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Review article (narrative review)

Artificial Intelligence in Dentistry: Applications in Modern Diagnosis, Treatment and Dental Business Management

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Abstract

Background and objective: Artificial intelligence (AI), particularly deep learning, is moving from research into routine dental practice. This narrative review synthesises current evidence on AI in modern dental diagnosis, treatment and dental business management, and appraises the barriers to safe adoption.

Methods: Targeted searches of PubMed-indexed and publisher-hosted literature, together with South African regulatory sources, were carried out in October 2026 using combinations of terms for AI, deep learning, dentistry, diagnosis, treatment planning, practice management and ethics. Systematic reviews, randomised and diagnostic accuracy studies, ethics frameworks and legal instruments were prioritised and synthesised narratively.

Results: Diagnostic evidence is strongest for radiographic caries detection, periodontal bone loss assessment and oral lesion screening. In these tasks, convolutional neural networks matched or exceeded dentists on controlled datasets, and one randomised trial showed improved sensitivity for enamel caries. In treatment, AI supports restorative diagnosis, cephalometric analysis and implant planning, although much of the evidence is preclinical and of low certainty. Business applications such as scheduling, claims preparation and patient communication are expanding quickly but rest mainly on non-peer-reviewed sources. Limited generalisability across centres, a risk of overtreatment, sparse ethical reporting and data-protection duties remain major concerns.

Conclusion: AI is best positioned as a supervised decision-support tool. Prospective multicentre trials, transparent reporting and compliant data governance are needed before routine reliance.

Keywords: Artificial intelligence; deep learning; dentistry; diagnostic imaging; practice management; dental ethics

1. Introduction

Artificial intelligence refers to machines performing tasks that normally require human intelligence. The term dates to the 1950s, but the recent growth of data and computing power has made practical applications possible [1]. Within AI, machine learning builds predictive models from data, and deep learning, most often using convolutional neural networks (CNNs), has proved especially effective at analysing images [1]. Because dentistry generates large volumes of radiographs, intraoral photographs, three-dimensional scans and clinical records, it is a natural setting for these methods.

Dental diseases such as caries and periodontitis are among the most prevalent conditions worldwide and impose a substantial burden on patients and health systems [2]. Digital dentistry now covers far more than computer-aided design and manufacturing. It extends to diagnostics, decision-making, treatment delivery, re-evaluation and the lifelong management of oral health [2]. Advocates envisage a more predictive, personalised, preventive and participatory form of care in which AI relieves clinicians of laborious routine tasks and widens access at lower cost [1,2].

The literature has grown quickly. A systematic review of 43 studies found that most dental AI research relies on CNNs and artificial neural networks, and that the reported performance of these systems is often comparable to that of trained specialists [3]. Nevertheless, a gap remains between published accuracy and robust clinical application. Industry-driven tools in imaging and computer-aided manufacturing are already in use, whereas AI for diagnostics and treatment planning has often remained closer to concept than to routine practice [2]. Ethical issues have also received little attention. A scoping review of 178 studies found that only 22 (12.4%) mentioned any AI-related ethical concern [4].

A further and less examined area is the business side of dentistry. Large language models and related tools may change the work of administrative staff and the delivery of dental telemedicine more than they change chairside care [5]. For a private practitioner, these are practical questions about workflow, cost, patient communication and legal compliance, not only technical ones.

The objective of this review is therefore threefold: (i) to summarise the evidence for AI in dental diagnosis; (ii) to describe its applications in treatment planning and delivery and in dental business management; and (iii) to identify the methodological, ethical and regulatory challenges that clinicians must weigh before adopting these tools, with attention to the South African context.

2. Materials and Methods

2.1 Study design

This is a narrative review. A narrative design was chosen because the topic spans heterogeneous study types, from diagnostic accuracy studies and randomised trials to ethical frameworks, legal instruments and practice-management commentary, which cannot be pooled quantitatively. No meta-analysis was attempted and no formal risk-of-bias scoring was applied.

