Queen Mary
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# Understanding the Role of AI in Dental Education

# A Rapid Evidence Assessment for Regulatory Insight

**Final report**

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- The authors declare no conflicts of interest in relation to the design, conduct, or reporting of this study.

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# Executive Summary

This report examines the role that Artificial Intelligence (AI) is playing in influencing pre-registration dental education and training. It examines the integration of advanced digital tools and automated systems, including artificial intelligence-enabled applications, throughout the dental education pathway. This encompasses stages from student selection and admissions to undergraduate training programmes, to non-clinical and clinical training, assessments, and early professional development. It considers the implications for public protection and dental education of the wider future dental workforce. The primary objective is to assist the General Dental Council (GDC) in ensuring that educational and training programmes leading to registration produce practitioners who are safe and competent, and who uphold professional judgment and ethical conduct in a clinical environment increasingly influenced by rapid technological advancements. This objective aligns with the GDC's overarching professional expectations that registrants prioritise patients' interests and practice within their scope of practice, using current evidence and professional guidance, to protect patients and deliver high-quality dental care.

The GDC's interest in this area extends across dental education and the preparedness of the future dental workforce. To ensure that the evidence synthesis remained focussed, the initial eligibility criteria prioritised pre-registration dental education and training. Within this scope, the eligible literature was reviewed and synthesised while recognising the relevance of the findings to the wider dental education pathway.

A Rapid Evidence Assessment (REA) methodology was adopted and tailored for fast-evolving fields, balancing timeliness with systematic transparency. The search strategy encompassed major biomedical, interdisciplinary, and educational databases (including PubMed/MEDLINE, Scopus, Web of Science Core Collection, and ERIC), alongside grey literature and supplementary identification methods. The search strategy was peer-reviewed using the PRESS framework, and reporting adhered to PRISMA-style transparency expectations. To enhance contextual and UK-specific interpretability, the report triangulates the literature synthesis with semi-structured interviews with recent graduates of English dental schools, regulators, and education experts in the field of AI.

The evidence indicates that AI-enabled systems are being utilised or piloted throughout the learner journey through innovation and transformation. The progress in AI is fast-moving, and this will be challenging for dental schools, learners and educators to keep curricula and policies up to date.

The key findings of the review are:

- In dental school admissions, AI tools may assist applicants in drafting personal statements and aid institutions in screening dental applications, potentially enhancing efficiency and ensuring equity for disadvantaged applicants.
- In didactic teaching and learning, evidence suggests potential educational benefits in personalised study support, formative assessment, case-based learning, and rapid feedback, with early studies indicating improvements in learner confidence, motivation, and some performance outcomes.
- In clinical education and simulation, the report identifies simultaneous benefits to both learners and patients. A plausible patient-safety benefit where digital simulation environments facilitate rehearsal, feedback, and skills development without exposing patients to avoidable risks. The students are benefitted with immediate feedback that can enhance their knowledge, skills and

confidence in performing surgical skills in preparation for real-world patient care.

- In evaluating the potential disadvantages of the use of AI in dental education, the report consistently identifies risks pertinent to learners' ability to develop clinical reasoning, professional judgment, and safe decision-making. A recurring theme is that certain systems can generate outputs that seem authoritative yet are inaccurate, including fabricated or unreliable references in academic tasks identified as “hallucinations”. The report also underscores concerns that excessive reliance may diminish critical thinking and problem-solving abilities, and that usage in assessment settings poses challenges to academic integrity and authenticity, affecting the validity of progression decisions and, consequently, patient safety when graduates begin practice.
- Performance varies significantly by task type and platform, with limitations particularly pronounced in image-dependent fields, which are crucial to dentistry.
- Interview participants expressed both cautious optimism, particularly regarding administrative efficiency and structured learning support, and explicit mistrust concerning treatment planning, accountability, and patient privacy risks, including potential neglect of data protection requirements in routine use.
- Ethical concerns were identified in relation to professional accountability and AI misuse, the lack of emotional intelligence and empathy, central to patient-clinician interactions.

Collectively, the findings advocate for a clear regulatory interpretation: the educational integration of automated tools should be considered part of the patient safety framework, rather than merely an educational innovation agenda. This perspective is justified as educational environments influence competence development, norms of professional responsibility, and the reliability of clinical judgment - core expectations under the GDC’s Standards for the Dental Team and *The Safe Practitioner: A framework of behaviours and outcomes for dental professional education.*

Based on the synthesis of the report, several actionable recommendations are proposed to include:

- Governance should be explicit and auditable: educational institutions should be required to delineate acceptable and unacceptable uses of AI tools in learning and assessment, mandate appropriate disclosure when such tools significantly contribute to submitted academic work, and design assessments that maintain validity, authenticity, and demonstrate independent clinical reasoning.
- Curriculum design using existing pedagogical frameworks should integrate digital literacy as a professional competence: both learners and educators need structured preparation to evaluate accuracy, recognise limitations, manage uncertainty, and uphold human accountability, in alignment with the Safe Practitioner emphasis on behaviours and the GDC’s core standards of professionalism and competence.
- Ethical concerns need to be addressed, and information governance must be enhanced in proportion to risk: when personal data is processed (particularly patient information used for teaching, assessment, simulation, or record-related tools) providers should adopt a risk-based approach consistent with UK GDPR obligations, including Data Protection Impact Assessments where processing is likely to be high risk or involves innovative technologies.
- Equity should be regarded as a safety and quality issue: unequal access to tools and variation in academic staff capabilities may exacerbate differential attainment and result in uneven readiness for practice, necessitating that providers consider access, training, and reasonable adjustments as part of implementation planning.
- The report advocates for prioritising UK-relevant evaluation to monitor learner and patient-based outcomes and ensure that we are continuously improving education and clinical

practice.

The report advocates for the establishment of a proportionate evidence surveillance function to keep pace with developments in tools, curricula, and governance, embedding stakeholder engagement that explicitly includes patients/public and the broader dental team, and commissioning evaluation priorities that focus on patient-safety–linked outcomes: clinical reasoning quality, diagnostic reliability (particularly in image-dependent domains), assessment validity, confidentiality and consent practices, and equity impacts across learner groups. Concurrently, implementation support for education providers - aligned with the revised Standards for Education and the Safe Practitioner framework - should emphasise transparent policies, staff development, and auditable information governance to ensure that innovation progresses in tandem with professional standards and public trust.

The report delineates several limitations. As a Rapid Evidence Assessment (REA), the review necessarily simplifies certain processes compared to a comprehensive systematic review, thereby increasing the likelihood of omitting some studies and supporting the interpretation that the conclusions are indicative rather than conclusive. The restriction to English-language sources and a contemporary time frame enhances feasibility but introduces language and selection biases. Additionally, much of the included literature is characterised as small-scale, single-institution, and country-specific, which limits its applicability to UK programmes without local validation.

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# List of Acronyms

**AI** – Artificial Intelligence

**AIEd** – Artificial Intelligence in Education

**AR** – Augmented Reality

**ASReview** – Active Learning for Systematic Reviews

**BDA** – British Dental Association

**CASP** – Critical Appraisal Skills Programme

**CBCT** – Cone Beam Computed Tomography

**COVID-19** – Coronavirus Disease 2019

**DCT** – Dental Core Trainee

**DPIA** – Data Protection Impact Assessment

**DRCF** – Digital Regulation Cooperation Forum

**EDI** – Equity, Diversity and Inclusion

**ERIC** – Education Resources Information Centre

**GDC** – General Dental Council

**GDPR** – General Data Protection Regulation

**GPT** – Generative Pre-trained Transformer

**LLM** – Large Language Model

**LLMs** – Large Language Models

**MCAT** – Munich Cephalometric Application for Training

**MR** – Mixed Reality

**NHS** – National Health Service

**OPG** - Orthopantomogram

**OSCE** – Objective Structured Clinical Examination

**PIO** – Population–Intervention–Outcome

**PRESS** – Peer Review of Electronic Search Strategies

**PRISMA** – Preferred Reporting Items for Systematic Reviews and Meta-Analyses

**PRISMA-AI** – Preferred Reporting Items for Systematic Reviews and Meta-Analyses – Artificial Intelligence Extension

**PRISMA-RR** – Preferred Reporting Items for Rapid Reviews

**RCT** – Randomised Controlled Trials

**REA** – Rapid Evidence Assessment

**SDGs** – Sustainable Development Goals

**SI-REA** – Scoping-Informed Rapid Evidence Assessment

**UK** – United Kingdom

**VR** – Virtual Reality

**XR** – Extended Reality

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# 1. Background

Over the past decade, societies have entered an era defined by rapid and far-reaching digital transformation. Digital systems now underpin most political, social, and economic processes, reshaping how people communicate, work, and make decisions. Within this broader context, health has emerged as one of the most significant domains of digital transformation, reflecting the growing appetite for digital and AI-enabled solutions across health care delivery and public health systems.[1] These developments have been further accelerated by the COVID-19 pandemic, which underscored the extent to which the organisation of health systems now depends on digital infrastructure.[1]

## 1.1 Digital Transformation: Assessing the Impact on Global Health Outcomes and Governance

Digital transformation has the potential to improve healthcare education, healthcare delivery, patient engagement and health outcomes. The influence of digital technologies has become so extensive that they are increasingly regarded as a new determinant of health, shaping wellbeing both directly, through their use in clinical and public health applications, and indirectly, by influencing the social and environmental conditions that determine health outcomes. Patterns of access, literacy, and inclusion in digital networks are therefore becoming central to the distribution of health opportunities and outcomes. Consequently, the "digital ecosystem" itself functions as an additional layer within the established framework of health determinants, alongside biological, behavioural, and socio-economic factors.[1]

Within this wider digital transformation, artificial intelligence (AI), defined as technology that enables computers and machines to simulate human learning, comprehension, problem-solving, decision-making, creativity and autonomy, has emerged as a defining force in the evolution of health innovation, shaping how data, technology, and care intersect.[2,3] AI is changing how health services are delivered, particularly in speciality areas such as radiology and pathology, where it enhances diagnostic precision and efficiency.[4-6] This progress has been enabled by the growing availability of large datasets and novel analytical methods that draw on them. Concurrent advances in information technology infrastructure and mobile computing power have also raised expectations that AI might help address persistent health-system challenges.[7] These challenges, including health workforce shortages and weak public health surveillance systems, have long undermined progress towards achieving the health-related United Nation's Sustainable Development Goals (SDGs).[8,9]

In October 2019, The Lancet and Financial Times inaugurated a joint Commission on the Convergence of Digital Health, AI, and Universal Health Coverage, reflecting the view that digital transformation and health equity are now inseparable.[1] The Commission's report, released in 2021, went on to argue that the digital transformation of health represents not merely a technological shift but a profound governance challenge. It warned that the same systems enabling innovation could also deepen inequities, accelerate data extraction, and concentrate power if not accompanied by ethical oversight and participatory governance.[1] To ensure that digital technologies advance sustainable development rather than undermine it, the Commission called for a global "governance architecture" rooted in democracy, solidarity, and human rights. It urged all governments and private actors to prioritise digital inclusivity and accountability, emphasising that health futures depend as much on governance and trust as on technological capability.[1]

Taken together, these global developments show that the impact of AI on health extends beyond technology and infrastructure to the ways professionals are educated and supported to use it responsibly. The next step is to consider how these dynamics are unfolding within specific disciplines.

Dentistry, which is long recognised for its early and enthusiastic adoption of digital innovation, offers a particularly clear lens through which to examine how AI is reshaping professional practice, education, and regulation.

**The General Dental Council's Emerging Role in AI and Digital Preparedness**

Within the UK, the General Dental Council (GDC) has increasingly recognised the implications of artificial intelligence for professional regulation and education. Its Corporate Strategy 2023-2025[10] identifies digital innovation and data literacy as key enablers of future professional standards, emphasising collaboration with education providers to embed digital capability and ethical awareness across undergraduate curricula and continuing professional development. This continuing emphasis is reflected in the GDC's 2026-2028 strategy, which commits to understanding advances in digital technology and innovation, supporting the profession to practice safely in a modern landscape, and ensuring accessibility and inclusion in its digital approach[11]. The GDC has also participated in cross-regulatory initiatives through the UK's Digital Regulation Cooperation Forum (DRCF), contributing to national discussions on transparency, accountability, and the governance of AI-enabled healthcare. Complementing these strategic efforts, the Council's Rapid Evidence Assessment on Artificial Intelligence and Dental Service Provision (2023)[3] represented its first formal inquiry into the opportunities and challenges of AI in clinical dentistry. The assessment underscored that educational preparedness and professional competence are decisive for the safe, ethical, and effective adoption of AI, highlighting the need for consistent standards of digital literacy across the dental workforce. Together, these initiatives demonstrate a coherent regulatory awareness that effective oversight of AI in dentistry depends as much on education and professional competence as on technological regulation, aligning the UK's approach with the global call for digitally ready health professionals.

## 1.2 AI in Dental Education: From Clinical Transformation to Educational Reform

Artificial intelligence is increasingly embedded within contemporary dental practice, influencing diagnostic, surgical, preventive, and administrative domains. Evidence from the GDC's Rapid Evidence Assessment on Artificial Intelligence and Dental Service Provision[3] indicates that AI applications are reshaping how dental care is planned, delivered, and evaluated. Advances in imaging analysis, computer-assisted navigation, predictive modelling, and digital workflow systems,[12-20] alongside AI-enabled patient communication tools such as remote monitoring platforms[21,22] and automated administrative systems[23,24] demonstrate that AI is no longer peripheral to practice. However, despite these developments, the evidence base remains uneven and fragmented, with most studies conducted in controlled or pre-clinical settings and limited external validation across diverse populations or contexts.[3,17,25] This imbalance between technological advancement and robust evaluation has implications not only for clinical governance but also for professional training.

As the clinical environment evolves, so too must the educational structures that prepare future practitioners. Emerging literature indicates that AI is beginning to influence both theoretical and clinical learning within dentistry.[26,27] Updating dental curricula to include AI literacy, spanning technical awareness, critical appraisal, and ethical reasoning, would help ensure that graduates are prepared to evaluate and apply these technologies responsibly.[26] AI-enabled simulation, intelligent tutoring systems, diagnostic support tools, and data-driven assessment models are increasingly incorporated into teaching environments, allowing students to practise procedures in controlled settings, receive adaptive feedback, and develop diagnostic reasoning skills.[28] At the same time, the translation of

clinically validated AI systems into routine educational use remains inconsistent, creating variability in how students are exposed to and trained in AI-supported practice.[27,28] This divergence highlights the need for a clearer understanding of how AI is conceptualised and operationalised within dental curricula.

Within the broader field of artificial intelligence in education (AIEd), the integration of intelligent systems has been associated with a shift toward more personalised, adaptive, and measurable learning environments.[29,30] Rather than replacing educator expertise, a central premise of this work is that AI should augment teaching practice by enabling targeted feedback, data-informed instructional decisions, and greater visibility of student learning processes.[30] In professional disciplines such as dentistry, where clinical reasoning, psychomotor skills, and ethical judgement are central to clinical competence, the challenge lies not simply in adopting AI-enabled tools but in ensuring that such technologies support, rather than replace, the formation of professional judgement.[30-32] Aligning with these principles, the 2024 UNESCO "AI competency framework for students" was the first global reference framework designed to prepare students as responsible users and creative co-creators of AI.[31] Grounded in principles of human rights, inclusion and equity, it calls for a shift in focus from passive technology use to active, ethical and responsible citizenship principles centred on human agency and environmental sustainability.[31] These developments underscore the expectation that professional education must cultivate not only technical familiarity with AI tools but also a critical understanding of their ethical, social, and governance implications.

However, these advances emphasise concerns about over-reliance on automation and the potential risks arising from bias in AI algorithms, "hallucinations" or inaccuracies in data interpretation. Implications within dentistry extend to concerns around the decline in core skills such as critical thinking, problem-solving, and creativity, a hindrance to professional development and diminished ethical adherence.[32] The UNESCO report also note that AI's growing role in assessment introduces academic integrity concerns, such as the misuse of generative tools to produce unauthentic work. These developments point to the need for clear governance and pedagogical strategies that preserve professional judgement and critical thinking while upholding the fundamental role of human accountability in AI-supported education.[31]

Collectively, the literature suggests that dental education now sits at the intersection of technological innovation, the formation of professional competence, and regulatory responsibility. While AI is increasingly present within both practice and learning environments, definitions of AI, modes of integration, evaluation frameworks, and governance approaches remain variable across institutions and studies. A structured synthesis of the evidence is therefore necessary to clarify how AI is defined, implemented, evaluated, and governed within dental education and training, and to identify where gaps persist.

