; matching learning; dental implants; prosthodontics.

Where Does AI Contribute Today?

Dento-maxillofacial imaging.

Deep learning algorithms have demonstrated strong performance in segmentation, caries detection, and bone-loss quantification. For example, an AI model for mandibular segmentation reached a 96% success rate and 83% accuracy in 3D reconstructions, non-inferior to trained human operators, suggesting automation feasibility in digital surgical workflows.[1]

Caries detection in intraoral photographs.

Systematic reviews confirm that CNNs and single-stage detectors (e.g., YOLO) can detect caries in clinical images with promising accuracy, yet methodological heterogeneity and small, poorly annotated datasets remain issues, highlighting the need for standardized datasets and reporting.[2,3,4]

Endodontics.

AI applications for detecting periapical lesions, fractures, and resorptions, predicting outcomes, and assisting execution (e.g., 3D segmentation and Grad-CAM interpretability) show near-term impact in diagnosis and education, though widespread clinical adoption is still limited.[5,6,7]

Periodontics.

AI has shown capability in identifying periodontally compromised premolars and molars with accuracies of around 90%–95%, supporting diagnostic and treatment planning in periodontal disease.[8]

Implantology.

AI models analyzing CBCT images have shown about 96% accuracy in identifying edentulous zones in the mandible and 83% for the maxilla crucial for implant planning. AI also assists in segmenting alveolar bone and mandibular canals, decision support for drilling protocols, and guided surgery, significantly improving speed and precision.[9,10,11]

Prosthodontics & Digital Design (CAD/CAM, Lab workflows).

AI is enhancing prosthetic design extracting finish lines with 97% precision, simulating smile outcomes, optimizing crown morphology, material selection, and aesthetic planning. AI-driven CAD/CAM workflows, aided by intraoral scanners and 3D printing, streamline design and fabrication with higher accuracy, reduced human error, and faster delivery.[12,13,14]

Smiles and esthetic planning.

AI-powered digital smile design, analyzing facial features (symmetry, lip line, tooth form), enables personalized esthetic planning and patient engagement. Tools like AI-driven cloud platforms offer photorealistic simulations and efficient interdisciplinary collaboration.[15]

How Models Are Being Developed

The field has matured from “proof-of-concept” to better practices: methodological reviews in cariology report deficiencies in image curation/annotation, data splitting, data leakage, and result reporting; they recommend standardized datasets, external validation, and clinically relevant metrics (not only AUC).[3]

Two emerging strategies may accelerate translation:

1. **Auto Matching-Learning and reproducible pipelines,** which democratize development with rigor comparable to experts and shorten experimentation timelines.[16]
2. **Open datasets and reference benchmarks.** The publication of annotated intraoral image sets (e.g., for caries detection) enables comparability and benchmarking, necessary for multicenter trials and regulatory approval.[2]

Barriers and Risks to address

Three bottlenecks explain why many models are not yet “chairside”:

- **Generalizability and external validity.** Models trained on single-center data risk degraded performance when deployed; solutions include multicenter datasets, geographic validation, and federated learning.[1,6,3]

- **Transparency and explainability.** Tools like Grad-CAM and probability mapping aid human interpretability—critical in endodontics and other diagnostic domains.[5]

- **Ethics, privacy, equity.** Risks include biased performance, data ownership ambiguity, and consent gaps. Ethically integrating governance, robust consent, and algorithmic impact assessments is essential.[1,3]

Emerging Trends

- **Multimodal clinical assistants**, integrating CBCT, photographs, occlusal scans, and clinical records into cohesive AI-supported planning.[13]

- **AI-augmented teledentistry**, including smartphone-based caries or lesion detection for screening and follow-up in underserved areas.[8]

- **Regulatory safety frameworks (SaMD).** Adoption of Good Machine Learning Practices and change-control plans for continuously learning models will be critical for clinician confidence and regulatory compliance.[17]

Call to Action

For AI to move from "paper" to practice, dentistry must: (1) co-design studies addressing clinically meaningful problems and hard outcomes, (2) share high-quality, standardized datasets and annotations, (3) report with transparency (protocols, code, data splits), (4) demand external validation and clinical impact evaluation, and (5) adopt ethical-regulatory frameworks from inception. The aim is not to replace clinical judgment but to enhance it with tools that reduce variability, free time, and improve patient outcomes.

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