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# Artificial Intelligence Teaching Tools for Undergraduate BDS Students: A Narrative Review

Gaganpreet Kaur[1], Subhashree Sahoo[2*], Priyadarshini B. G.[3], Natasha Gambhir[4], Priyanka Sachdeva[5], Divya Singh[6], Shriya Srivastava[7]

[1]*Undergraduate Student, Bachelor of Dental Surgery, Santosh Dental College, Ghaziabad, Uttar Pradesh, India – 201009*

[2]*Senior Lecturer, Department of Pediatric and Preventive Dentistry, Santosh Dental College, Ghaziabad, Uttar Pradesh, India – 201009*

[3]*Senior Lecturer, Department of Periodontics and Oral Implantology, Santosh Dental College, Ghaziabad, Uttar Pradesh, India – 201009*

[4]*Professor and Head, Department of Pediatric and Preventive Dentistry, Santosh Dental College, Ghaziabad, Uttar Pradesh, India – 201009*

[5]*Reader, Department of Pediatric and Preventive Dentistry, Santosh Dental College, Ghaziabad, Uttar Pradesh, India – 201009*

[6]*Reader, Department of Pediatric and Preventive Dentistry, Santosh Dental College, Ghaziabad, Uttar Pradesh, India – 201009*

[7]*Postgraduate Student, Department of Pediatric and Preventive Dentistry, Santosh Dental College, Ghaziabad, Uttar Pradesh, India – 201009*

***Corresponding Author:** Dr. Subhashree Sahoo*
*Senior Lecturer, Department of Pediatric and Preventive Dentistry, Santosh Dental College, Ghaziabad, Uttar Pradesh, India – 201009*

***Abstract***
*Introduction: Artificial intelligence (AI) is increasingly being explored as a teaching, training, and assessment aid in undergraduate dental education. However, diagnostic accuracy of an AI system should not be assumed to indicate educational effectiveness.*
*Methods: This narrative, non-systematic review discusses literature published from 2021 to 2026 on AI-based instructional tools in undergraduate and preclinical dental education. It considers AI-assisted case generation, AI-supported radiographic training, explainable AI, large language models used in assessment, and relevant digital-learning comparisons. Studies focused solely on clinical algorithm performance are treated as background rather than direct evidence of educational benefit. A reproducible systematic search and formal study-selection process were not documented; therefore, the review does not claim to be exhaustive.*
*Results: The available studies suggest potential benefits for diagnostic accuracy, sensitivity, engagement, and perceived learning, particularly among less experienced learners and when AI-generated material is reviewed by faculty. Findings are inconsistent: some AI-assisted tools did not improve performance and could encourage automation bias. Evidence is predominantly short-term and based on small or heterogeneous studies.*
*Discussion: AI tools may be useful as adjuncts to faculty-led teaching and hands-on practice, but evidence for long-term knowledge retention and clinical competence remains insufficient. The narrative approach and limited primary evidence restrict the certainty of conclusions. Larger, multicentre studies using validated educational outcomes and longer follow-up are needed.*
*Keywords: Artificial intelligence; Dental education; Undergraduate dental students; Generative artificial intelligence; Large language models; Digital learning; Educational effectiveness.*

***Key Messages***

- *AI-based teaching tools show promise as supplementary resources for case-based learning, diagnostic reasoning, and assessment in undergraduate dental education.*
- *Educational benefits must be evaluated independently of AI diagnostic accuracy, with faculty supervision and safeguards against automation bias.*
- *Larger, multicentre studies are needed to establish long-term knowledge retention, clinical competence, and the effectiveness of AI-integrated dental curricula.*

# I. Introduction

***1. Introduction***

***1.1 Rationale***

Although AI in dentistry has been widely discussed in relation to clinical diagnosis, its role as a direct teaching and assessment resource for undergraduate dental students requires separate consideration. Educational effectiveness, learner perceptions, and risks such as automation bias are distinct from the technical accuracy of an algorithm.