## 1.3 National and Regulatory Context: The UK's Pro-Innovation Approach to AI

In the United Kingdom, national policy has increasingly recognised that the safe and effective use of artificial intelligence depends on developing sector-specific skills and governance. The National AI Strategy (2021) established a vision for the UK to become a global leader in trustworthy and responsible AI, built on three pillars: investing in the AI ecosystem, ensuring AI benefits all sectors, and governing AI effectively.[33] Education and workforce training feature prominently within this strategy, reflecting the view that professional competence and ethical awareness are prerequisites for sustainable innovation.

Evidence from a recent sentiment analysis of UK AI policy documents provides deeper insight into this pro-innovation orientation. The analysis of the National AI Strategy and the AI Regulation White Paper revealed that the UK's policy discourse places education, skills, and workforce development at

the centre of responsible AI adoption.[34] Terms such as skills, training, governance, and ethics were not only frequent but also closely linked to innovation and trust, suggesting that capability-building is viewed as inseparable from regulation.[34] The report's concept-mapping analysis further identified government, data, and innovation as structural anchors within the policy ecosystem, suggesting that national governance is framed as both an enabler of innovation and a steward of ethical practice.[34]

Additionally, the sentiment profile of these documents was overwhelmingly neutral to positive, reflecting a collaborative and facilitative tone that prioritises readiness and participation over control. UK policy consistently frames professional education and digital literacy as the primary levers for achieving trustworthy AI, positioning the workforce not merely as implementers but as co-regulators of ethical innovation.[34] This framing directly supports sector-specific initiatives, such as in higher education, where preparedness, transparency, and human oversight are treated as conditions for safe technological advancement.[34]

This national direction is reflected in the NHS Long Term Plan, which positions digital transformation at the core of healthcare modernisation.[35] The accompanying "Analogue to Digital" strategy demonstrates how this shift is being operationalised across NHS services, using technology to deliver faster, more efficient, and more personalised care.[35] Hospitals and community settings are increasingly adopting digital systems to streamline clinical workflows, improve accessibility, and enhance patient engagement, signalling a system-wide commitment to embedding digital capability and readiness.

This vision is further reflected in NHS England's Workforce, Training and Education Directorate,[36] which promotes the integration of digital and data competencies into professional education and continuing development. Dentistry, situated within this wider ecosystem, faces parallel expectations to embed AI literacy, ethical awareness, and digital competence into its training pipelines. As the use of AI expands across diagnostics, workflow optimisation, and patient communication, educational frameworks must evolve to ensure practitioners can apply these technologies safely, interpret outputs critically, and uphold patient-centred standards of care.

This evolving policy landscape provides an essential backdrop for the current review. It underscores that preparedness for AI in dentistry cannot be achieved solely through technological adoption; it depends equally on a strong, evidence-informed understanding of how education, regulation, and workforce development interact to build digital readiness. As national and sectoral strategies increasingly emphasise professional competence, ethics, and lifelong learning as foundations for responsible AI adoption, there is a clear need for systematic approaches to examine how these priorities are being translated into educational practice. The following section introduces the frameworks and evidence base that inform this inquiry, outlining how a structured review can help the General Dental Council (GDC) evaluate current progress and identify future directions for AI integration in dental education.

## 1.4 Building Evidence and Frameworks for AI in Education

The rapid integration of AI across sectors, from healthcare to higher education, underscores an urgent need for structured approaches to understanding its educational impact. AI is transforming clinical practice, reshaping professional expectations, and prompting national and international policy responses that emphasise workforce readiness and ethical competence. Yet despite this accelerating momentum, there remains a limited synthesis of how these technological, pedagogical, and regulatory developments are being addressed within dental education.

To address this gap, a Rapid Evidence Assessment (REA) has been commissioned to provide a timely, policy-relevant synthesis of evidence published since 2020 on the role of artificial intelligence

in dental education and training leading to registration. This review is designed to inform the General Dental Council's (GDC) understanding of how AI is defined and applied across the continuum of dental education, how providers have responded through curriculum design, education and training and what strategies or frameworks exist to evaluate and mitigate associated risks.

The REA adopts a streamlined scoping review methodology to balance rigour with timeliness.[37,38,47] The process involved identifying focused research questions, systematically searching and selecting relevant studies, extracting and charting key data, and synthesising the findings to inform policy and practice. By generating a structured, evidence-informed overview, the REA aims to equip the GDC with actionable insights into how AI is being integrated into dental education and how these developments can be best evaluated, governed, and supported through future educational policy.

This study uses a structured evidence-mapping approach based on the Population – Intervention – Outcome (PIO) framework, designed to develop a clearer understanding of how AI is shaping dental education and how these developments can be evaluated and governed effectively. The following objectives have been established to guide the inquiry and inform a coherent framework for understanding AI in dental education.

## 2. Aim and Objectives:

**Aim:**

The review aims to explore how AI is defined and applied in dental education and training, and how providers have responded through curriculum and training, the emerging challenges (including those related to EDI), and what strategies or frameworks exist to evaluate and mitigate associated risks.

**Objectives:**

1. To develop a PIO framework for the research question
2. To conduct a literature search to answer the following questions, which can inform the screening, coding, and synthesis framework:
   a. What parameters are best applied to identify and assess the current evidence base about AI and undergraduate dental education?
   b. In relation to the provision of dental education, how is AI currently understood and defined as a distinct and novel intervention?
   c. How have dental education providers responded to current and potential uses of AI in the practice of dentistry to ensure that dental professionals have the necessary clinical, research and professional skills? What policies, training initiatives, or structural responses have emerged?
   d. How have dental curricula include emerging AI technologies? How have institutions integrated AI to ensure preparedness, skill development, and literacy?
   e. What evidence is there about the use of AI in the delivery of dental education, including recruitment, teaching, learning and assessment? What are the challenges, and how have these been addressed (including in relation to EDI and different socio-economic groups)?
   f. What evidence is there about what works to address challenges and mitigate risks in response to AI in dental education, including those associated with:
      - Information governance and protecting privacy.
      - Potential uses of AI by learners that undermine academic and development integrity (e.g. to complete assessments).
   g. What methods have been used to evaluate the impact of AI in dental education?
   h. What current gaps are there in the evidence in relation to the evidence base on AI in dental education?

# 3. Methods

## 3.1 Overview and Rationale

The Rapid Evidence Assessment (REA) method used in this study incorporates the structured, transparent processes of a systematic review, as recommended by the Cochrane Rapid Reviews Methods Group[39] and is guided by the established methods to conduct exploratory and mapping orientation of scoping studies.[37,38] This blended approach, termed a scoping-informed rapid evidence assessment (SI-REA), has become increasingly recognised as appropriate for topics such as AI in education, where the evidence base is expanding rapidly but remains methodologically diverse and conceptually unsettled. The SI-REA thus provides a mechanism to identify, appraise, and map current knowledge while maintaining sufficient flexibility to capture emerging trends and grey literature relevant to educational policy and regulation. Table 1 summarises the main elements of Rapid Evidence Assessment that were followed by this study, along with the main elements of scoping review that have been added to it.

Ethical approval for the study was obtained from the Queen Mary University of London Research Ethics Committee (Reference No: 2025-1554-2482). The approval covered the stakeholder interview component and the associated data handling procedures.

**Table 1: Elements of Scoping-Informed Rapid Evidence Assessment (SI-REA)**

| Transparent processes consistent with the Cochrane Rapid Review guidance (2020-2024) | Exploratory and mapping orientation of scoping review methodology |
|---|---|
| • Time-bound<br>• Focused question<br>• Streamlined processes<br>• Critical appraisal performed (CASP)<br>• Pragmatic decisions | • Mapping landscape of AI use<br>• Broad conceptual inclusion<br>• Grey literature integrated as core<br>• Semi-structured interviews<br>• Thematic mapping |

Conceptually, the review also aligns with the methodological rationale articulated by Tricco et al. (2018) and Peters et al. (2020), who recommend rapid, mapping-oriented approaches for synthesising evidence in fast-moving fields where a comprehensive systematic review would be impractical or premature.[40,41] The focus on AI in dental education presents precisely this scenario: the evidence encompasses multiple domains, including pedagogy, informatics, ethics, and clinical training, and evolves at a pace that challenges traditional review cycles. The REA design enables the synthesis of diverse evidence sources, including empirical studies, conceptual papers, and professional reports, to generate a holistic understanding of how AI is shaping dental education and professional development.

In line with emerging standards for transparency in evidence synthesis, the review adheres to the reporting principles of PRISMA-RR (for rapid reviews) and PRISMA-AI (for documenting the use of artificial intelligence within the review process).[42,43] AI tools were employed selectively to enhance efficiency and consistency in search, screening, and appraisal, specifically through ASReview and Rayyan for citation prioritisation and deduplication, and GPT-based assistance for preliminary quality appraisal summaries, while ensuring that all decisions remained under human supervision. This integration of AI-assisted methods reflects the review's commitment to methodological transparency and accountability, consistent with recent guidance on responsible AI use in evidence synthesis.

## 3.2 Rationale and Scope

AI in dental education represents a rapidly evolving and multidisciplinary domain that spans clinical, pedagogical, technological, and ethical dimensions. Accordingly, the search strategy was designed to capture evidence from both health and education databases, incorporating cross-disciplinary sources such as psychology, data science, and digital learning. This approach ensured that the review captured diverse perspectives from empirical research on AI teaching tools to policy discussions on digital competence and ethics.

The initial scoping work indicated that the evidence base relating to AI and dental education was broad and heterogeneous. To maintain a proportionate and manageable evidence base within the timeframe of the Rapid Evidence Assessment, the formal eligibility criteria prioritised pre-registration dental education and training. The emphasis of the synthesis therefore reflects both the predefined operational scope of the review and the distribution of the available evidence. It should not be interpreted as limiting the GDC's broader regulatory interest in dental education, workforce preparedness and public protection.

## 3.3 Study Design and Methodological Framework

The SI-REA was conducted using an established evidence-mapping framework consisting of five sequential stages, with an additional stage incorporated for quality appraisal. This structure provided a transparent and reproducible process for identifying, organising, and synthesising the literature, while maintaining flexibility to accommodate the methodological diversity of studies across educational, clinical, and regulatory domains.

The conduct of this review was organised into the following sequential stages, reflecting the structured SI-REA framework described above.

### 3.3.1 Stage 0 (prior to main search): Protocol Development

Prior to conducting formal searches, a preliminary scoping search was undertaken to estimate the breadth, heterogeneity, and maturity of the evidence base and to calibrate the parameters of the scoping-informed rapid evidence assessment (SI-REA). This exploratory search did not contribute to study inclusion but informed refinement of the Population–Intervention–Outcome (PIO) framework.

During protocol refinement and preliminary scoping searches, the review team identified substantial variation in the nature and scope of the available evidence across dental education and training contexts. Evidence relating to pre-registration dental education formed the largest and most coherent body of literature and therefore became the primary focus of the review. Evidence relating to dental care professional (DCP) education was comparatively limited; however, all relevant and eligible studies involving DCP learners or training programmes were retained and integrated into the final synthesis where appropriate.

In contrast, the post-registration evidence base was highly heterogeneous, dispersed across multiple speciality areas, and frequently focused on clinical implementation, diagnostic performance, or service delivery outcomes rather than educational or training-related processes. Preliminary mapping indicated substantial conceptual and methodological differences between pre-registration educational contexts and post-registration professional or speciality training, limiting the feasibility of conducting a coherent integrated synthesis within the scope and timelines of a Rapid Evidence Assessment. Consequently, the review was refined during Stage 0 to focus primarily on pre-

registration dental education and training, while retaining foundation/vocational training and equivalent early-career pathways where relevant.

- A primary search was conducted to assess the width of available evidence and mapping the SI-REA procedure.
- The Protocol was written prior to searches
- The following elements were pre-defined:
  - Research question, objectives, and PIO
  - Inclusion/exclusion criteria
  - Databases
  - AI tools to be used
  - Screening approach
  - Quality tools
  - Planned synthesis method

A version-controlled log was maintained throughout the review process to document any methodological amendments, with justification recorded to preserve transparency and auditability. Table 2 presents the PIO framework created at this stage.

**Table 2: Population–Intervention–Outcome (PIO) framework**

| **P - Population** |
|---|
| • Learners undertaking pre-registration education and training across the dental team along with early years training (foundation or vocational trainees) and equivalent pre-registration pathways internationally, and students or trainees from dental care professional (DCP) programmes (e.g., dental hygiene, dental therapy, dental nursing, dental technology, orthodontic therapy, and clinical dental technology). |

| **I - Intervention** |
|---|
| • **Artificial Intelligence (AI) technologies used within dental education contexts:**<br>**1. AI-Enabled Educational Tools such as Intelligent tutoring systems, Adaptive learning platforms, AI-assisted grading and feedback tools, Virtual or simulated patients powered by AI, Machine learning–based educational modules, AI-assisted clinical decision support used for teaching purposes.** |
| **2. AI as Curricular Content or taught as subject matter, such as machine learning, deep learning, large language models (LLMs), AI ethics, diagnostic simulators, and curriculum AI modules.** |

| O - Outcomes |
| --- |
| • **Professional/personal-based outcomes & educational outcomes: AI literacy, knowledge, skills development, clinical competency, self-efficacy and professional preparedness.** |
| • **Academic institution-related outcomes: Curriculum evolution, pedagogical innovation, teaching/assessment impact, faculty readiness, implementation challenges, digital strategy implementation, and EDI considerations.** |
| • **Ethical/regulatory outcomes: AI ethics awareness, academic integrity, data governance and privacy protection.** |
| • **Engage stakeholders early (QMUL Library Services, BDA Library Team, and GDC) to refine scope and outcomes.** |

### 3.3.2 Stage 1: Question refinement and development of search strategy

Stage one focused on refining the review question and clarifying the conceptual boundaries of the SI-REA prior to formal database searches. Structured consultation with General Dental Council (GDC) stakeholders ensured alignment with current regulatory priorities, particularly digital preparedness, professional standards, ethics, and equity. These discussions clarified that the review would focus specifically on AI within dental education and early professional training, rather than on clinical performance of AI systems in practice. Explicit boundary-setting limited inclusion to studies where AI functioned as an educational tool or curricular subject, thereby maintaining conceptual precision and preventing scope drift into broader clinical AI literature. Ethical considerations, including academic integrity, data governance, algorithmic bias, and equality, diversity and inclusion (EDI), were embedded within the review framework at this stage.

The Population–Intervention–Outcome (PIO) framework and draft search strategy were refined iteratively through consultation with QMUL Library Services and the British Dental Association (BDA) Library team. To ensure accuracy, transparency, and reproducibility, the search strategy was peer-reviewed and refined in accordance with the PRESS 2015 Guideline Statement.[43] PRESS provides a structured framework using six key domains for evaluating electronic search strategies to minimise bias and improve comprehensiveness, the details of which are provided in **Appendix 1**.

Pilot searches were conducted to test sensitivity, terminology, and Boolean structure across health and education databases. Feedback-informed adjustments to synonym clusters, inclusion of generative AI and large language model terminology, and alignment with controlled vocabulary where applicable. This validation process ensured methodological robustness, regulatory relevance, and reproducibility prior to commencement of the formal search. Final search strategies that were used in this SI-REA are provided in **Appendix 1**.

### 3.3.3 Stage 2: Identifying relevant evidence

A comprehensive, predefined search strategy was executed across four core databases: PubMed (biomedical and dental education research), Scopus (interdisciplinary and international research coverage), Web of Science Core Collection (cross-disciplinary and citation-tracked sources), and ERIC via EBSCOhost (education and pedagogy-focused studies). Eligibility criteria were established prospectively and applied consistently throughout this stage.

A structured, reproducible, and quality-assured search strategy was developed and implemented to identify evidence relating to the integration and impact of artificial intelligence (AI) in dental education. The process combined established systematic review methodology with innovations in AI-assisted screening. All procedures adhered to international reporting standards, including the Peer Review of Electronic Search Strategies (PRESS) 2015 Guideline Statement[43] and the PRISMA-AI extension (2024)[42] for AI-enhanced systematic and scoping reviews.

The review covered literature published between January 2020 and December 2025, reflecting the period of rapid AI evolution in health and education following the emergence of deep learning and large language models (LLMs). The search and screening phases were conducted between October 2025 and January 2026.

Title and abstract screening was conducted thoroughly using an AI-assisted approach, with full details of the process and the two AI tools used, Rayyan[44] and ASReview[45] provided in **Appendix 2.**

Following completion of title and abstract screening, additional studies identified through hand-searching of reference lists and targeted grey literature searches were incorporated into the remaining dataset. Given the policy-driven and rapidly evolving nature of AI in education, grey literature was systematically included alongside peer-reviewed research. Searches encompassed key institutional and professional sources, including General Dental Council (GDC) reports, NHS and WHO digital strategy documents, as well as policy statements from the British Dental Association (BDA), the Royal Colleges, the International Association for Dental Research (IADR), the FDI World Dental Federation, and selected American and international regulatory bodies involved in dental and health professions education and digital governance. Additional materials such as university repositories, conference proceedings, dissertations, and white papers were also reviewed to capture emerging or non-indexed evidence.