2.2 Literature search

Targeted searches were carried out in October 2026 across PubMed and PubMed Central, publisher-hosted journal pages, professional association publications, and South African legal and regulatory sources. Search terms combined the following concepts with Boolean operators: “artificial intelligence”, “machine learning”, “deep learning”, “convolutional neural network”, “large language model”, “dentistry”, “caries”, “periodontal”,

“oral cancer”, “orthodontic”, “implant”, “practice management”, “ethics” and “Protection of Personal Information Act”.

2.3 Selection and appraisal

Systematic reviews, randomised trials, diagnostic accuracy studies, consensus checklists and ethics frameworks published in English were prioritised. Primary studies were included when they illustrated a clinically meaningful application or a methodological limitation. Practice-management material from professional associations was included to describe current applications, and is identified as non-peer-reviewed where it is discussed. Studies were considered against the reporting recommendations for dental AI research developed by the ITU/WHO focus group and the IADR e-oral health network [6], with particular attention to the independence of test data, comparison with clinicians and reporting of external validation.

2.4 Synthesis

Findings were grouped into three domains (diagnosis, treatment, and business management), followed by cross-cutting challenges (generalisability, ethics and regulation). Results are summarised narratively and in tabular form.

2.5 Ethical approval and consent

This review analysed published literature only. No human participants, patient data or animal subjects were involved, and ethical approval and informed consent were therefore not required.

3. Results and Discussion

3.1 AI in modern dental diagnosis

Diagnosis is where dental AI is best evidenced, because radiographs and photographs suit image-based deep learning and because reference standards can be built by expert annotation.

Caries detection. Cantu et al. trained a U-Net CNN on 3,686 bitewing radiographs annotated pixel by pixel by four dentists and compared it with seven independent dentists [7]. The network reached an accuracy of 0.80 against a mean of 0.71 for the dentists, and kept sensitivities of 0.70 or higher for both initial and advanced lesions. Almost all of the dentists had sensitivities below 0.25 for initial lesions [7]. These figures come from a controlled test set, so they show potential rather than chairside benefit. A cluster-randomised crossover trial then tested AI assistance with 22 dentists, each assessing 20 bitewings with and without a commercial caries-detection package [8]. AI support improved sensitivity for enamel caries but did not markedly improve it for dentin lesions [8]. Because earlier detection only helps if it leads to appropriate management, the trial also classified each detection by the treatment chosen (none, non-invasive, micro-invasive or invasive), and reports of the study note that greater sensitivity may come with more invasive decisions [8]. Overtreatment is therefore a real risk that has to be monitored when such tools enter practice.

Periodontal disease. Krois et al. applied a CNN to 2,001 segments of panoramic radiographs and found discrimination at least similar to that of six dentists for periodontal bone loss [9]. DeNTNet, trained on 12,179 panoramic radiographs, detected bone loss and also reported the affected tooth numbers, achieving an F1 score of 0.75 against 0.69 for dental clinicians [10]. Such systems could shorten radiographic review and support consistent staging, but both studies were retrospective.

Oral cancer and potentially malignant disorders. Deep learning has been applied to ordinary clinical photographs, including smartphone images, for early detection. Warin et al. trained classification and detection networks on 980 oral photographs and reported areas under the curve of 1.00 for oral squamous cell carcinoma (OSCC) and 0.98 for oral potentially malignant disorders with their best model [11]. Flügge et al. reported an accuracy of 0.986 and an AUC of 0.99 for a Swin-transformer model on a test set of 141 clinical photographs [12]. These results are striking, yet the test sets were small and drawn from limited sources. In a general dental practice, where such lesions are uncommon, the predictive value of a positive result would also depend on prevalence. Prospective validation is needed before these tools can inform referral decisions.