***1.2 Objective and review question***

The objective of this narrative review is to describe current applications of AI-based tools in undergraduate dental education and critically discuss the available evidence on learning-related outcomes, comparisons with conventional teaching, student and faculty perceptions, limitations, and future research needs. The population of interest is undergraduate or preclinical dental learners; the interventions are AI-based teaching, training, or assessment tools; comparators, where reported, include conventional teaching or non-AI digital learning; outcomes include diagnostic performance, perceived learning, engagement, assessment quality, and clinical competence; and the evidence includes educational studies and relevant reviews.

Dental education has traditionally relied on didactic lectures, preclinical practice on manikins or extracted teeth, and supervised clinical work, structured around a recurring cycle of instruction, demonstration, practice, and evaluation. [1,4] That model works, but it runs up against limited faculty time, uneven exposure to cases, the workload involved in preparing case material, and inconsistency between examiners marking the same work. [1,4] Over the past decade AI has moved well past a narrow research interest: machine learning, deep learning, convolutional neural networks and, most recently, large language models such as ChatGPT are now being actively trialled in dental schools. [5,6]

Much of the published work on AI in dentistry still centres on diagnostic performance in clinical settings, detecting caries, periodontal bone loss, apical lesions, cephalometric landmarks, oral malignancies and the like. [5,6] A separate and growing strand looks at AI differently: not as decision support for practising clinicians, but as a teaching instrument used directly within BDS programmes to build diagnostic reasoning, procedural skill and case-based thinking in students who are still training. This review focuses on that emerging literature, with particular interest in generative-AI case creation, AI-supported radiographic training platforms, explainable AI, and LLMs used in assessment.

For the purposes of this review, an AI-based educational tool is a teaching, training or assessment resource in which a machine-learning component, such as a large language model, a convolutional neural network or a segmentation model, generates content, labels images, gives feedback or marks student work. General digital learning resources, and immersive technologies such as conventional virtual reality, haptic simulators and virtual-patient platforms, are not AI tools in themselves. They are discussed only where an AI element is identifiable or where they provide a useful comparison, and the AI component is identified wherever it is discussed.

Two questions are also kept apart throughout. The first is how accurately an AI system performs a diagnostic or assessment task; the second is whether using that system improves what students learn or how competent they become. Good algorithmic performance does not automatically translate into better learning or clinical competence, so evidence on AI diagnostic accuracy is presented as background and is not treated as evidence of educational effectiveness.

***1.1 Search approach***

1.3 Methods and search approach

This article is a narrative, non-systematic review of literature published between 2021 and 2026 concerning AI-based instructional, training, and assessment tools in undergraduate and preclinical dental education. The review was organised around the following question: how have AI-based teaching and assessment tools been used in undergraduate dental education, and what evidence is available regarding student learning, diagnostic performance, perceptions, and limitations?

Eligibility considerations: Literature was considered relevant when it described an AI-based teaching, training, or assessment application involving undergraduate or preclinical dental students, or closely related health-professions students, and reported educational use or outcomes. Literature addressing clinical diagnostic performance without an educational application was used only to provide technical background. Relevant contextual reviews of digital and immersive learning were included where they helped distinguish AI-specific effects from those of non-AI technologies. The review focused on English-language publications from 2021 to 2026, as reflected in the literature discussed in this manuscript; any additional language or publication-status restrictions were not systematically recorded.

Information sources and search strategy: The manuscript draws on the studies and reviews cited in the reference list. A complete database-by-database search log, exact search dates, reproducible Boolean strategies, and the date of the last search were not retained. Accordingly, no claim is made that all eligible studies were identified. Terms relevant to the topic include "artificial intelligence," "generative artificial intelligence," "ChatGPT," "large language model," "explainable AI," "dental education," "undergraduate," "BDS," "preclinical," "case-based learning," and "radiographic training." These terms describe the concepts addressed but should not be interpreted as a verified, reproducible electronic search strategy.

Study selection and data synthesis: Selection was purposive and narrative rather than a formal, duplicate screening process. The manuscript does not have a complete record of the number of records identified, duplicates removed, full texts assessed, or reasons for exclusion; therefore, a PRISMA-style flow diagram and numerical study-selection counts cannot be reported reliably. Information was summarised narratively by educational application and outcome. No formal risk-of-bias tool was applied by the authors of this narrative review; methodological concerns reported by the cited reviews are described where relevant. Diagnostic accuracy of an AI model was kept distinct from evidence that students learn more effectively or demonstrate improved clinical competence.