Grey literature sources were assessed against the same inclusion criteria used for academic studies to ensure consistency and comparability. The credibility of non-peer-reviewed sources was evaluated qualitatively, considering authorship, institutional provenance, methodological transparency, and the robustness of the evidence. This inclusive approach allowed the review to incorporate real-world insights into how AI in dental education is being implemented, governed, and discussed beyond formal academic channels.

The combined set of records proceeded to full-text retrieval and assessment, forming the basis for the subsequent stage of transparent study selection and quality appraisal.

### 3.3.4 Stage 3: Study Selection and Quality Appraisal

The transparent selection of articles continued with all records remaining after Stage Two being proceeded to full-text retrieval and assessment against the predefined eligibility criteria. Full texts were obtained through institutional subscriptions and verified sources. Each article was assessed by a reviewer to confirm eligibility, including relevance to the Population–Intervention–Outcome (PIO) framework and the established educational scope. Studies were excluded at this stage where AI was used solely for clinical application without an educational component, where outcomes did not relate to training or curriculum, or where methodological detail was insufficient. Reasons for exclusion were recorded to ensure transparency and auditability.

Methodological quality appraisal was conducted using the Critical Appraisal Skills Programme (CASP) checklists, selected according to study design (e.g., qualitative, cohort, randomised, or systematic review). Where a specific CASP checklist was not available for a given design, an adapted/modified version consistent with CASP principles was applied.

Quality appraisal was undertaken independently through a dual-assessment process. One appraisal was conducted using ChatGPT Teams (Version 5.2, OpenAI, USA, 2025), prompted to apply the relevant CASP checklist systematically to each study. In parallel, a researcher independently appraised the same study using the identical CASP checklist. The outputs were then compared. Where assessments were consistent, the judgment was accepted. Where discrepancies occurred, a second reviewer evaluated the study and made the final determination. AI outputs were treated as decision-support only; final inclusion decisions remained under human oversight.

Given the substantial volume of eligible studies at this stage, methodological rigour was prioritised. Only studies assessed as demonstrating high methodological quality were retained for final synthesis. Studies not meeting this threshold (missing less than of 2 scores) were excluded following appraisal. The remaining high-quality studies constituted the final evidence base for analysis.

Figure 1 shows the number of articles included and excluded in each step, detailed in Stages 1-3 above, in the form of a Prisma Flowchart. The Prisma checklist used for quality assurance of the procedure is provided in **Appendix 3**.

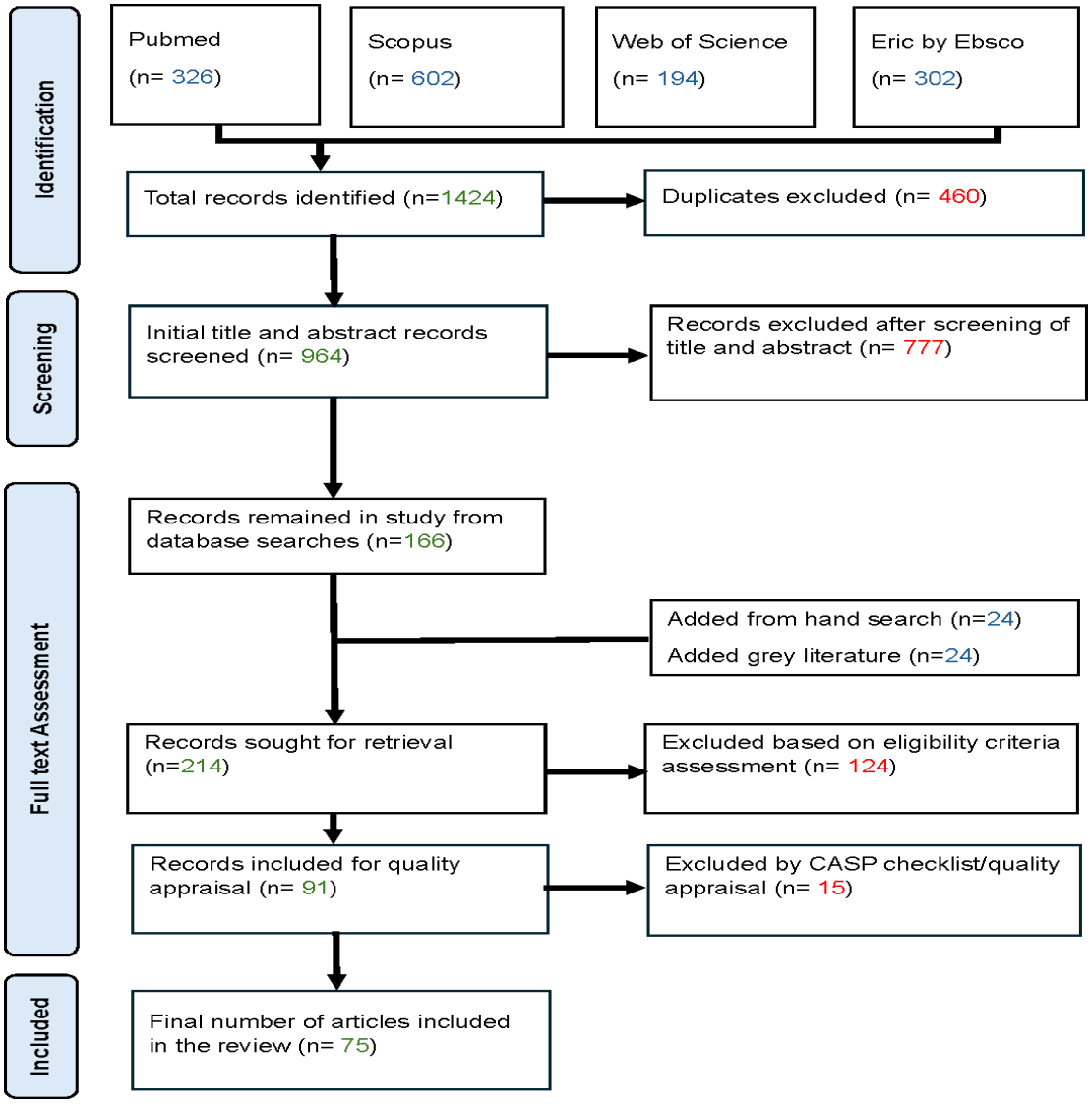



**Figure 1: PRISMA flowchart of evidence selection process**

### 3.3.5 Stage 4: Data Extraction and Evidence Mapping

Data extraction and charting were undertaken using a structured, transparent, and replicable process to ensure methodological rigour and consistency across all included sources. The approach followed the principles of the JBI Manual for Evidence Synthesis (2020), and reporting adhered to both PRISMA-ScR and PRISMA-AI guidelines to ensure transparency in documenting AI-assisted processes.

A standardised data extraction framework was developed collaboratively by the review team, informed by pilot testing and calibration meetings with GDC stakeholders and information specialists. A preliminary template was created in Microsoft Excel and refined through two pilot rounds on a subset of studies to ensure clarity, completeness, and applicability to multidisciplinary evidence spanning educational, clinical, and regulatory domains. The final template incorporated structured fields for quantitative mapping and narrative fields for qualitative contextual data, aligned with the predefined Population–Intervention–Outcome (PIO) framework and review objectives.

#### 3.3.5.1.a. Pass 1: Structured Extraction and Evidence Mapping

Data extraction was conducted in two sequential phases. Pass 1 consisted of structured extraction designed to capture standardised, non-interpretive data suitable for mapping and quantitative analysis. A predefined extraction framework was applied to each study individually.

AI-assisted structured extraction was implemented using a custom GPT API pipeline. Each article was processed one at a time, with prompts designed to extract predefined fields in a concise, structured format. After completion of each article, the session context was cleared before processing the next record to minimise cross-article contamination and ensure the independence of outputs. AI-generated entries were restricted to factual, non-interpretive summaries to preserve consistency.

The structured template captured the following elements:

- Bibliographic information (author(s), year, country, publication source, document type);
- Study characteristics (design, setting, population group, sample size, data collection methods);
- AI intervention details (technology type, pedagogical purpose, implementation context);
- Educational and institutional outcomes (AI literacy, skills development, curriculum reform, faculty readiness, EDI and governance elements);
- Evaluation and methodological features (study aims, outcome measures, analytical approach, reported impact, limitations, bias, conclusions);
- Relevance to GDC priorities (digital competence, ethics, professional standards, EDI considerations, risk mitigation);
- Key findings (barriers, enablers, advantages, effectiveness, concerns).

Each field was accompanied by coding guidance to maintain consistency. Following AI-assisted extraction, at least one member of the research team manually reviewed each entry against the full-text article to verify accuracy and completeness. Amendments were made where necessary. A second reviewer independently audited 15% of extracted studies to ensure reliability.

The structured dataset generated in Pass 1 enabled descriptive mapping across PIO dimensions, frequency analysis by AI type, population, and geography, and identification of evidence clusters and gaps. This evidence matrix also supported subsequent quantitative tabulation and trend visualisation.

#### 3.3.5.1.b. Pass 2: Targeted Qualitative Extraction

Pass 2 involved human-led, in-depth qualitative extraction focused on thematic domains relevant to synthesis and interpretation. This phase captured richer descriptive content not amenable to structured coding, including:

- Conceptual definitions of AI within education;
- Detailed descriptions of curriculum integration strategies;
- Ethical, governance, and EDI discussions;
- Reported implementation challenges and mitigation strategies;
- Institutional and regulatory responses.

Pass 2 extraction prioritised contextual nuance, interpretive depth, and cross-study comparison. Data were coded narratively to support thematic synthesis, triangulation with stakeholder interviews (where applicable), and development of the discussion and policy implications sections. This phase ensured that analytical insight extended beyond frequency mapping to interpretive understanding.

### 3.3.5.2 Quality Assurance and Transparency

Multiple quality assurance measures were implemented to ensure robustness:

- Independent verification of 15% of extracted records for completeness and consistency;
- Compliance with PRISMA-AI transparency requirements for AI-assisted extraction;
- Detailed logging of extraction dates, reviewer identity, and AI tool usage;
- Maintenance of a version-controlled audit trail documenting template modifications;
- Archiving of the final evidence matrix and codebook to enable reproducibility.

By integrating structured AI-assisted extraction with human verification and qualitative depth analysis, this stage produced a comprehensive, transparent, and methodologically defensible dataset. The resulting evidence matrix forms the empirical foundation for subsequent thematic synthesis and integrative analysis.

## 3.3.6 Stage 5: Thematic Synthesis and Analytical Integration

The synthesis process aimed to integrate heterogeneous evidence from empirical studies, policy documents, and conceptual papers into a coherent analytical narrative aligned with the review's eight guiding objectives. The approach was informed by JBI's convergent integrated synthesis framework and adapted for rapid review methodology. Synthesis proceeded through three analytical phases.

### Phase 5a: Descriptive Mapping

All included studies were first subjected to quantitative and categorical mapping using the structured dataset generated in Stage 4. Variables analysed included publication year, study design, country of origin, AI intervention type, educational level, and reported outcomes. This mapping enabled identification of temporal trends, geographic distribution, methodological patterns, and thematic clusters (e.g., simulation-based learning, AI literacy, curriculum reform).

This phase established a structural overview of the evidence base and addressed the review objective relating to defining the scope and maturity of current research.

### Phase 5b: Thematic Synthesis

A thematic analysis was then conducted to integrate qualitative and quantitative findings within a unified interpretive framework. Extracted textual data (study aims, findings, recommendations) were coded inductively and iteratively. Themes were refined through cross-comparison across Population–Intervention–Outcome dimensions and aligned with the predefined objectives.

Six principal thematic domains emerged:

1. Definitions and conceptualisations of AI in dental education
2. Curriculum integration and competency development
3. Teaching and assessment innovations
4. Institutional and professional responses
5. Equality, diversity, and inclusion (EDI) considerations
6. Evaluation methods, challenges, and mitigation strategies

One researcher conducted final clustering and cross-tabulation of themes by study design and population group. Sub-themes were derived inductively within each domain. This phase provided the analytic scaffolding for narrative synthesis.

### Phase 5c: Integrative Analysis

The final analytical phase within synthesis brought together findings across empirical, policy, and conceptual evidence. The analysis focused on intersections between educational outcomes, institutional readiness, and regulatory implications. Three interpretive questions guided this integration:

1. What is the current scope and maturity of AI integration in dental education?
2. How are educational, ethical, and regulatory dimensions intersecting?
3. What are the key gaps and future priorities for governance and research?

Convergence and divergence across study types were examined, including differences between empirical evaluations and policy-oriented discourse.

AI tools were used in a limited and transparent manner. An unsupervised NLP clustering method was employed for exploratory visualisation of thematic co-occurrence, and a local LLM-assisted summariser was used to generate draft theme summaries. All outputs were manually validated, and no interpretive decisions were delegated to AI systems.

### 3.3.7 Stage 6: Stakeholder Triangulation and Regulatory Interpretation

To strengthen contextual validity and regulatory relevance, findings from the literature synthesis were triangulated with semi-structured interviews with stakeholders. This stage aimed to assess the alignment between published evidence and lived educational and regulatory experience within contemporary dental and health professions contexts.

Ethical approval for the stakeholder interview component was granted by the Queen Mary University of London Research Ethics Committee (Reference No: 2025-1554-2482). All participants received an information sheet outlining the purpose of the study and provided informed consent prior to participation. Interviews were conducted in accordance with approved protocols, and data were anonymised at the point of transcription. All identifiable information was removed, and data were stored securely in line with institutional data governance policies. Participation was voluntary, and participants were informed of their right to withdraw at any stage.

**1. Interview Design and Participants**

Eight stakeholders were purposively sampled to represent complementary perspectives across regulation, academia, and learners:

- 2 General Dental Council (GDC) experts;
- 2 academics working closely with the integration of AI in medical and dental education;
- 2 recently graduated Dental Core Trainees (DCTs);
- 2 current dental students who had experienced some degree of AI integration within their teaching.

Participants were selected to ensure diversity of regulatory, institutional, and learner viewpoints. While some participants had experienced formal AI integration within their institutions, others reported informal or personal use of AI tools in private study or clinical environments. This variation allowed exploration of both structured curricular implementation and emergent, unofficial AI engagement among learners.

Semi-structured interviews were conducted using a predefined topic guide (**Appendix 4**). The guide was developed in alignment with the review's objectives and thematic domains, covering:

- Conceptual understanding of AI in dental education;
- Experiences of AI integration in teaching and assessment;
- Perceived benefits and risks;
- Ethical and governance considerations;
- Equity and access issues;
- Regulatory readiness and professional standards implications.

The semi-structured format ensured consistency across interviews while allowing participants to elaborate on context-specific experiences. Interviews focused on professional and educational perspectives rather than personal opinion alone.

**2. Analytical Integration**

Interview data were analysed using structured thematic alignment rather than fully independent grounded coding. Insights were mapped onto the six principal domains identified in Stage 5 to assess:

- Convergence with literature findings;
- Divergence between published evidence and lived experience;
- Areas underrepresented in the academic literature;
- Emerging risks or governance considerations not yet formally documented.

This triangulation served a confirmatory and refinement function. It did not replace evidence synthesis but strengthened interpretation by situating findings within real-world educational and regulatory contexts.

**3. Regulatory Interpretation**

The combined literature and stakeholder insights were then interpreted through a regulatory lens, focusing on implications for:

- Digital competence and preparedness for safe practice;
- Ethical oversight and governance mechanisms;
- Academic integrity safeguards;
- Equity and inclusivity in AI-enabled learning environments;
- Institutional readiness and faculty capability.

Particular attention was paid to tensions between rapid technological adoption and slower curriculum reform processes, as well as to discrepancies between formal integration and informal learner usage.

Data analysis was conducted using thematic analysis for both the rapid review and the semi-structured interview. The first step was to be familiarised with the data and identification of themes and the second step was to refine and review the themes. The themes were then presented narratively to address the study objectives.

## 3.4 Documentation and Reporting

All appraisal results were logged in the master evidence matrix, including tool type, reviewer initials, assessment date, and rationale for any quality-related interpretive decisions. A synthesis-level summary of study quality by design type is presented in the Results section, accompanied by a narrative description highlighting common methodological strengths and weaknesses in the AI and dental education literature.