Application	Study	Data and design	Main finding
Proximal caries, bitewings	Cantu et al. [7]	3,686 bitewings; U-Net CNN vs 7 dentists	Accuracy 0.80 vs 0.71 (dentist mean); sensitivity of 0.70 or higher for initial and advanced lesions
Caries detection with AI assistance	Mertens et al. [8]	Cluster-randomised crossover; 22 dentists, 20 bitewings	Higher sensitivity for enamel caries; no marked gain for dentin lesions
Periodontal bone loss, panoramic	Krois et al. [9]	2,001 image segments; CNN vs 6 dentists	Discrimination at least similar to dentists
Periodontal bone loss and tooth numbering	Kim et al. [10]	12,179 panoramic radiographs	F1 0.75 vs 0.69 for clinicians
Oral lesions, photographs	Warin et al. [11]	980 photographs (OSCC, OPMD, normal)	AUC 1.00 (OSCC) and 0.98 (OPMD) for the best model
OSCC, photographs	Flügge et al. [12]	1,406 photographs; Swin transformer	Accuracy 0.986 and AUC 0.99 on 141 test images

Table 1. Representative diagnostic studies of AI in dentistry. OSCC, oral squamous cell carcinoma; OPMD, oral potentially malignant disorders; AUC, area under the curve.

Generalisability. The most important caution concerns transfer between settings. Krois et al. trained models to detect apical lesions on panoramic radiographs from one German centre and tested them on images from an Indian centre [13]. The F1 score fell from 54.1% on the home data to 32.7% on the external data, and aligning image characteristics did not fix the problem, although training on images from both centres improved performance [13]. A vendor's reported accuracy is therefore not a guarantee for a particular practice, its equipment or its patient mix.

Economic value. A health-economic model suggests that AI-supported proximal caries detection is likely to be cost-effective, mainly because fewer lesions go undetected [14]. A later trial-based evaluation from the same group found AI-supported detection significantly more sensitive and suggested that cost-effectiveness could improve further if AI also supported the management decision that follows detection [15].

3.2 AI in treatment planning and delivery

Evidence for AI at the treatment stage is thinner than for diagnosis. Much of it measures technical accuracy against expert labels rather than patient outcomes, and AI for treatment planning has often stayed nearer to concept than to routine use [2].

Restorative dentistry. A systematic review of AI in restorative dentistry identified models for caries diagnosis and for detecting vertical tooth fracture, among other tasks, and called for further studies of clinical performance [16]. The practical value lies in a second reading that can flag subtle findings, while the decision to restore remains with the clinician.

Orthodontics. Automated cephalometric landmark detection is the most reviewed orthodontic application, and a systematic review with meta-analysis has compared deep learning with manual landmarking [17]. Automation can standardise tracing and save chairside time. Decisions on extraction, growth modification and treatment sequencing still depend on clinical judgement and on the patient's goals.

Implant dentistry. A systematic review of implant planning described AI models that detect bone, the maxillary sinus, neural structures and teeth on imaging, with evidence of improved precision and predictability compared with conventional methods, and noted links with navigation and robotic systems [18]. For the general practitioner, these tools are most useful for faster segmentation and a checked, editable plan. They do not replace surgical experience, and a plan should be verified against the scan before use.

3.3 AI in dental business management

Beyond the surgery, AI is entering the administrative core of the practice. A professional association review describes AI-assisted appointment scheduling, coding, billing and claims processing, patient data management and electronic prescribing, including systems that audit billing statements and claims in real time [19]. Large language models (LLMs) may affect administrative personnel, such as office staff and insurance claims processors, and the delivery of dental telemedicine, while having less effect on hands-on clinical work [5]. Their potential uses include text summarisation, drafting, clinical decision support and multilingual communication, which could reduce language barriers for patients [5]. The same authors warn that LLMs sometimes give incorrect answers or present misinformation as fact [5].

Function	Typical AI application	Evidence base	Principal caution
Scheduling and recall	Automated booking, reminders, call handling	Association commentary [19]	Integration with practice software; patient consent for messaging
Billing and claims	Coding support, pre-submission checks, denial follow-up	Association commentary [19]	Human review of codes; the practice remains accountable for each claim
Patient communication	Chat assistants, multilingual messages, summaries	Expert overview of LLMs [5]	Incorrect or invented content; no clinical advice without clinician review
Clinical documentation	Drafting notes and letters from dictation	Expert overview of LLMs [5]	Accuracy checks; confidentiality of what is entered

Table 2. Business-management applications of AI in dental practice and the evidence behind them.