### *2. AI-Assisted Case Generation for Case-Based and Small-Group Learning*

One of the most immediate uses of generative AI in undergraduate dental teaching is writing case-based learning (CBL) material. Malpe Gopal et al. piloted a hybrid case-based learning/small-group teaching (CBL-SGT) format for second-year BDS students studying haematology, using ChatGPT-4o to draft case vignettes, clinical images and structured descriptive questions tied to the curriculum. [1] The AI-generated material went through a three-stage generation-assessment-modification process, with four subject experts reviewing it independently before it reached students, a workflow in line with the commonly held view that generative AI output should receive human sign-off before it is used for teaching. [1]

Seventy-two students, in small groups of seven or eight, worked through the AI-generated cases individually before joining faculty-led cross-group discussion. Post-activity and post-assessment questionnaires (Cronbach's alpha 0.95) returned favourable mean Likert scores, 4.01 to 4.26 out of 5, across study-material quality, perceived learning value, exam readiness, team interaction, engagement and faculty facilitation. [1] Ninety-two percent of students wanted similar AI-assisted CBL sessions extended to other subjects. Thematic analysis of faculty feedback kept surfacing the same three points: how much time the AI-generated cases saved, how authentic they generally felt, and the non-negotiable need for a human to check the work; unrevised scenarios sometimes missed learning objectives or read as "a little vague." [1] This small pilot, whose outcomes were mainly questionnaire-based perceptions rather than measured learning gains, suggests that generative AI may be useful mainly as a productivity aid for faculty preparing teaching materials, rather than as a direct tutor for students, provided that expert review is kept in place as a quality check. It does not demonstrate improved learning.

### *3. AI-Based Platforms for Diagnostic Skill Training*

#### *3.1 Radiographic caries detection*

A second strand of work trains students' own diagnostic ability using AI-generated feedback or AI-labelled material. Nagyová et al. ran a controlled comparison of three teaching methods for bitewing caries detection in 52 dental students at different stages of training: a prerecorded lecture, a dentist-annotated dataset standing in for case-based instruction, and a web-based AI tool generating bounding-box predictions of carious lesions (an ensemble of RetinaNet-SwinT, Faster R-CNN-ResNet50, YOLOv5-M and RetinaNet-R101 models) with an adjustable confidence threshold. [3] All three methods were associated with statistically significant gains in diagnostic accuracy, sensitivity and reduced annotation errors relative to baseline. [3] The outcome measured here is the students' own diagnostic performance, not the accuracy of the AI models themselves.

Comparing groups, dataset-based training was associated with the largest gains in sensitivity and F1 score, ahead of the lecture group, while the AI-trained group cut average errors the most but with more uneven, less predictable results between individuals, possibly because the way students engaged with the AI tool was more self-directed and less controlled. [3] The benefit also shrank with clinical experience: preclinical students improved the most and most variably, while senior clinical students, already performing near qualified-dentist level, showed no significant improvement. [3] AI-based diagnostic training, may therefore be most useful earlier in the curriculum, before pattern-recognition skills are already well developed, although this rests on a single study of 52 students and needs confirmation.

#### *3.2 Explainable AI and AI-enhanced radiographic imaging in periodontal training*

Explainable AI (XAI), which shows labelled or highlighted regions of interest rather than acting as a black box, has been tested directly as a teaching aid at undergraduate level. Glick et al. (summarised in a systematic

review by Wei et al.) randomly assigned third- and fourth-year students to identify furcation involvement on radiographs, either unaided or with AI-generated labels from a purpose-built U-Net segmentation model. [4] AI assistance was not associated with gains in accuracy, efficiency or confidence and, more worryingly, students given AI assistance were more likely to accept incorrect AI suggestions, which is consistent with automation bias appearing in a training context. [4] Boehm et al. found something similar comparing a commercial AI-enhanced imaging tool (Overjet) with standard viewing software for spotting periodontal bone loss in novice and more experienced predoctoral students: both groups improved with training, but the AI tool gave no statistically significant edge over conventional software, though novices gained more than their more experienced peers. [4] Together these findings suggest that simply adding AI predictions to training images may not automatically improve undergraduate learning outcomes, and may introduce risks that need to be taught against explicitly. These trials compared student performance with and without AI input, so they speak to educational effect rather than to the accuracy of the underlying AI models, which is a separate question.