# 4. Results

We identified 1,424 records from four databases: PubMed, Scopus, Web of Science, and ERIC (via EBSCOhost). After removing duplicates and screening titles and abstracts, 166 records remained from the automated search of peer-reviewed sources. At this stage, 24 records identified through hand searching and 24 records identified through grey literature searching were added, bringing the total number of records to 214. These underwent full-text assessment, during which 124 were excluded based on eligibility criteria, and 15 were removed following quality appraisal. The 75 records remaining after full-text assessment were included in the final analysis **(Figure 1).**

The included evidence base comprised 75 peer reviewed publications, reflecting a rapidly evolving and methodologically diverse literature on the application, governance and implications of AI on dental education and training. The evidence was notably recent, with 62 records (82.7%) published in 2024 or 2025, underscoring the accelerated development of this field. The literature included cross-sectional surveys, mixed-methods studies, randomised and quasi-experimental studies, comparative evaluations, pilot studies, qualitative research, curriculum-development exercises and consensus-based frameworks. Geographically, the evidence base was international but retained a strong UK focus. Substantial contributions originated from the United States, Turkey, China and Canada. Additional studies were undertaken across Europe, South and Southeast Asia, the Middle East, Latin America and other international settings. Sample sizes varied considerably, ranging from small pilot and experimental studies involving approximately 30–40 participants to larger surveys involving several hundred respondents **(Appendix 5).**

The pathway of AI in dental education starts with student admissions to student education including non- clinical and clinical stages and culminates with a graduating dentist or a dental care professional.

Admissions systems for dental education and training vary by country and academic institution and usually incorporate a metric test score for aptitude tests alongside an application or a personal statement. The intricacy of evaluating applications and personal statements is intended to get a holistic overview of the potential applicant and their reflective and analytical abilities in their desire to pursue a career in the field of dentistry. Students may get assistance with their applications from writing services, as well as utilising AI-based platforms, which may potentially give them an advantage.[46] On the other hand, the use of AI may help students from disadvantaged backgrounds by providing them with a fairer playing field and thereby tackling inequity in the admissions system. Those with a lack of or limited access to AI may lead to further disadvantage highlighting socioeconomic inequalities. AI can also be utilised in screening applications, including personal statement analysis, thereby reducing the manpower required for dental admissions.

AI can support students with didactic, knowledge- and case-based learning, exam preparation, clinical skills and research. It can also contribute to clinical / technical education, including simulation-based training, clinical decision-making, and treatment planning. AI can be shown to help students with adaptive learning, depending on students' needs and preferences, respecting diversity in learning.[47] It can enhance learners' knowledge and skills in becoming a dental professional and support them in the provision of personalised and patient-focused dental care.[47]

From a provider of dental education perspective, AI can support with lesson planning, development of examination questions, scoring of assessments, as well as providing feedback. Additionally, AI has the capability of undertaking automated routine tasks such as administration (booking patients, setting reminders), but also in marking assessments, thereby improving efficiency and reducing the burden

on academic staff to deliver the curricula.

In knowledge-based education, large language models (LLMs) support personalised learning, formative assessment, exam preparation, and case-based learning. In clinical education, AI is used to enhance simulation-based training, image interpretation, clinical decision support, and feedback on procedural skills.[48,49]

## 4.1 Thematic analysis

A number of themes were identified from the selected studies and are outlined below:

- Awareness, Attitudes, Perceptions, and Knowledge on the Use of AI in Dental Education
- Use of AI in diagnosis and treatment planning
- Use of AI in assessments in dental education
- Haptics
- Dental speciality specific findings
- Ethics and risk mitigation in the use of AI

### 4.1.1 Awareness, Attitudes, Perceptions, and Knowledge on the Use of AI in Dental Education

There were a number of studies that explored these domains, but the majority were country-specific with small sample sizes. A global scoping review which explored awareness of AI among dental students revealed that there was a significant variation, which ranged from 16.80% to 80%, with a mean 42.58%. However, awareness of AI was more pronounced among dentists than students, which ranged between 64.3% and 70.03%, with a mean 67.16%.[50]

A survey of Malaysian dental students demonstrated that they had a moderate understanding of AI.[51] Staff using AI were more likely to take advantage of using AI in everyday life than for professional reasons. However, students associated the use of AI with patient management, diagnosis, image analysis, and treatment planning.[51]

Positive attitudes towards the use of AI in dental education were more prominent in Africa, Asia and the Americas vs Europe.[52] A study among staff and students in Pakistan revealed that both groups had positive attitudes towards AI in dental education. Staff had learnt about the use of AI from social media and other professionals, which provided opportunities for learning and sharing experiences.[53] Attitudes and positive perceptions of AI varied by age, with mid-career professionals being more enthusiastic about the use of AI in dental education than any other age groups.[53] A survey conducted across German-speaking countries demonstrated that attitudes towards and the use of AI increased as students progressed through their dental education, with confidence growing towards graduation.[54] This is in line with other studies.[55,56]

Utilisation of ChatGPT in dental education has been reported for case-based learning, problem-solving, and seeking clarification on subject matter.[57] Other studies reported its use in role play, lesson plans, the delivery of quiz assessments, and the enhancement of critical thinking.[52,53] In contrast, some studies suggest that students may be reluctant to use AI for their learning due to concerns around reliability and safety[58]

In relation to assessment, a survey found that dental educators were critical of using AI for assessments and preferred to mitigate against the inappropriate use of AI, which they perceived as "disruptive" to assessment.[59]

### 4.1.2 Use of AI in diagnosis and treatment planning

There were six studies that explored the use of AI in diagnosis and treatment planning, including improving diagnostic accuracy and pre-cancer diagnosis.[60-65] A small study revealed that the use of AI when using Orthopantomogram (OPG) improved caries (enamel and dentine) detection among students, and this was pertinent for final year students.[60] This was in line with findings from a Randomised Controlled Trial (RCT)[62] Furthermore, students reported increased satisfaction with the clarity of the feedback and motivation to learn. Mixed results were observed in a study of third-year dental students, where AI-assisted mounting of full- mouth radiographs improved efficiency but decreased accuracy. Therefore, the use of AI was perceived to be a supplementary tool rather than relying on AI in its entirety.[61]

The use of virtual patients to support learning using AI chatbots in enhancing diagnostic skills was found to create a controlled and safe environment to stimulate student learning.[64] A small RCT showed that learning was more enhanced among students using virtual reality (SD Menter) for surgical decision-making, compared to those who were in the control group.[65]

One study assessed the use of ChatGPT among dental students to draft consent for treatment, which demonstrated that it was sufficient in producing a first draft, but students had to elaborate on dental procedure-specific information.[63]

### 4.1.3 Use of AI in assessments in dental education

A large number of studies in this review focused on the use of AI in assessments within the dental curricula.[58,66-76]

An exploratory study using ChatGPT to assess performance in multiple choice questions, short answer and short essay assessments that were developed by faculty staff found that it provided adequate responses for text-based questions but not for questions that used images. Chat GPT performed well in dental assessments, but this highlights that dental educators need to mitigate against the risk of inappropriate use of AI in dental education. [66] However, ChatGPT can be used in other aspects of assessments such a calibration/standardisation and marking of assessments. including blue printing and psychometric analysis.

A small study compared the performance of ChatGPT vs Gemini for multiple-choice and short-answer questions in dental prosthetic technology and oral health assessments. The study demonstrated that ChatGPT was superior in its accuracy (90% for MCQ and 85% for true/false questions) when compared with Gemini (60% and 70%), respectively. However, the accuracy for short answer questions (SAQs) for ChatGPT was reduced to 60% and for Gemini to 70%.[68] In a similar study in Canada, which compared the use of ChatGPT 3.5 and 5 versions for periodontology assessments using multiple-choice questions, found that 57.9% and 73.6% of responses were correct, respectively. However, both platforms were liable to misinformation and inaccuracy.[71] A study from Peru, where students were assessed on a writing assignment based on the scientific literature review found that higher scores were achieved among students who used traditional methods vs a group of students who used ChatGPT.[77]

Four large language model applications (LLMAs), ChatGPT-4o, ChatGPT-o1, Gemini 1.5 Pro, and

Gemini 2.0 Advanced, were compared in an assessment which comprised over 230 questions (basic and clinical sciences) to assess their accuracy in providing the correct responses.[73] Accuracy rates varied significantly between LLMAs; Gemini 2.0 had the highest performance when compared with ChatGPT-4o: Gemini 2.0 Advanced( 97.90%, 95% CI: 94.62%, 100.00%),ChatGPT-o1 (97.46%, 95% CI: 94.62%, 100.00%), Gemini 1.5 Pro (91.60%, 95% CI: 87.75%, 95.45%) and ChatGPT-4o (86.66%, 95% CI: 85.43%, 91.89%) and , respectively. A similar study, which compared the use of ChatGPT 3.5 vs ChatGPT 4.0 in Japanese national examinations, showed that overall correct responses were higher when using ChatGPT 4.0 (84.6%) VS ChatGPT 3.5 (45.46%), respectively.[76]

Comparing the performance of LLMAs ((ChatGPT-3.5, -4.0 and -4.0o) and Gemini 1.0) in clinical-specific domains of restorative dentistry and endodontics based on a pool of 51 multiple choice questions revealed that ChatGPT-4.0o (72%) had the highest performance when compared to the three others (62%, 44% and 25%), respectively.[74]

When comparing dental students who used ChatGPT for an assignment to conduct a literature search in radiology compared to a second group which relied on the internet, showed the ChatGPT group had a higher performance than that of the conventional group. However, challenges associated with using ChatGPT were identified, including the need to repeatedly rephrase the queries, the presence of false citations and the inability to process images or videos.[72]

Another RCT compared dental students who utilised ChatGPT with a control group which used videos to assess skilled learning on multiple learning domains. Students in the ChatGPT group had increased performance in skills learning, reduced cognitive load, and higher self-efficacy and motivation in clinical operative skills education.[70] This was also in agreement with other studies in which students who utilised ChatGPT as part of their learning for pharmacological quizzes performed better than those in the control group.[58]

ChatGPT (GPT-4) was compared with academic staff's performance in assessing reliability to mark essays for oral and maxillofacial surgery examinations among 60 undergraduate dental students. Although there was evidence of good correlation between the use of ChatGPT and academic staff in marking essays, ChatGPT was susceptible to deviation, which resulted in a decrease or an increase in total marks. The study also highlighted the need to be as accurate as possible with the marking rubric for ChatGPT to score correctly.[75] The only study that included solely dental technicians found that when ChatGPT-4o was employed as the LLM to respond to over 400 questions. AI showed superior accuracy in responding to basic knowledge-based questions, such as dental materials and laboratory equipment (84.1%), but inferior accuracy in responding to questions relating to complex procedures and visual interpretation. This was especially prominent in paediatrics (50.0%) and orthodontics (46.2%), where the visual elements, including 3D images and spatial relations, were inaccurately interpreted.[69]

Feedback provides an opportunity to assess the progress of dental students in relation to their clinical skills, which is vital for academic progression. Virtual reality (VR) has been used to support learners and educators to assess the surgical skills of students with immediate feedback, as well as to collect data longitudinally through the dental clinical procedures and progression over period of time. Feedback has been shown to be effective and act as an adjunct tool for learning.[78]

A study which explored the use of AI in two question assessments and the provision of feedback showed no perceived significant differences between feedback provided by ChatGPT or academic staff.[79]

### 4.1.4 Haptics

Although haptics was not included in the rapid review, it was thought to be important to include the brief evidence base around it, as there is potential for AI to be integrated with haptics.

Digital technologies in dental education have increasingly centred on immersive simulation approaches, particularly virtual reality (VR) and augmented reality (AR), which enable learners to visualise, rehearse, and interact with complex dental and surgical procedures in digitally mediated environments. Immersive technologies such as haptics and virtual reality, known as extended reality (XR), which includes augmented reality (AR), mixed reality (MR), and virtual reality (VR), are now integrated in some of the dental curricula worldwide. Haptics specifically support students with skills in restorative dentistry, providing tactile simulation and immediate feedback to students, and providing them with a hand in clinical training. There are several advantages to using haptics, including simulation of real-world environments and incorporation of immediate feedback to the user, thereby facilitating muscle memory, increasing skills and confidence and enhancing fine motor skills.[62,80-82] It can also be cost-effective and can minimise risks and promote patient safety. However, there are also some drawbacks, including cost and accessibility of haptics, as it tends to be resource-intensive, and technology is rapidly progressing, with limited evaluation and research in the area.

Within this extended reality (XR) continuum, haptic technology occupies a distinct role by providing force and tactile feedback that simulates the sense of touch, thereby enhancing psychomotor engagement and procedural realism during simulated dental tasks. Haptics function as a sensory interface embedded within XR systems rather than as an independent instructional modality, relying on deterministic, physics-based models to generate resistance and tactile cues.[80,83-85] Across the literature, artificial intelligence is frequently discussed alongside VR, AR, and haptics as part of an emerging vision of “smart” or technology-enhanced dental education, with particular emphasis on the potential to improve realism, individualisation, and feedback within simulated environments. However, these references to AI are typically framed in conceptual or forward-looking terms, positioning AI as a prospective enhancement to XR and haptic systems rather than as a consistently implemented feature of current undergraduate dental education.[83,85,86]

A substantial body of evidence indicates that XR-based simulation, particularly when combined with haptic feedback, can support positive educational outcomes in dental training. Studies consistently report improvements in psychomotor skill acquisition, manual dexterity, procedural accuracy, and learner confidence when haptic or VR-enhanced simulators are used alongside conventional preclinical teaching methods.[82,84,87-89] The ability of haptic simulators to generate objective performance metrics, such as force application, angulation, time to completion, and error rates, has been shown to support structured feedback, self-directed practice, and differentiation between learners at different stages of skill development.[80,84,88] Published literature also highlights several challenges associated with the adoption of XR and haptics in dental education, including high costs, infrastructure and maintenance demands, variability in curriculum integration, and the need for faculty training and acceptance. Concerns are also raised regarding realism in certain procedures, the risk of over-reliance on simulation, and the continued importance of supervised clinical experience and professional judgement.[80,85,87] Together, these findings suggest that XR and haptic technologies are most effective when implemented as complementary tools within broader educational frameworks rather than as replacements for traditional teaching and patient-based learning.

Within the established XR and haptics landscape, artificial intelligence is increasingly proposed as a means of extending the educational value of simulation technologies. Across the reviewed literature, AI is described as having the potential to support adaptive task difficulty, personalised feedback, automated assessment, and intelligent tutoring within VR- and haptics-enhanced learning environments.[80,86,90,91] Some authors suggest that the growing use of simulator-generated performance data could, in future, enable more sophisticated learner modelling and predictive analytics to inform personalised training pathways.[84,87,88] However, while these aspirations are articulated with increasing clarity, limited empirical evidence was identified demonstrating the implementation or evaluation of true AI-enabled haptic systems, such as those incorporating machine learning, real-time adaptive decision-making, or intelligent tutoring, within undergraduate dental education. Instead, most existing systems rely on predefined parameters and rule-based analytics, which, although valuable, fall short of the autonomous or learning-driven capabilities typically associated with artificial intelligence. This gap between conceptual promise and demonstrated application underscores the need for clearer definitions of AI functionality, more transparent reporting of system capabilities, and robust longitudinal research examining how AI-enhanced haptics might meaningfully augment dental education while addressing issues of governance, ethics, and equity.[83,86,91]

A scoping review of endodontic education found that AI can support students with a wide range of non-clinical and clinical activities, including interpretation of radiographs, assessment of case complexity, differential diagnosis, treatment planning and decision-making, clinical simulation, robotics, as well as learner-focused education.[67]

### 4.1.5 The use of AI in dental specific specialties

AI has been utilised for cephalometric training of dental undergraduates in identifying landmarks when undertaking patient assessment for orthodontics. The results showed that digital cephalometric training provided real-time feedback, which supported students with their ability to locate the landmarks correctly and with heightened accuracy, and therefore enhanced their knowledge and skills.[92] In a separate study which evaluated the use of MCAT (Munich Cephalometric Application for Training) among students by submitting their traced radiographs, showed reduced variability when compared to the control group. There was increased satisfaction among students who used the MCAT with positive learning outcomes.[93]

From a prosthodontic training perspective, AI and game-based learning have been used in partial denture design, with a favourable outcome. Overall, 60% of students in the AI group achieved a grade of A or B compared with the conventional group (31%). The AI group also had the advantage of receiving immediate feedback.[94]

A study which involved the use of ChatGPT 3.5, developed by specialist input, compared with real patient simulations to assess differences in diagnosis of temporomandibular disorders and orofacial pain, found no difference in diagnostic accuracy between the two groups.[95]

A retrieval-augmented generation known as EndoQ, which combines evidence-based literature with videos, was evaluated to support learners with their endodontic education across 5 areas, and there were significant improvements across all respective areas: clinical accuracy, contextual relevance, completeness, decision-making professionalism, and communication fluency.[96]

### 4.1.6 Ethics and risk mitigation in the use of AI

There have been limited studies exploring the ethics and legal frameworks of using AI specifically in dental education. There are ethical concerns for both learners and academic institutions, which may pose a risk to academic integrity and patient safety **(Figure 2).**

Studies have highlighted that over-reliance of students on AI may reduce their ability in critical thinking and problem solving, thereby impacting learner development.[53] Although AI often appears convincing in its interpretation of information and data, this does not mean that its outputs are always accurate. This can lead to disseminating misinformation and inaccurate assessments of patients, which is potentially harmful to both learners and patients.[46,81]

When using AI for research, the risk of copyright infringement with AI-generated content remains unresolved and may compromise academic integrity.[97] In relation to assessments, biased grading or limited reliability in assessments can have significant impacts on the academic progression of students as well as their well-being.[97] Furthermore, there are additional challenges with equity of digital access, diversity and inclusion, and overall responsibility for patient care.[32,47,77]

Studies have reported challenges with a lack of robust guidelines and serious risks to data protection.[53,67,98] There is also the risk of harmful misuse. Additionally, when AI is utilised in decision-making, human accountability is essential, especially if harm arises from over-reliance of AI generated outputs that are inappropriate or incorrect. .[81] In relation to patient care, clinicians or students can breach patient confidentiality due to a lack of anonymisation of patient-sensitive data, and heavy reliance on AI for decision-making cannot replace human judgment, which takes into account the context and patient- related factors.[98] Furthermore, AI lacks emotional intelligence and empathy that would be expected from a clinician in providing high-quality patient-centred care.[67]

The need for guidance on the use of AI in dental education has been explored in numerous studies.[26,99,100] A study by Schwendicke et al. (2023) focused on the integration of AI specifically into the dental curricula and highlighted the following domains which need to be considered: defining AI and its use in medical applications, what tools are available, the importance of evaluation, and what areas learners and academic staff should increase their knowledge and skills in AI.