In the sources reviewed, claims of time saved or revenue gained come from association and commercial material, and no controlled evaluation of practice-level outcomes was identified. This is a clear research gap. Economic evaluation should also follow the chain of decisions downstream, as the caries studies show, because the value of a tool depends on what it changes in treatment and cost [15].

Legal duties in South Africa. Business tools handle exactly the information that South African law protects most strictly. The Protection of Personal Information Act 4 of 2013 (POPIA) treats information on a person's health as special personal information, and its processing is prohibited unless an exception in section 27 applies [20]. The Information Regulator published Regulations on the processing of health information in March 2026. They restate the general prohibition, require appropriate technical and organisational safeguards and a duty of confidentiality, and bar transfer of health information to a third party in another country unless one of the conditions in section 72 of the Act is met [21]. Health practitioners must also read POPIA together with the National Health Act and the Health Professions Council of South Africa (HPCSA) guidelines on confidentiality [22]. In practice, a practitioner who uses a cloud-based AI scheduler, scribe or chatbot should establish where patient data are stored and processed, whether the vendor will use the data to train its models, and what the patient has been told and has agreed to.

3.4 Cross-cutting challenges and the way forward

Ethics and reporting. Ethical analysis has lagged behind technical progress. The scoping review of 178 studies identified 45 ethical issues in 22 studies, spread across six principles: prudence, equity, privacy, responsibility, democratic participation and solidarity [4]. The ITU/WHO topic group on dental diagnostics and digital dentistry has since published an ethics framework and checklist to help developers and researchers evaluate dental AI applications [23]. A companion checklist sets out what dental AI studies should report, from independence of test data to comparison with clinicians [6]. Using these documents would help readers judge whether a published accuracy figure deserves trust.

Human oversight. Trustworthiness and generalisability must be assured, and continuous human oversight and standards grounded in evidence-based dentistry should be expected [1]. Present evidence supports AI as a decision-support aid, not an autonomous decision-maker.

Practical implications for the clinician. The evidence reviewed above points to five measures:

1. Ask whether a product has been validated externally on images resembling your own patients and equipment [13].
2. Treat output as a second opinion, and record your own clinical reasoning [1].
3. Audit treatment decisions after adoption, to detect any drift towards overtreatment [8].
4. Confirm POPIA compliance, data location and vendor terms before any patient information is processed [20,21].
5. Tell patients when AI contributes to their care, in line with the transparency and privacy principles in ethics frameworks [4,23].

Limitations of this review. This is a narrative review based on targeted rather than exhaustive searches, restricted to English-language sources, with no formal quality scoring. Practice-management evidence is largely non-peer-reviewed. The field is also moving quickly, so individual products and regulations may change after the search date. The conclusions should be read with these limits in mind.

Future directions. Priorities include prospective, multicentre trials with patient-relevant outcomes rather than detection accuracy alone, evaluation of AI that supports management decisions as well as detection [15], routine external validation [13], transparent reporting against agreed checklists [6], and controlled evaluations of AI in practice administration.

4. Conclusion

AI is already useful in dentistry, but its value differs by domain. In diagnosis, the evidence is strongest for radiographic caries detection, periodontal bone loss assessment and oral lesion screening, where deep learning performs well on controlled datasets and has improved enamel caries sensitivity in a randomised trial. In treatment, applications in restorative dentistry, orthodontics and implant planning are promising but rest mainly on technical accuracy, not on patient outcomes. In business management, tools for scheduling, claims and communication are spreading faster than the evidence that supports them.

Three conditions should govern adoption: external validation in the setting of use, because performance does not transfer reliably between centres; clinician oversight, because greater sensitivity can bring overtreatment; and strict data governance, because South African law treats health information as special personal

information. Used within these limits, AI can act as a second reader and an administrative assistant that frees clinicians for the work that only they can do.

Declaration of Conflicting Interests

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