***4. Immersive Digital Technologies and Their Relationship to AI***

Haptic VR, 360-degree VR and virtual-patient platforms are immersive simulation technologies rather than AI tools in themselves. They are included because the systematic review by Wei et al. examined them alongside AI in periodontal education [4], and because AI can be built into such platforms, for example to drive virtual-patient dialogue, adapt scenario difficulty or provide automated performance feedback. Unless a specific AI component is stated, the findings below reflect the effect of immersive simulation rather than of AI and should not be read as evidence that AI-based teaching is effective. [Authors: identify the AI component, if any, of each platform named below from the primary studies.]

A related and growing area of AI-adjacent work involves immersive digital tools: force-feedback (haptic) VR, 360-degree VR environments and simulated virtual patients. In a systematic review of 15 studies (3,062 participants) on AI and immersive technologies in periodontal education, Wei et al. found that haptic VR simulators (PerioSim, Haptodont, iDental, UniDental) were associated with improved procedural skills such as probing-force control and scaling/root-planing technique, with the biggest gains when VR training came after, rather than instead of, traditional jaw-model practice. [4] One Haptodont design feature, a mechanism that physically supports the user's finger, was reported to improve probing accuracy at hard-to-reach sites; adding vibrotactile feedback, on the other hand, was reported to be distracting and to reduce performance, a reminder that not every added feature helps. [4] A 360° VR self-learning module for hand-scaling instruction was reported to be more efficient for skill acquisition than paper handouts or standard 2D video. [4] A virtual-patient web platform used before students' first real patient encounter was also associated with improved history-taking, question relevance and empathetic communication compared with delaying that exposure, suggesting that immersive tools may help build non-technical skills as well as technical ones. [4]

***5. Recent Innovations: Large Language Models in Content Generation and Assessment***

The fastest-moving recent development is the use of general-purpose LLMs, several ChatGPT versions plus Gemini, Claude and DeepSeek, to both generate and mark undergraduate assessments. Wei et al. reviewed several comparative studies: ChatGPT-4 outperformed periodontal residents on a standardised in-service exam (79.6% accuracy against lower resident scores), while dental students outperformed ChatGPT-3.5 and ChatGPT-4 on multiple-choice periodontal surgery questions, though ChatGPT-4's marking of open-ended answers tracked human teacher grading closely, which suggests that it may be possible to use LLMs as grading assistants rather than independent examiners. [4] These figures describe how well the models performed the tasks; they measure AI performance, not whether using LLMs improves student learning.

When an LLM was asked to write an entire 90-item periodontology exam, the result covered content more broadly but had a markedly lower discrimination index than a human-written exam. Students judged it less well-calibrated in difficulty and less “inspiring,” and it struggled to reliably separate stronger from weaker students, which led the study's authors to recommend a hybrid AI-human approach to writing exams rather than full automation. [4] A follow-up found that ChatGPT-4's score on a periodontology exam, initially above final-year students, dropped back to student-level accuracy when retested six months later: suggesting that LLM performance may not be stable and may need ongoing checking before it is relied on for high-stakes teaching decisions. [4]