There are several stakeholders in the embedding of AI into dental curricula. This includes the dental regulator, higher education institution, the academic units, professional organisations, staff, students, and the public and patients. Development of best practices and policies would support setting expectations for faculty staff as well as learners, including monitoring use of AI and meeting with privacy and GDPR requirements.[99] Supervision of students is fundamental in ensuring that students are making evidence-based decisions in terms of patient care and minimising the risk to patient safety **(Figure 3).**[99]

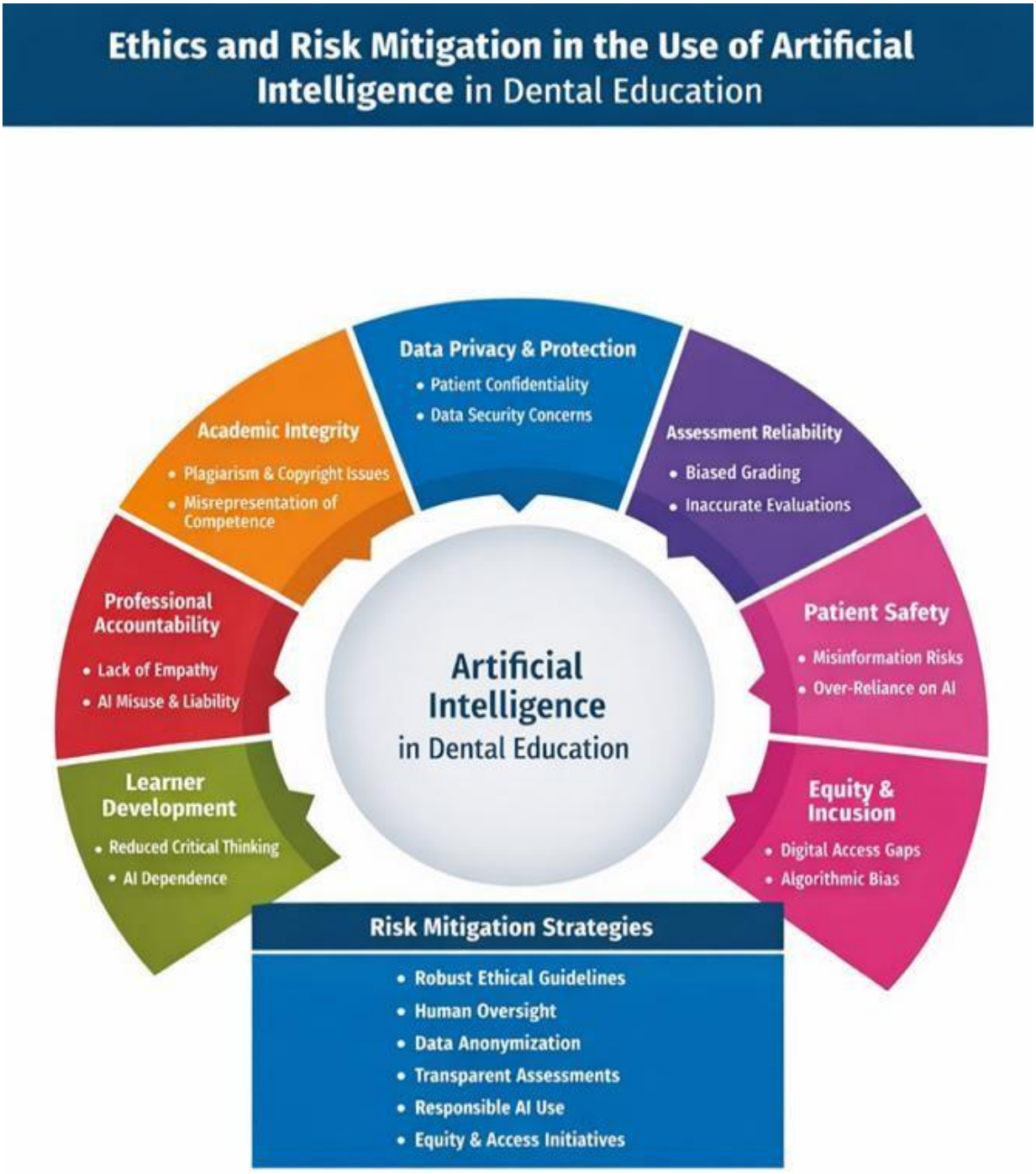



**Figure 2: Ethics and risk mitigation in the use of AI**

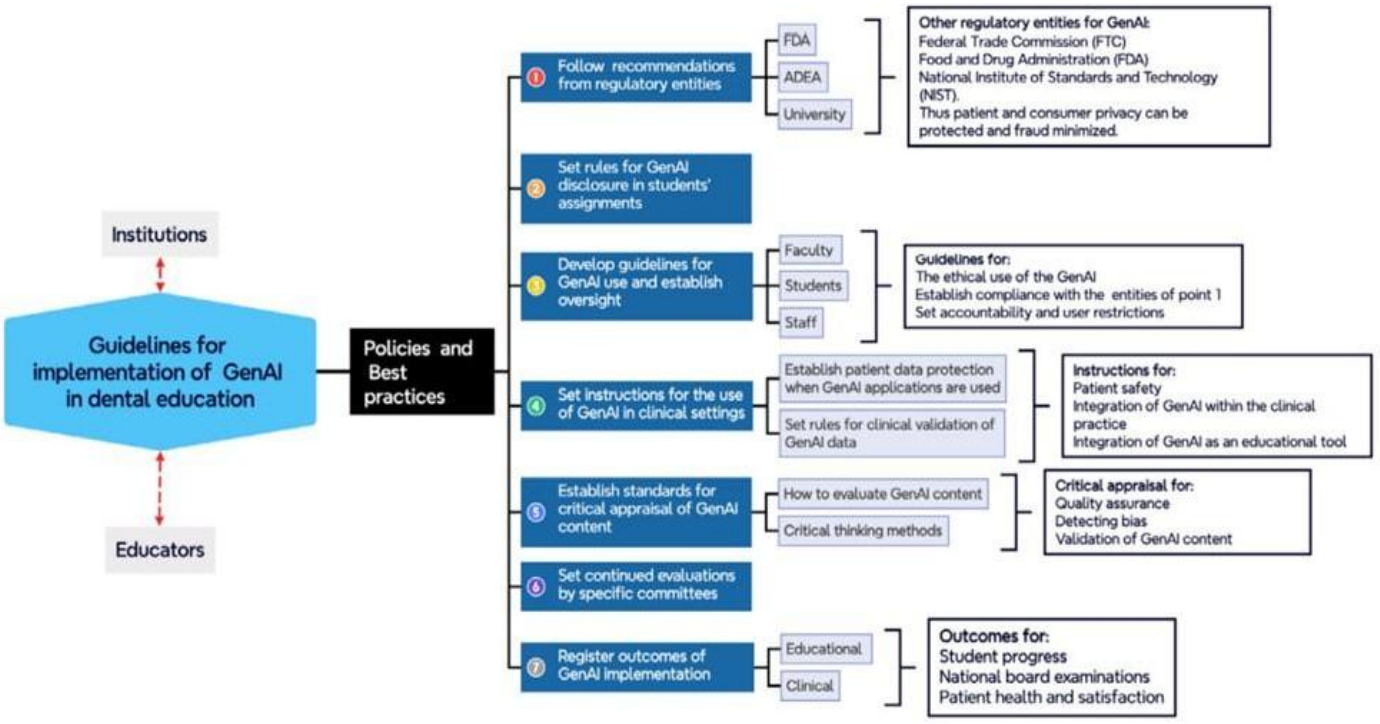



**Figure 3: Suggested guideline for the implementation of Generative Artificial Intelligence (GenAI) in dental education.** [99]

### 4.1.7 Opportunities and Challenges

There are a number of opportunities and challenges to the implementation of AI in dental education (Table 3). Opportunities include the use of AI in dental schools' admissions, the standardisation of education to support didactic teaching, assisting academic staff with lesson planning, clinical skills and assessment, and serving as a research tool, including literature reviews, data analysis and interpretation.[53,67] It is used to summarise a topic or respond to a question and can optimise learning.[46] It further allows students to have additional support with their learning by providing a platform of interactive simulation which can tailor some of the learning according to individual learners' needs and preferences.[46,97] The use of AI can lead to increased knowledge acquisition, as demonstrated by a systematic review, which showed that AI-powered problem-based learning and case-based learning.[101]

It can support the development of tailored lesson plans and develop different levels of assessment with feedback to engage with learners. In essence, the adoption and implementation of AI can support educational pedagogy and encourage constructivist learning. AI can support learners with overcoming spatial conceptualisation by providing immediate feedback to support manual dexterity. AI facilitates students' interaction with virtual objects that mirror a 360° spatial environment and can therefore simulate real-life patient interactions and environments, thereby enhancing skills and confidence in performing dental procedures.[32,49] Mixed reality, which includes virtual and augmented reality, can support students in learning dental anatomy and in facilitating diagnosis, image interpretation, and precision implant placement.[49]

One of the significant challenges is the financial constraints of academic institutions and healthcare systems, limited infrastructure development and lack of training and capacity building.[53] There may be additional obstacles to implementation for both learners and educators due to negative attitudes and a lack of familiarity with using AI, its reliability and accuracy.[47,52] There are concerns of over-reliability on the use of AI among learners, which can impede critical thinking and cognitive capacity.[46,52] AI does not generate new knowledge and content, as it relies heavily on existing knowledge and may therefore have limited contribution in generating hypotheses and pedagogy. Furthermore, AI can lack specific domain knowledge unless this is embedded with specialist human knowledge.[46]

AI is liable for technical “hallucination” where LLM sometimes generate inaccurate information, inaccurate or references that may not exist and may compromise the validity of the information.[32,97] It can also have consequences for academic misconduct, plagiarism, and a lack of transparency.[32,102] Furthermore, LLM cannot always process image-based information, which may impact both learning and assessments.[97]

There are gaps in the ethical and legal frameworks to ensure adoption of AI is in line with GDPR, data protection, accuracy, consistency and sustainability. There are challenges in regulation and governance of AI systems alongside difficulty in understanding complex human contexts, lacking empathy and emotional intelligence.[46]

**Table 3: Facilitators and barriers to the use of AI and immersive digital platforms in dental education**

| Domain | Facilitators | Barriers |
|---|---|---|
| University Dental **Admissions** | • AI in dental school admissions<br>• Standardisation of processes<br>• Supporting students with their application | • Ethical concerns regarding fairness and transparency<br>• Risk of bias embedded in algorithms |
| **Teaching & Learning (Didactic)** | • Standardisation of teaching content<br>• Summarisation of topics and question answering<br>• Optimisation of learning efficiency | • Over-reliance on AI potentially limiting critical thinking<br>• AI does not generate novel knowledge and relies on existing datasets |
| **Personalised Learning** | • Tailored learning experiences based on learner needs and preferences<br>• Interactive simulations to support individual learning | • Variable familiarity and acceptance among students and educators |
| **Clinical Skills & Simulation** | • Virtual, augmented, and mixed reality for skill development<br>• Support for spatial conceptualisation and manual dexterity<br>• Immediate feedback to build confidence and competence<br>• Simulation of real-life patient environments | • Inability of some LLMs to process image-based information<br>• Potential inaccuracies affecting learning and assessment |
| **Assessment & Feedback** | • Development of tiered assessments<br>• Automated feedback to enhance learner engagement | • Concerns regarding assessment validity and reliability |
| **Research & Scholarship** | • Support for literature reviews<br>• Data analysis and interpretation<br>• Assistance with academic writing | • Technical “hallucinations” “black-box” (inaccurate content or fabricated references)<br>• Limited domain-specific knowledge without expert input |
| **Ethical, Legal & Governance,** including academic integrity | • Opportunity to develop responsible AI governance frameworks | • Gaps in ethical and legal frameworks<br>• Data protection and GDPR concerns<br>• Lack of regulatory clarity and competence<br>• Fear of misuse<br>• Risk of plagiarism and academic misconduct<br>• Lack of transparency in AI-generated content |
| **Workforce & Capacity Building** | • Collaboration between educators, students, researchers, clinicians, and computer scientists | • Lack of training and capacity building for staff and learners |

## 4.2 Semi-structured Interviews

Eight semi-structured interviews were conducted, two with current dental students who had experienced some degree of AI integration within their teaching, two with recent graduates from English Dental Schools (North and Southern England), two with General Dental Council regulators and two with education experts in the field.

### 4.2.1 Attitudes towards AI in dental education

The two recent graduates, although they were familiar with the use of AI, used it more for personal use rather than specifically for dental education purposes. There was a general consensus that there was variation in the use of AI, which was more common in the final stages of dental education. The use of AI largely relied on supporting their understanding of lecture content and slides. One of the participants highlighted that one of the universities had employed AI to deliver a pilot OSCE assessment for the potential diagnosis of oral diseases and conditions. Perceptions of the pilot were generally positive among students, but certain risks were highlighted, including over-reliance on AI, which may impede critical thinking.

> "It (pilot OSCE) seemed quite uniform and standardised….. it felt like speaking to a real person…….but I think for myself in terms of assessment, I prefer to speak to a person just because I feel more comfortable speaking to people in real life" (P1)

The participants reported some positive attitudes towards AI. One of the participants had developed a module on AI literacy as well as an AI literacy toolkit for staff in collaboration with the library team. Participants used AI to draft emails, for administrative and research purposes, as well as to create learner guides, figures and diagrams.

> "You know, there, I mean, I suppose each student is an individual, and they will have their own preferences about how they like to receive information, how they learn." (P3)

> They should allow educators to be able to present information or present information for educators, you know, in a range of ways. So if someone's a visual learner, it can create something for them." (P5)

However, there was also a lack of trust in the use of AI in supporting treatment planning, and significant ethical concerns were raised, including who would ultimately be responsible for making the right decisions and providing safe, evidence-based patient care.

> "So I think from a patient point of view, I would say ethics around how it's being used, how it's being shared, I think GDPR is really large and probably has been overlooked" (P3)

> "Whether they're dental professionals or students, that, you know, AI is a tool. It doesn't take away your professional responsibility." (P5).

> "My concern, not just purely ethics perspective, though, in terms of how you use AI, clinical judgment, you know, completely divorcing yourself of the decisions you're making because the machine, quote unquote, does it better. So that is definitely of interest." (P6)

There were also concerns raised when AI is being utilised for assessments, and the risks of bias and plagiarism. However, the use of AI was also perceived to be beneficial in reducing mundane administrative tasks, such as marking of assessments, which could be automated.

### 4.2.2 AI in dental education and clinical practice

Participants reported that AI can be especially relevant at the early stages of training, especially in terms of widening dental knowledge and clinical skills. The phantom head and plastic teeth do not provide real-time feedback as you would receive when using haptics. This was even more pertinent if there aren't adequate opportunities for clinical exposure with real patients, and the idea of case-based simulation can further enhance students' clinical skills. However, participants reported that the human element of dentistry and that AI on its own cannot deliver the dental curriculum in its entirety, and ethical concerns were raised about the use of AI in delivering patient care.

> "It can also make students a lot lazier in terms of doing their own studying. I think it's like a good shortcut, especially when you are doing a long project or a lot of research" (P2).

> "AI may give you answers, but it may not be like one of the ethical things to do…It doesn't have human values" (P2)

Participants reported mixed perceptions, noting potential threats to job security on the one hand, yet also recognising that AI and robotic technologies may enable dental service provision for a larger proportion of patients with significant benefits to the population. While AI can be used for imaging and treatment planning, and improving clinical skills, data privacy and GDPR in relation to patients can be compromised with its use.