***6. Supporting Evidence from Preclinical and Digital Learning Literature***

Broader evidence from digital and blended learning in preclinical basic sciences echoes several of these themes, even in studies done in medical rather than dental curricula. These studies concern digital and blended learning in general rather than AI-based tools, and are included as contextual evidence only. A large scoping review of 98 studies on digital and blended approaches to teaching histology and pathology found that digital microscopy and web-based tools with quizzes, annotations and instant feedback were reported to improve access

and engagement, but that students and faculty alike still preferred blended formats, pairing digital tools with in-person teaching, over fully digital instruction, citing weaker peer interaction and motivation as drawbacks of digital-only approaches. [2] The review also set out a framework for future digital learning tools built around three elements: visual interpretation and guided observation (zoom/pan, annotation, hide/show markers), active-learning features (instant-feedback quizzes, flashcards, learning analytics), and clinical or team-based activities (graded-difficulty case scenarios), a framework that appears to overlap with features already being trialled in the AI-based dental tools discussed above. [2] The overlap suggests that lessons from digital pathology and histology education, about blended sequencing, formative feedback and the continuing value of human facilitation, may potentially carry over to AI-based dental instruction, although this evidence comes from medical rather than dental curricula and from tools that are not necessarily AI-based.

***7. Broader Applications and Diagnostic Domains Relevant to Teaching***

Narrative and systematic reviews of AI in dentistry more broadly, even where the focus is mainly on clinical diagnostic performance, supply technical background for the models that teaching applications draw on, although they do not themselves evaluate educational outcomes. Surdu et al. catalogued AI applications across caries detection (accuracies often reported above 90%), screening for paediatric anomalies such as mesiodens detection using convolutional neural networks, identifying orthodontic cephalometric landmarks, staging periodontal bone loss, detecting oral cancer and precancerous lesions via cytology and fluorescence imaging, identifying maxillary sinus pathology, and classifying salivary gland tumours. [5] The same neural-network and deep-learning architectures underlie many of the training platforms discussed earlier, CNN-based caries detectors and U-Net-based bone-loss segmentation among them, so advances in clinical AI diagnostic accuracy may be adapted into undergraduate teaching tools. High diagnostic accuracy in an algorithm does not, however, show that students taught with it learn better or become more competent clinicians. [5]

A systematic review by Ahmed et al., covering 32 studies across oral diagnosis, restorative dentistry, prosthodontics, orthodontics, endodontics, periodontics and oral/maxillofacial surgery, likewise found that AI models, artificial neural networks, convolutional neural networks and robotic systems among them, were reported to help with diagnostic accuracy, working-length determination, tooth segmentation and predicting treatment outcomes. The underlying studies, though, were rated low-to-moderate risk of bias, largely because of missing blinding, no pre-registration and limited randomisation. [6] That quality gap matters for any teaching application built on this evidence, particularly as these studies assessed clinical rather than educational outcomes.

***8. Effectiveness, Perceptions, and Comparative Outcomes***

A few tentative patterns emerge from this literature, which consists of a small number of mostly small, short-term studies. AI-assisted and AI-generated training materials appeared comparable to, and on some sensitivity-related measures possibly better than, traditional lecture-based teaching, though they rarely beat expert-curated case-based or dataset-driven instruction on every measure at once. [1,3] Students and faculty tend to view AI tools favourably when human oversight and validation are clearly built into the process; faculty keep citing time savings and innovation as benefits, while still insisting on expert review before anything reaches students. [1] Students earlier in their training seem to gain more from AI-based instruction than those with more clinical experience, whose performance is already close to expert level, which suggests these tools may be best aimed at earlier stages of the curriculum. [3] And pairing AI or digital tools with traditional hands-on or faculty-led teaching, done deliberately and in sequence, appears to be more effective than either approach alone for building procedural skill, although this evidence comes mainly from VR and digital rather than AI-specific studies. [2,4]

***9. Discussion: Evidence, limitations, and implications***

These are encouraging results, but several things temper the enthusiasm. Automation bias, learners accepting incorrect AI output without scrutinising it enough, has been reported in dental students using explainable AI for furcation diagnosis, and keeps getting flagged as a risk that curricula need to address head-on, for instance by teaching students to question and verify algorithmic suggestions rather than simply defer to them. [4]

Reliability over time is another concern: ChatGPT-4's declining exam performance after six months, and AI-generated exams' weaker ability to tell strong students from weak ones, are both examples. [4] The methodological quality of the underlying evidence is still only low-to-moderate overall, with recurring problems: poor reporting of randomisation, no pre-registration, inconsistent blinding for subjective outcomes, and small, single-site samples that limit how far the findings generalise. [4,6] There are practical obstacles too: haptic simulators and AI licensing cost money, high-resolution imaging and digital slide libraries need infrastructure, digital literacy varies among both students and faculty, and faculty still have to spend real time checking AI-generated content before students ever see it. [1,2,4] Finally, most of these studies are short-term, single-institution, and do not follow students long enough to know whether knowledge sticks or clinical performance improves later, so some of what looks like benefit here may just be novelty rather than lasting learning gains.

Taken together, the evidence base is limited in several respects. Sample sizes in the primary teaching studies discussed here were small, for example 52 students in the caries-detection comparison [3] and 72 in the case-generation pilot [1]. Study designs varied widely, from questionnaire-based pilots with no stated comparison group [1] to controlled comparisons [3], randomised trials [4] and a systematic review of heterogeneous studies [4]; randomisation, blinding and pre-registration were inconsistently reported, and the broader AI literature was rated at low-to-moderate risk of bias [6]. Outcomes were mostly short-term perceptions or immediate post-test accuracy and sensitivity, with little or no follow-up. There is therefore very limited evidence on long-term knowledge retention, transfer to real patient care, or clinical competence, and some of the apparent benefit may reflect novelty rather than lasting learning.

### *10. Future research directions*

Several directions look promising from here. Larger, multi-centre randomised trials with adequate statistical power, standardised outcome measures and longer follow-up are needed to find out whether short-term gains in accuracy and sensitivity actually translate into lasting clinical competence. [4] Such studies should compare AI-based tools with well-designed non-AI instruction, use validated educational outcomes (including delayed retention testing and clinical or workplace-based assessment), report randomisation and blinding transparently, and measure learning outcomes separately from the diagnostic accuracy of the underlying AI model. Curriculum design could build in deliberate sequencing, foundational hands-on or jaw-model practice before AI- or VR-based refinement, rather than leaving that choice to individual instructors, and the benefit of such sequencing should itself be tested. [8] Training students to critically appraise AI output, specifically to counter automation bias, needs to be built into any AI diagnostic-training tool rather than assumed to happen on its own. [4] For generative-AI case authoring and LLM-based assessment, ongoing performance monitoring, domain-specific fine-tuning and transparent human-in-the-loop validation, along the lines of the CBL-SGT generation-assessment-modification model, should become standard practice. [9] And before AI teaching tools are recommended for wider adoption, more work is needed on cost-effectiveness, faculty workload, and making sure lower-resource dental schools are not left behind. [2,4]

### *11. Conclusion*

AI teaching tools, generative-AI case authoring, AI-driven radiographic and diagnostic training platforms, explainable AI, and large language models used for both content generation and grading, are now being actively trialled across undergraduate BDS curricula. The results so far, drawn from a small number of mostly small and short-term studies, suggest possible benefits for students' diagnostic accuracy, sensitivity, engagement and satisfaction, particularly when paired with expert validation and conventional teaching methods. Findings are not uniformly positive, however: AI-assisted labelling did not improve furcation detection, and there is little evidence on long-term retention or clinical competence. At the same time, the current evidence carries real risks: automation bias, AI reliability that varies and can decline over time, and supporting literature that is still only low-to-moderate in methodological quality. Dental educators should treat AI as a supplementary tool under faculty supervision, potentially most useful for less experienced learners, and possibly most effective when deliberately combined with hands-on, faculty-led instruction, rather than as a replacement for conventional dental teaching, pending more rigorous, multi-centre, long-term research. Good diagnostic accuracy of an AI system should not be assumed to translate into better learning or clinical competence.

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**Author Contributions**

Gagan .: Literature search, collection of relevant information, screening of articles, and preparation of the initial manuscript draft.

Subhashree Sahoo, Natasha Gambhir.: Conceptualization, methodology, supervision of the literature search and synthesis of findings, critical revision of the manuscript for important intellectual content, coordination of manuscript preparation and submission, and corresponding author responsibilities.

Priyadarshini B. G., Divya Singh.: Literature review, interpretation and synthesis of relevant findings, and critical revision of the manuscript for intellectual content, particularly periodontal and oral health aspects relevant to the review topic.

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