> "I have mixed feelings about it….am I going to lose my job…the government could just put AI robots to treat all these patients who need a dentist, so I think in that sense it is very beneficial" (P1)

> "To ensure that you know patients feel comfortable and confident in the registrants that is treating them….. how we're going to keep pace with these developments and make sure that we use AI in a safe and ethical way for the benefit of patients, but really trying to be innovative at the same time" (P3).

> "It depends if they're trusting of a robot, because I think especially because in dentistry you've got lot of patients that already have a fear of the dentist. If you have got something that is less human, I don't know if this is going to get worse for anxious patients" (P2)

It was also clearly reported that inequity in the use of AI needs to be considered, as those students from disadvantaged backgrounds may not be able to afford AI and this may compromise their accessibility and learning outcomes.

> "But we have students where they have a laptop for the whole family. So there are still a lot of concerns in terms of equal and equitable access. So there needs to be equal and equitable access for students and obviously academics as well. And then training for academics so that they can actually teach and support the students." (P6)

Participants acknowledged that the pace of AI was fast-moving, which could pose challenges to academic institutions to keep up pace with the progress. Implementing AI in dental education can be resource-intensive, and it may be difficult in the future to keep up with advances. It is important to facilitate learning during undergraduate education to enable implementation in the workplace.

> "I suppose that creates a challenge for the educator in terms of where to set those boundaries around the use of AI and how to check that understanding." (P5)

> "So, we absolutely have to make sure that we are keeping up with technological advances and that's where, you know, AI is supporting, for example, let's say, radiological reporting, record keeping, disease detection, risk assessment, care planning, those types of things. So those are the expert systems I was saying that are in application. And actually, we have to make sure that we train our students in how to safely use the AI platforms which are going to be most definitely embedded in many of the software, once they graduate and they are practising." (P6)

In terms of the advantages of using AI these varied from administrative tasks such as transcribing and note- taking to diagnostics and treatment planning. One of the graduate participants mentioned a special software that would summarise discussions with patients and generate consent forms as well as referral letters to other health professionals, thereby automating administrative tasks and reducing the workload on clinicians.

> "I would like to see AI introduced across the curriculum so that its relevance is applied to the different specialities as the students go through" (P5)

> "Assist with the clinical side of treatment. Looking, you know, and I suppose it could potentially help individual registered dental professionals to develop and identify where, you know, perhaps they need to get additional skills." (P6)

In terms of future directions in dental education, four of the participants emphasised the need for regulatory frameworks and guidance to incorporate AI into dental curricula.

## 4.3 Triangulation of data

Triangulation of the rapid review with the semi-structured interviews aligned with the majority of the themes found in the rapid review. There were positive attitudes to the use of AI in dental education, but there were also concerns raised around bias, misinformation, GDPR issues and patient safety. Ethical concerns were raised around the use of AI in dental education but also in clinical practice.

There was a strong consensus that AI can be implemented strategically to improve educational outcomes for students, as an adjunct rather than a replacement of dental professionals. While AI is a valuable tool for supporting learners, streamlining assessment and improving quality feedback, study participants emphasised that AI could not replace the human element of patient-clinician interaction, which was perceived to be at the heart of providing patient-centred care. This includes the human dimensions of empathy, rapport-building, ethical judgment and contextual understanding of patients lived experience. Additionally, professional accountability is pertinent to shared decision making and sole reliance on AI was viewed as inappropriate and could compromise patient safety. AI was seen as a supportive tool but is not a substitute to the clinician's emotional intelligence, ethical responsibility and critical thinking taking the patient's needs into consideration.

AI was also perceived as having the potential to enhance patient outcomes, particularly through improved diagnostic support, streamlined workflows, and more consistent decision-making. However, participants stressed that these benefits can only be realised if significant ethical considerations are addressed. They emphasised the need for strict, transparent, and robust governance frameworks to ensure that AI is used safely, responsibly, and in ways that uphold professional standards. Therefore, AI should not be replacing the clinician's critical and holistic judgement thereby maintaining the integrity of patient-centred care.

# 5. Discussion

The use of generative AI and LLMs in dental education is progressing at a pace; however, their systematic and consistent integration into dental education remains at an early stage. While AI applications offer opportunities to improve learning efficiency, consistency, and patient safety, their use requires appropriate governance to address issues of academic integrity, bias, and data protection.[48,49,55] AI can be considered to be a "double-edged sword" in providing benefits, yet serious ethical concerns are raised.[66]

Overall, although attitudes of students and academic staff towards using AI are positive, both groups recognise the challenges and limitations of AI. Students have the ability to adapt and embed AI in their learning to enhance their knowledge and skills, but they also recognise its limitations.[72] AI provides innovation and adaptability in dental education, facilitating student engagement, supporting critical thinking and supporting personalised learning that improves performance and learning outcomes with potential benefit to patients.[48]

AI has been demonstrated to increase efficiency and student performance in diagnosis and treatment planning, but this has not been consistent in terms of accuracy, which may result in misdiagnosis and treatment planning and ultimately, poorer treatment outcomes for patients.[61,79] It can support students in accurately identifying landmarks for radiography and cephalometry, with the advantage of real-time feedback, thereby reducing the teaching load on academic staff. However, AI can sometimes find it difficult in interpreting radiographs and managing procedural workflows involved in taking and analysing radiographs. Therefore, AI can be utilised as a supplementary tool rather than the sole reliance on its use for diagnostics.

The application of LLMs remains in its infancy in dental education despite observable advancements in this field. AI-enhanced clinical training can contribute to improving competency-based pedagogy in dental education. Different large learning models, when used responsibly, can provide students with a dynamic and personalised learning environment and instant feedback, which can support dental students with self-directed learning and building on existing knowledge or clarifying complex content.[97] They can also be utilised in research, conducting literature reviews, data analysis, and drafting written assignments. Although they can be proficient in acquiring knowledge, their performance and accuracy tend to vary between different models and platforms. Furthermore, all LLMs had challenges with the interpretation of images and simulation-based learning. One of the major concerns raised was the phenomenon known as "hallucinations" or "black-box", whereby false knowledge, inaccurate and unsubstantiated data is presented, which can potentially result in learner misinformation impacting treatment planning and patient safety.[67,97] LLMs cannot replace humans in the healthcare system and lack the emotional intelligence and empathy required for any clinician- patient interaction.[67] Therefore, although LLMs were useful overall, they should not be relied upon as the primary education tool but as a supplementary resource.

LLMs also lack true clinical understanding, psychomotor skills, and ethical judgment. Dental education relies heavily on hands-on training, faculty supervision, and real patient interactions within ethical frameworks to develop competence in procedures such as restorations, extractions, and periodontal therapy. These competencies cannot be taught or assessed by LLMs. Furthermore, excessive dependence on AI tools may impair the development of independent clinical reasoning and lifelong learning skills among students.

The dental curricula involve enhancement in surgical clinical skills and will inevitably include students working on a phantom head, which dates back to 1894.[103] This has been widely implemented to simulate the clinical environment in dental education. This simulation-based training provides learners with opportunities to practise technical and psychomotor skills before undertaking procedures involving patients. Haptic systems contribute physical or tactile feedback to the operator but are not, in themselves, a form of AI. Rather, haptics may form part of a broader digital simulation environment that can be enhanced by AI-enabled software. AI may support adaptive feedback, objective performance assessment and tailored practice based on a learner's developing skills. These technologies should be regarded as complementary to supervised clinical education, rather than as substitutes for authentic patient-based learning. Their principal educational benefit is the opportunity to rehearse procedures and receive structured feedback in a controlled environment without exposing patients to avoidable risk. AI can also have an impact on the dental workforce by increasing their capability and capacity to deliver the dental curricula through innovation and adaptability. The use of AI in assessments has shown some promise in reducing the human burden of developing and automating the marking of assessments. However, educationalists cannot solely rely on AI, but it can be used as an adjunct to quality-assuring assessments in the dental field.

Equality, diversity and inclusion must be considered in the implementation and evaluation of AI in dental education to support inclusive educational practices and tackle any pre-existing inequities. In one study, female students were more likely than males to believe that AI will be beneficial to dental care,[55] and female students were also more likely to be aware of ethical concerns.[56] In a study in Saudi Arabia, male dental students were more likely to use AI compared with females.[104] This is in contrast to findings from German-speaking countries, which found no differences between male and female students.[54] However, older age was associated with improved understanding of AI, with older participants reporting a higher level of AI than their younger counterparts. There was no data on ethnicity, but there was regional variation in attitudes towards the utility of AI in dental education. There were positive attitudes in Africa, Asia and the Americas when compared to Europe. This difference could be attributed to pedagogical approaches and traditional teaching methods or regulatory frameworks.[52] However, one significant consideration is the socio-economic background of students; those from low-income backgrounds may find it difficult to access AI, which may cause a "digital divide" and may result in widening existing educational inequalities.[105] As seen in this review, there was variation in implementing of AI by country and affordability of the technology. This poses an important challenge in terms of variation in accessibility and affordability of AI to support dental students and dental educators.

AI undoubtedly raises ethical concerns in terms of learner development, academic integrity and assessment. Dental professionals need to develop the ability for critical thinking and problem-solving as a focal component of education in preparation for the provision of patient care. Although AI can supplement some of the learning, students cannot solely rely on its use. There needs to be boundaries in the use of AI in dental education to enhance the knowledge and skills of students without compromising academic integrity. There are also concerns around data privacy and patient safety, which have been overlooked or not addressed. Considering the hallucinations and Blackbox effects of AI, this could have a negative impact on learning and decision-making in relation to patient care. Therefore, AI could not be a replacement for professional judgment. The human element is intrinsic to interactions between patients and clinicians, encompassing empathy, contextual understanding (social, cultural and wider environment), and emotional intelligence-qualities that AI systems cannot replicate.

The evidence on the application of AI in dental education will require multi-disciplinary collaboration among educators, learners, researchers, practitioners, patients, and computer scientists to develop context-relevant interventions that can be evaluated longitudinally to explore the long-term impacts of AI in dental education.

The use of AI represents a complex trade-off in terms of sustainability. On the one hand, it can offer opportunities for learners in enhancing their knowledge and skills in the identification of disease risks, providing differential diagnosis and treatment planning to foster a more personalised and data-informed oral health care for patients.[106] This can lead to improved patient oral health outcomes and contribute to delivering efficient health care. On the other hand, the development of AI equipment, deployment and maintenance requires substantial technological infrastructure. The training of LLMs and data processing result in a significant deployment of resources, including energy and water, which can have detrimental impacts on carbon emissions and environmental health, compromising planetary health. Therefore, responsible adoption is needed as the NHS has committed to becoming a net-zero health system and achieving a delicate balance between innovation in AI and environmental stewardship.

## 5.1 Strengths:

This report possesses several strengths that enhance its utility for regulatory decision-making and the assurance of educational quality.

- This review employs a policy-relevant Rapid Evidence Assessment (REA) approach, specifically designed for rapidly evolving fields, which effectively balances timeliness with systematic processes. This approach aligns with established rapid review practices, where transparency regarding methodological streamlining is crucial to maintain interpretability for decision-makers.
- The review utilises a structured evidence-mapping methodology consistent with scoping review principles, such as systematic searching, transparent selection, and both descriptive and thematic synthesis. These methodologies are extensively employed to map emerging evidence and identify knowledge gaps.
- The methods outlined exhibit high transparency and reproducibility safeguards for the search and selection process. This includes peer review of the search strategy, structured reporting mechanisms, and the auditability of screening decisions, even when automation tools are employed to aid prioritisation. This minimises the risk of selective identification or interpretation of key evidence.
- The report's mixed-methods design, especially integrating empirical evidence with stakeholder insight, enhances interpretive validity and policy relevance. By triangulating the literature synthesis with semi-structured interviews, the report improves contextual relevance to UK regulatory concerns, such as professional responsibility in AI usage, governance, ethics and equity of access. This is particularly valuable in contexts where the empirical literature is heterogeneous and often context specific.
- The report demonstrates explicit regulatory alignment, consistently anchoring its implications to principles of patient protection, professional accountability, and information governance. These principles are embedded across the GDC's Standards for the Dental Team. This alignment enhances the report's "fitness for purpose" as a submission intended for regulatory review rather than solely for an academic audience.

## 5.2 Limitations:

This report should be interpreted considering several significant limitations, primarily due to the nascent and varied nature of the evidence base and the pragmatic constraints inherent in rapid evidence approaches.

- As a Rapid Evidence Assessment, the review employs streamlined methods compared to a comprehensive systematic review. While this approach is suitable for urgent, rapidly evolving topics, it increases the likelihood that some pertinent studies, unpublished evaluations, or non-indexed implementation reports were overlooked. Consequently, the conclusions should be regarded as directional and risk-focused, rather than as definitive estimates of effectiveness.
- The review is confined only to English-language sources due to time constraints, introducing a time window and language bias. This may result in the underrepresentation of relevant evidence from non-English-speaking contexts, even where innovation (or alternative governance models) is advanced, thereby limiting confidence in global generalisations and potentially biasing the prevalence of themes.
- The included primary literature is methodologically diverse, often based on small samples, single-institution studies, and surveys with country-specific contexts - patterns that typically constrain internal validity (bias/confounding), comparability, and generalisability to UK dental education. As a result, apparent benefits might not reliably translate across settings, student groups, or assessment modalities without stronger multi-site replication. The majority of studies focused on dental students studying dentistry rather than the wider dental team.
- The stakeholder interview component, while valuable for triangulation, comprises a small number of interviews and limited stakeholder breadth. This restricts representativeness across the full dental team, education providers, students at different stages, patients and the public. Therefore, the findings should be considered as insight-generating rather than saturating and not assumed to reflect consensus across stakeholder groups.
- There are also limitations related to governance and ethics evidence. There is limited direct research on ethical and legal frameworks for AI, specifically within dental education. This restricts the ability to recommend highly granular regulatory rules based purely on evaluated interventions, increasing reliance on broader, well-established governance principles.
- Finally, where AI tools supported aspects of screening or appraisal workflow (as described in the draft methods), even with human oversight, this introduces a residual risk of automation bias (e.g., over-trusting prioritisation rankings) and may affect reproducibility if model settings or versions change. Transparent logging and partial dual-checking mitigate this, but do not eliminate it entirely.

## 5.3 Recommendations on a framework for the use of AI in dental education

It is recommended that educational institutions integrate the use of AI into dental curricula, but this will need to be carefully balanced with the needs of learners and academic staff, while adhering to ethical and responsible practice. Robust professional, educational and regulatory frameworks are required to maximise learning opportunities yet maintain patient and public safety.

The recommended framework for the use of AI in dental education was developed based on the literature, as well as guidance used by Higher Education Institutions and the grey literature.[26,99,100] It consists of four major domains, including governance and regulatory alignment, transparency and disclosure policies, pedagogical integration and AI literacy, and continuous evaluation and adaptation. It is important to note that the professional regulator, higher education institutions, and professional bodies need to be aligned and to influence academic institutions to collaborate with students and educators in developing, implementing, and evaluating policies on AI. Outcome monitoring and evidence generation will ensure that this is a dynamic and cyclical process. This is intended to ensure that we are continuously assessing risk, technological advancements, together with regulatory frameworks to promote responsible, ethical and safe integration of AI in dental education without compromising innovation, professional standards and patient safety.

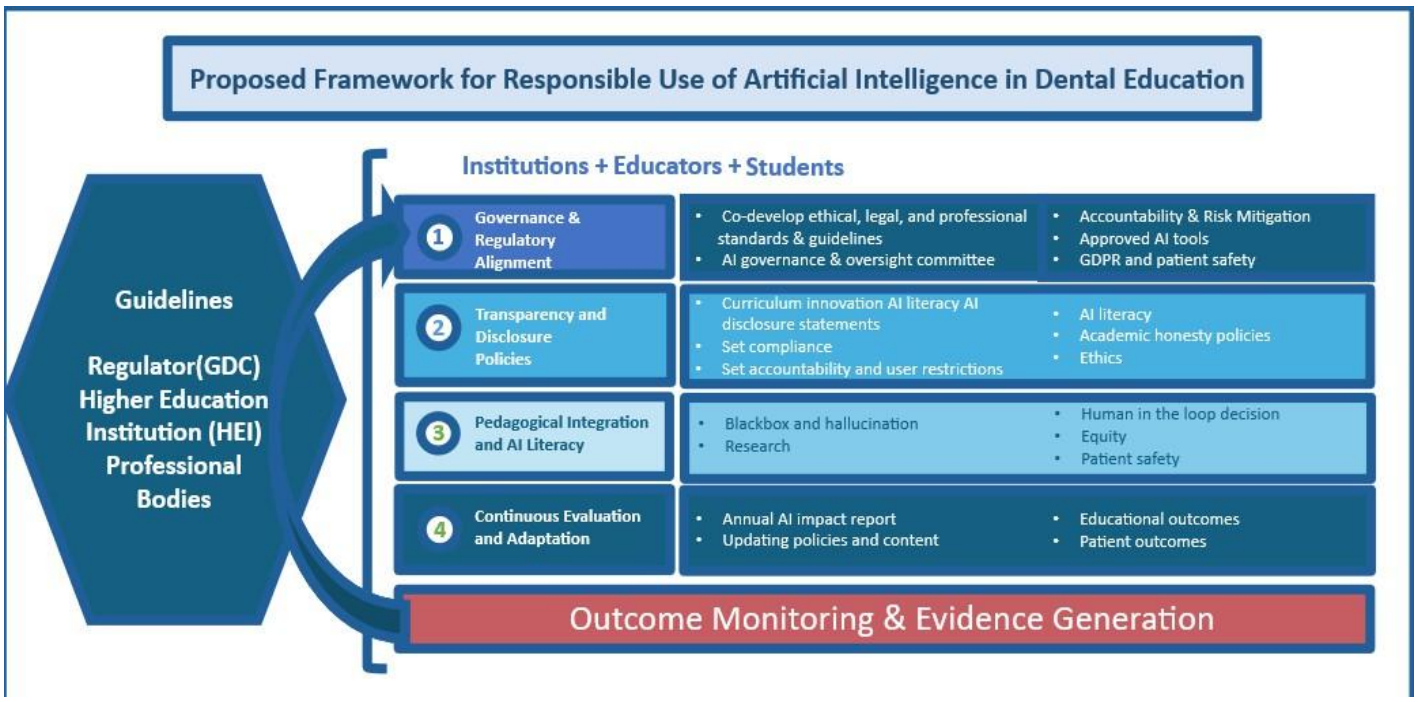



**Figure 4: Recommended framework for use of AI in dental education**

# 6. Conclusions

This Rapid Evidence Assessment indicates that AI tools, particularly generative systems and AI-enabled simulation/decision-support, are increasingly integrated into dental education, with preliminary evidence suggesting benefits in learning support, feedback, and specific diagnostic training contexts. However, the literature reviewed is diverse and often context-specific. Stakeholder perspectives highlight that trust, accountability, and information governance are primary concerns rather than secondary afterthoughts. From a regulatory perspective, the adoption of AI in dental education is significant because it influences the reliability of clinical reasoning, professional judgment, and safe decision-making, thereby having implications for patient safety, equality, and public confidence. AI should be regarded as an adjunct educational tool requiring explicit governance, rather than a replacement for human-led education, supervised clinical experience or professional responsibility and accountability. The General Dental Council's (GDC) Standards for the Dental Team already mandate evidence-based care, working within competence, valid consent, confidentiality, and raising concerns when safety is compromised. These principles provide immediate, defensible foundations for expectations placed on education providers. The GDC's revised Standards for Education and the Safe Practitioner Framework further bolsters the case for action by explicitly addressing technological advancements, behaviour monitoring, inclusive admissions, and differential attainment alongside patient protection and safety. The report proposes a phased regulatory approach: (i) establish clear minimum expectations for AI literacy, disclosure, and acceptable use within training and assessment; (ii) mandate proportionate information governance safeguards, including Data Protection Impact Assessments (DPIAs) where AI processing involves personal data and where risks to individuals are significant; and (iii) prioritise UK-based, multi-site evaluation using standardised reporting guidance to ensure that future regulatory decisions are evidence-based rather than reactive to market adoption.

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# 8. Appendices

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| 2. Use of Rayyan and ASReview AI Tool for AI-Assisted Title–Abstract Screening |
| 3. PRISMA 2020 Checklist |
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| 5. Bibliometric Snapshot of Studies Included in the Review |

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## Appendix 1: Search Strategies

The Population–Intervention–Outcome (PIO) framework and draft search strategy were refined iteratively through consultation with QMUL Library Services and the British Dental Association (BDA) Library team. To ensure accuracy, transparency, and reproducibility, the search strategy was peer-reviewed and refined in accordance with the PRESS 2015 Guideline Statement.43 PRESS provides a structured framework using six key domains:

1. Translation of the research question into searchable concepts (Population, Intervention, Outcomes);
2. Boolean and proximity operators (use of AND, OR, truncation, and parentheses);
3. Controlled vocabulary (e.g., MeSH terms and subject headings) and corresponding free-text keywords;
4. Syntax and spelling accuracy, ensuring platform-specific compliance;
5. Use of limits and filters, such as language or date restrictions; and
6. Overall structure and logic, confirming the search could reliably retrieve relevant studies while minimising noise.

Feedback from the PRESS review resulted in minor adjustments to synonym inclusion (e.g., “AI in dental education,” “digital education,” “intelligent tutoring systems AND dental”) and refinements in Boolean logic to balance recall and precision.

Pilot searches were conducted to test sensitivity, terminology, and Boolean structure across health and education databases. Feedback-informed adjustments to synonym clusters, inclusion of generative AI and large language model terminology, and alignment with controlled vocabulary where applicable. This validation process ensured methodological robustness, regulatory relevance, and reproducibility prior to commencement of the formal search. Final search strategies that were used in this SI-REA are provided below.

Searches were conducted within the defined time window and adapted appropriately for each database platform. All retrieved records were exported and imported into EndNote 21 (Clarivate Analytics, Philadelphia, PA, USA, 2023) for citation management and initial duplicate removal using automated matching of bibliographic metadata (author, title, year).

### A. The complete PubMed database search strategy:

((((("Students, Dental"[Mesh] OR ("Students"[Mesh] AND "Dental Assistants"[Mesh] OR "Dental Hygienists"[Mesh] OR "Dental Auxiliaries"[Mesh] OR "Dental Technicians"[Mesh] OR "Dentists"[Mesh])) OR ((((((((((((((((("Education, Dental"[Mesh]) OR ("dental students")) OR ("dental undergraduates")) OR ("undergraduate dental")) OR ("vocational training")) OR ("foundation dentist")) OR ("dental foundation trainee")) OR ("dental vocational trainee"[tiab:~0])) OR ("dental trainees")) OR ("dental professionals in training"[tiab:~0])) OR ("oral health students")) OR ("dental nurse students")) OR ("dental hygienist students")) OR ("dental therapist students")) OR ("orthodontic therapist students"[tiab:~0])) OR ("clinical dental technician students"[tiab:~0])) OR ("dental education participants"[tiab:~0])) OR ("dental school*"))) AND (("Artificial Intelligence"[Mesh] OR "Machine Learning"[Mesh] OR "Deep Learning"[Mesh] OR "Large Language Models"[Mesh] OR "artificial intelligence" OR "AI" OR "machine learning" OR "deep learning" OR "large language models" OR "LLM" OR "ChatGPT" OR "generative AI" OR "diagnostic AI" OR "AI simulators"[tiab:~0] OR "AI-enhanced learning"[tiab:~0] OR "AI-assisted teaching" OR "AI in dental education"[tiab:~0] OR "AI

curriculum" OR "AI ethics in dentistry"[tiab:~0] OR "AI applications in training"[tiab:~0] OR "adaptive learning" OR "computer-assisted instruction" OR "computer-assisted learning" OR "simulation-based learning" OR "virtual patient" OR "virtual simulation" OR "augmented reality" OR "virtual reality" OR "chatbot" OR "AI chatbot" OR "natural language processing" OR "NLP" OR ("intelligent tutoring systems" AND dental) OR ("ITS"[tiab] AND dental) OR "educational technology" OR "digital pedagogy" OR "technology-enhanced learning")) AND (((((("Clinical Competence"[Mesh]) OR "Risk"[Mesh]) OR "Ethics, Dental"[Mesh]) OR "Learning"[Mesh]) OR "Teaching"[Mesh]) OR "Curriculum"[Mesh]) OR (("AI literacy" OR "artificial intelligence literacy" OR "digital literacy" OR "digital competence" OR "knowledge acquisition" OR "learning performance" OR "clinical competency" OR "self-efficacy" OR "student perception" OR "learner perception" OR "student satisfaction" OR "attitude toward AI" OR "perception of AI" OR "curriculum development" OR "teaching innovation" OR "learning outcomes" OR "assessment methods" OR "academic integrity" OR "ethical awareness" OR "professional preparedness" OR "professional development" OR "faculty readiness" OR "equity in education" OR "EDI"[tiab] OR "diversity" OR "inclusivity" OR "access to AI"[tiab:~0] OR "curriculum reform" OR "risk mitigation" OR "ethical risk" OR "academic risk")))) AND ((2020/1:2025[pdat]) AND (english[Filter])))

**B. The complete Scopus database search strategy:**

(TITLE-ABS-KEY(("dental students" OR "student dentists" OR "dental undergraduates" OR "undergraduate dental" OR "vocational training" OR "dental vocational trainee" OR "dental foundation trainee" OR "vocational trainee" OR "dental core training" OR "dental professionals in training" OR "dental trainees" OR "oral health students" OR "dental nurse students" OR "dental hygienist students" OR "dental therapist students" OR "orthodontic therapist students" OR "clinical dental technician students" OR "dental education participants" OR "dental school" OR "dental education")) AND TITLE-ABS-KEY(("artificial intelligence" OR "AI" OR "machine learning" OR "deep learning" OR "large language models" OR "LLM" OR "ChatGPT" OR "generative AI" OR "diagnostic AI" OR "AI simulators" OR "AI-enhanced learning" OR "AI-assisted teaching" OR "AI in dental education" OR "AI curriculum" OR "AI ethics in dentistry" OR "AI applications in training" OR "adaptive learning" OR "computer-assisted instruction" OR "computer-assisted learning" OR "simulation-based learning" OR "virtual patient" OR "virtual simulation" OR "augmented reality" OR "virtual reality" OR "chatbot" OR "AI chatbot" OR "natural language processing" OR "NLP" OR ("intelligent tutoring systems" AND dental) OR ("ITS" AND dental) OR "educational technology" OR "digital pedagogy" OR "technology-enhanced learning")) AND TITLE-ABS-KEY(("AI literacy" OR "digital literacy" OR "digital competence" OR "knowledge acquisition" OR "learning performance" OR "clinical competence" OR "self-efficacy" OR "student perception" OR "learner perception" OR "student satisfaction" OR "attitude toward AI" OR "perception of AI" OR "curriculum development" OR "teaching innovation" OR "learning outcomes" OR "assessment methods" OR "academic integrity" OR "ethical awareness" OR "professional preparedness" OR "professional development" OR "faculty readiness" OR "equity in education" OR "EDI" OR "inclusivity" OR "diversity" OR "student access to AI" OR "curriculum reform" OR "risk mitigation" OR "ethical risk" OR "academic risk"))) AND PUBYEAR > 2019 AND PUBYEAR < 2027 AND PUBYEAR > 2019 AND PUBYEAR < 2027 AND (LIMIT-TO (LANGUAGE,"English") )

**C. The complete Web of Science database search strategy:**

("dental students" OR "dental undergraduates" OR "undergraduate dental" OR "vocational training" OR "foundation dentist" OR "dental foundation trainee" OR "dental vocational trainee" OR "dental trainees" OR "dental professionals in training" OR "oral health students" OR "dental nurse students"

OR "dental hygienist students" OR "dental therapist students" OR "orthodontic therapist students" OR "clinical dental technician students" OR "dental education participants" OR "dental school" OR "dental schools") (All Fields) and ("artificial intelligence" OR "AI" OR "machine learning" OR "deep learning" OR "large language models" OR "LLM" OR "ChatGPT" OR "generative AI" OR "diagnostic AI" OR "AI simulators" OR "AI-enhanced learning" OR "AI-assisted teaching" OR "AI in dental education" OR "AI curriculum" OR "AI ethics in dentistry" OR "AI applications in training" OR "adaptive learning" OR "computer-assisted instruction" OR "computer-assisted learning" OR "simulation-based learning" OR "virtual patient" OR "virtual simulation" OR "augmented reality" OR "virtual reality" OR "chatbot" OR "AI chatbot" OR "natural language processing" OR "NLP" OR ("intelligent tutoring systems" AND dental) OR ("ITS" AND dental) OR "educational technology" OR "digital pedagogy" OR "technology-enhanced learning") (All Fields) and ( "AI literacy" OR "digital literacy" OR "digital competence" OR "knowledge acquisition" OR "learning performance" OR "clinical competency" OR "self-efficacy" OR "student perception" OR "learner perception" OR "student satisfaction" OR "attitude toward AI" OR "perception of AI" OR "curriculum development" OR "teaching innovation" OR "learning outcomes" OR "assessment methods" OR "academic integrity" OR "ethical awareness" OR "professional preparedness" OR "professional development" OR "continuing professional development" OR "CPD" OR "lifelong learning" OR "faculty readiness" OR "equity in education" OR "EDI" OR "inclusivity" OR "student access to AI" OR "curriculum reform" OR "risk mitigation" OR "ethical risk" OR "academic risk" ) (All Fields) and 2020 or 2022 or 2021 or 2024 or 2023 or 2025 (Publication Years) and English (Languages)

**D. The complete ERIC (EBSCOhost Research Databases interface) Search Strategy:**

("dental students" OR "student dentists" OR "dental undergraduates" OR "undergraduate dental" OR "vocational training" OR "dental vocational trainee" OR "dental foundation trainee" OR "vocational trainee" OR "dental core training" OR "dental professionals in training" OR "dental trainees" OR "oral health students" OR "dental nurse students" OR "dental hygienist students" OR "dental therapist students" OR "orthodontic therapist students" OR "clinical dental technician students" OR "dental education participants" OR "dental school" OR "dental education") AND ("artificial intelligence" OR "AI" OR "machine learning" OR "deep learning" OR "large language models" OR "LLM" OR "ChatGPT" OR "generative AI" OR "diagnostic AI" OR "AI simulators" OR "AI-enhanced learning" OR "AI-assisted teaching" OR "AI in dental education" OR "AI curriculum" OR "AI ethics in dentistry" OR "AI applications in training" OR "adaptive learning" OR "computer-assisted instruction" OR "computer-assisted learning" OR "simulation-based learning" OR "virtual patient" OR "virtual simulation" OR "augmented reality" OR "virtual reality" OR "chatbot" OR "AI chatbot" OR "natural language processing" OR "NLP" OR ("intelligent tutoring systems" AND dental) OR ("ITS" AND dental) OR "educational technology" OR "digital pedagogy" OR "technology-enhanced learning") AND ("AI literacy" OR "digital literacy" OR "digital competence" OR "knowledge acquisition" OR "learning performance" OR "clinical competence" OR "self-efficacy" OR "student perception" OR "learner perception" OR "student satisfaction" OR "attitude toward AI" OR "perception of AI" OR "curriculum development" OR "teaching innovation" OR "learning outcomes" OR "assessment methods" OR "academic integrity" OR "ethical awareness" OR "professional preparedness" OR "professional development" OR "faculty readiness" OR "equity in education" OR "EDI" OR "inclusivity" OR "diversity" OR "student access to AI" OR "curriculum reform" OR "risk mitigation" OR "ethical risk" OR "academic risk")

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## Appendix 2: Use of Rayyan and ASReview AI Tool for AI-Assisted Title–Abstract Screening

## A. Purpose of using Rayyan and ASReview for screening

Following automated de-duplication in EndNote, records were transferred to Rayyan, a web-based systematic review platform designed to support screening and duplicate detection.44 Although Rayyan offers automated duplicate removal, the duplicate-identification function was set to manual verification mode. This allowed the system to flag potential duplicates while preserving researcher oversight in determining whether records were true duplicates and which version should be retained. This two- step de-duplication process reduced the risk of erroneous deletion while ensuring dataset integrity prior to screening.

Title and abstract screening were then conducted using ASReview (Active Learning for Systematic Reviews, ASReview Lab Developers, Netherlands, 2025), an open-source machine-learning tool that supports prioritised screening through active learning.[45] ASReview was used to support semi-automated screening of titles and abstracts. The tool prioritises potentially relevant studies using machine learning and active learning to increase screening efficiency while maintaining transparency and reproducibility. It was used alongside human supervision as described in the main report text.

Two reviewers worked collaboratively within ASReview, assessing records in order of predicted relevance. Studies were excluded only when both reviewers reached agreement based on predefined eligibility criteria. AI-assisted prioritisation was used solely to enhance efficiency; all inclusion and exclusion decisions remained under human control. Screening continued in ranked order until a predefined stopping criterion was met. Specifically, screening was concluded when 31 consecutive records were identified as non-eligible, indicating diminishing likelihood of further relevant studies within the prioritised set. This stopping rule is consistent with active-learning approaches in rapid reviews, where screening continues until the probability of identifying additional eligible studies becomes negligible. The description (prompt) provided to ASReview, the settings used, and the outcome report figures are reported below.

## B. Text provided to ASReview describing the review scope

This project aims to identify and screen literature on the use, role, and impact of artificial intelligence (AI) in dental education prior to GDC registration, including undergraduate dentistry, dental hygiene and therapy programmes, preclinical learning, and dental foundation training where relevant to pre-registration educational outcomes.

We are only interested in evidence that relates to AI as part of dental education, either:

- AI as a subject of learning (e.g., AI literacy, curriculum integration, competencies), or
- AI as an educational tool (e.g., AI-supported teaching, assessment, simulation, feedback, clinical skills development).

At this stage, we are not including post-registration training, CPD, specialist training, or workforce-level AI applications, unless the study clearly includes an undergraduate or pre-registration learner group.

Eligible evidence includes empirical studies (quantitative, qualitative, mixed-methods), systematic/scoping reviews, grey literature, policy documents, case studies, and evaluation reports published from 2020 onward.

Studies must explore:

- The definition or conceptualisation of AI in dental education
- Curriculum development, teaching or assessment involving AI
- Student knowledge, skills, competencies, or preparedness related to AI
- Implementation of AI tools in pre-registration learning environments
- Challenges, barriers, risks, ethics, or EDI implications of AI for dental students
- Institutional or educator responses to AI

We will exclude:

- Studies solely focused on clinical AI applications with no educational component
- Studies solely examining post-registration, CPD, or specialist programmes
- Opinion pieces without relevant educational insights

## C. ASReview model configuration

| Parameter | Setting |
|---|---|
| Feature extraction | TF-IDF |
| Classifier | Logistic Regression |
| Query strategy | Mixed (95% certainty / 5% uncertainty) |
| Balance strategy | Dynamic resampling (double) |

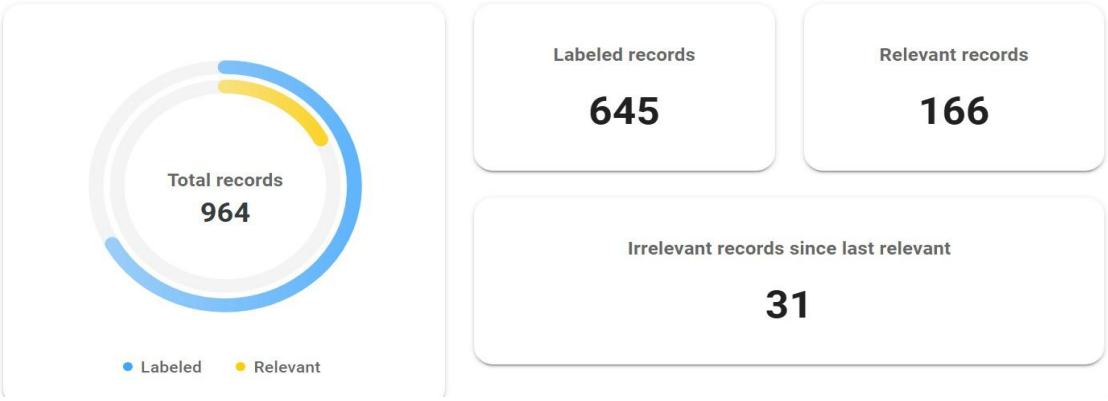
## D. Model training and seed records

The ASReview model was initialised using a set of seed records generated through manual screening. Two reviewers jointly screened a random sample of 10 records, of which 2 were labelled as relevant and 8 as irrelevant. These labelled records formed the initial training set used by the active learning algorithm to prioritise records for subsequent screening.

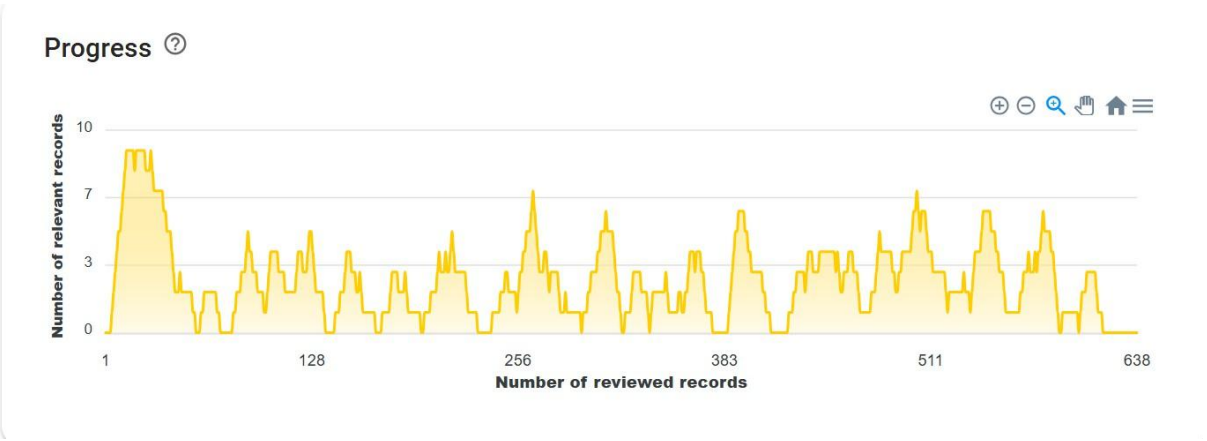
## E. Stopping rule

Screening continued with two reviewers jointly making decisions inside ASReview, until the prioritisation algorithm yielded a prolonged sequence of non-relevant records of 30 (in practice it was 31) and the probability of identifying additional relevant studies was considered low. At this point the screening process was stopped.

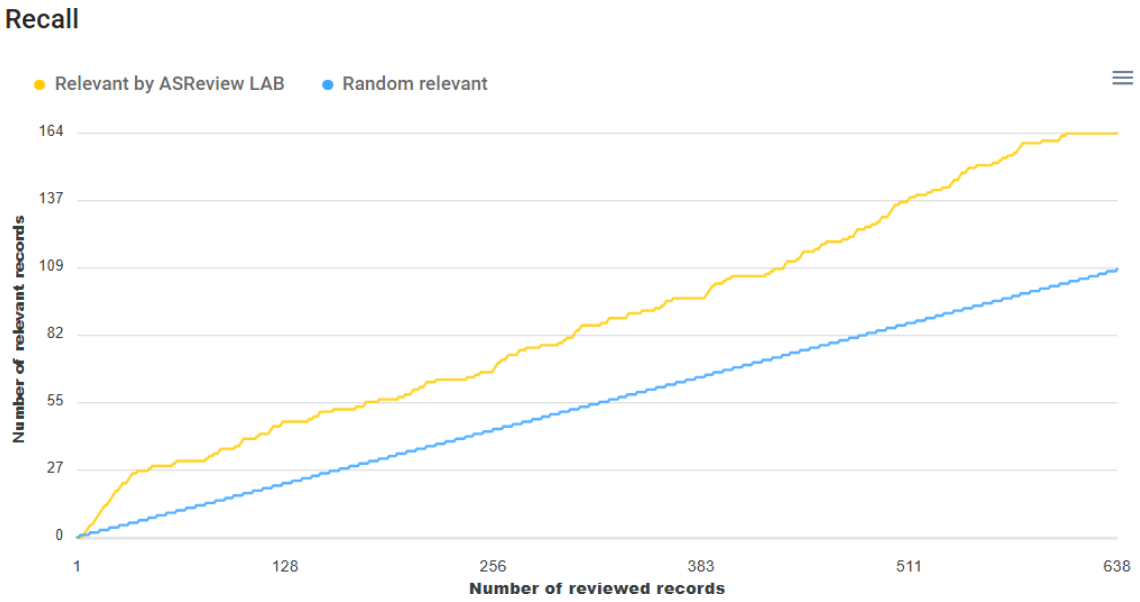
## F. Summary of ASReview screening statistics.




## G. ASReview screening progress showing the cumulative number of relevant records identified (Y-axis) against the number of records reviewed (X-axis).




## H. Estimated recall of relevant studies during ASReview screening.



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## Appendix 3: PRISMA 2020 Checklist

The **PRISMA 2020 reporting checklist** was used to ensure transparency and completeness in reporting the methods and findings of this rapid evidence assessment. The completed checklist indicating where each item is addressed in the report is provided below. The first item of checklist was modified by replacing "scoping review" with "SI-SEA" to present the nature of this study.

| Item | Item Description | Location (or reason for not reporting) |
|---|---|---|
| **Title and Abstract** | | |
| 1. Title | Identify the report as a SI-REA. | Methods.<br>**3.1** Overview **and Rationale** |
| 2. Abstract | Include all items from the *PRISMA 2020 for Abstracts* checklist. | Executive Summary |
| **Introduction** | | |
| 3. Rationale | Describe the rationale for the review in the context of existing knowledge. | **3.1 Overview and Rationale** |
| 4. Objectives | Provide an explicit statement of the objective(s) or question(s) the review addresses. | 2. Aim and Objectives |
| **Methods** | | |
| 5. Eligibility criteria | Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses. | 3.3.3 Stage 2: Identifying relevant evidence<br><br>3.3.4 Stage 3: Study selection and quality appraisal |
| 6. Information sources | Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted. | 3.3.3 Stage 2: Identifying relevant evidence |
| 7. Search | Present the full search strategies for all databases, registers and websites, including any filters and limits used. | Appendix 1 |
| 8. Selection Process | Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and, if applicable, details of automation tools used in the process. | 3.3.4 Stage 3: Study selection and quality appraisal |

| | | |
|---|---|---|
| 9. Data collection process | Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process. | 3.3.5 Stage 4: Data extraction and evidence mapping |
| 10. Data Items | | |
| 10a. Outcomes | List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect. | 3.3.1 Stage 0 (prior to main search): Protocol development<br><br>3.3.6 Stage 5: Thematic synthesis and analytic integration |
| 10b. Other Variables | List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information. | 3.3.5.1.a. Pass 1: Structured Extraction and Evidence Mapping<br><br>Supplementary data file: Pass 1 data extraction |
| 11. Risk of bias in individual studies | Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process. | Risk of bias was considered in:<br>3.3.4 Stage 3: Study selection and quality appraisal<br><br>No formal risk of bias assessment tools was used in this rapid review, as it is not required in rapid reviews. |
| 12. Effect measures | Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results. | This item is only relevant when there are quantitative outcomes and meta-analysis. Not applicable to this SI-REA. |
| 13. Synthesis Methods | | |
| 13a. Deciding which studies were eligible for each synthesis | Describe the processes used to decide which studies were eligible for each synthesis (such as tabulating the study intervention characteristics and comparing against the planned groups for each synthesis described in item 5. | 3.3.6 Stage 5: Thematic synthesis and analytic integration<br><br>3.3.7 Stage 6: Stakeholder triangulation and regulatory interpretation |

| | | |
|---|---|---|
| 13b. Data preparation methods | Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions. | 3.3.6 Stage 5: Thematic synthesis and analytic integration<br><br>3.3.7 Stage 6: Stakeholder triangulation and regulatory interpretation |
| 13c. Methods for tabulating or displaying results | Describe any methods used to tabulate or visually display results of individual studies and syntheses. | 3.3.6 Stage 5: Thematic synthesis and analytic integration<br><br>3.3.7 Stage 6: Stakeholder triangulation and regulatory interpretation |
| 13d. Synthesis methods | Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used. | 3.3.6 Stage 5: Thematic synthesis and analytic integration<br><br>3.3.7 Stage 6: Stakeholder triangulation and regulatory interpretation |
| 13e. Methods for exploring heterogeneity | Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression). | This is specifically for systematic reviews. Not relevant to SI-REA |
| 13f. Sensitivity analyses | Describe any sensitivity analyses conducted to assess robustness of the synthesized results. | This is specifically for systematic reviews. Not relevant to SI-REA |
| 14. Reporting bias assessment | Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases). | 3.3.2 Stage 1: Question refinement and development of search strategy<br><br>3.3.5 Stage 4: Data extraction and evidence mapping |
| 15. Certainty assessment | Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome. | Not applicable – certainty of evidence (GRADE) was not assessed due to the exploratory nature of the REA. |
| **Results** | | |
| 16. Study Selection | | |
| 16a. Results of the search and selection process | Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram. | 4. Results<br><br>Figure 1. PRISMA Flowchart of Evidence Selection Process |

| | | |
|---|---|---|
| 16b. Excluded studies | Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded. | 4. Results<br><br>Figure 1. PRISMA Flowchart of Evidence Selection Process |
| 17. Study characteristics | Cite each included study and present its characteristics. | Supplementary data file: Pass 1 data extraction |
| 18. Risk of bias in studies | Present assessments of risk of bias for each included study. | 4.3 Triangulation of data |
| 19. Results of individual studies | For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots. | Some individual results are presented in: Supplementary data file: Pass 1 data extraction<br><br>Summary of statistics are meant for systematic reviews/meta-analysis. Not relevant to SI-REA |
| 20. Results of Synthesis | | |
| 20a. Summary of studies | For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies. | Supplementary data file: Pass 1 data extraction |
| 20b. Statistical results | Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect. | Meant for systematic reviews/meta-analysis studies. Not relevant to SI-REA. |
| 20c. Heterogeneity | Present results of all investigations of possible causes of heterogeneity among study results. | Meant for systematic reviews/meta-analysis studies. Not relevant to SI-REA. |
| 20d. Sensitivity analyses | Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results. | This item is tied to meta-analysis.<br>Not applicable to this SI-REA. |
| 21. Risk of reporting biases in syntheses | Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed. | 4.1.6 Barriers and facilitators |
| 22. Certainty of evidence | Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed. | Not applicable – certainty of evidence was not formally graded in this rapid evidence assessment. |

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| **Discussion** | | |
| 23. Discussion | | |
| 23a. General interpretation of the results | Provide a general interpretation of the results in the context of other evidence. | 5. Discussion |
| 23b. Limitations of included evidence | Discuss any limitations of the evidence included in the review. | 5.2 Limitations |
| 23c. Limitations of the review processes | Discuss any limitations of the review processes used. | 5.2 Limitations |
| 23d. Implications | Discuss implications of the results for practice, policy, and future research. | 5.3 Recommendations on a framework for the use of AI in dental education |
| **Other Information** | | |
| 24. Registration and Protocol | | |
| 24a. Registration | Provide registration information for the review, including register name and registration number, or state that the review was not registered. | Information regarding ethical approval is provided under section 3.1 Overview and rationale.<br><br>No other formal registration was required for this study. |
| 24b. Protocol | Indicate where the review protocol can be accessed, or state that a protocol was not prepared. | Upon request. |
| 24c. Amendments | Describe and explain any amendments to information provided at registration or in the protocol. | Not applicable. |
| 25. Support | Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review. | Acknowledgement p2 |
| 26. Competing Interests | Declare any competing interests of review authors. | Acknowledgement p2 |
| 27. Availability of data, code, and other materials | Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review. | Acknowledgement p2 |

# Understanding the Role of AI in Dental Education:

## A Rapid Evidence Assessment for Regulatory Insight

## Appendix 4: Topic Guide Used for Semi-Structured Interviews

**TOPIC GUIDE**

Investigating the Perceptions, Experiences, and Future Applications of Artificial Intelligence (AI) in Dental Education.

This topic guide is designed for a **Focus Group or Semi-Structured Interview** with dental students, educators, and clinicians regarding the use of AI in dental education. It is structured into four main sections, moving from general experiences to specific challenges and future visions.

**Section 1: Introduction and Current Experience**

- **Objective:** To establish the participant's background and gauge their overall experience and current use of AI tools.
- **Warm-up:** Could you briefly describe your role (student, educator, clinician) and how long you've been in the field?
- How familiar are you with the concept of AI?
- What sources (media, professional development) informed your understanding of AI?
- **Current use:** In your work/ study, are you currently using any AI tools (e.g., ChatGPT, image analysis software, diagnostic aids)?
- Which tasks/activities? How frequently are you using AI?
- What role AI currently plays, or could play, in the field of dentistry and oral healthcare?

**Section 2: AI in Dental Education and Training**

- **Objective:** To explore specific uses of AI in educational settings, focusing on perceived value and impact on learning.
- Where do you see the most valuable current or potential applications of AI in the dental curriculum or training environment? Prompts: *simulated patient training, grading assessments, clinical decision support, personalized learning paths*
- How could AI tools (e.g., virtual reality simulators, haptic feedback systems) change how students learn and practice clinical skills before treating real patients?
- What is your opinion on using AI for grading practical and theoretical assessments in dental education? What are the ethical concerns (e.g., cheating, bias) if AI is used in assessment?
- **Student Impact:** How might AI tools change student/trainee engagement or the way students approach self-study and learning outside of the classroom?

**Section 3: Barriers, Challenges, and Ethical Concerns**

- **Objective:** To identify the practical, institutional, and ethical obstacles to widespread AI adoption.

- What are the most significant **barriers** preventing your institution (or the dental field generally) from effectively adopting AI tools in education? *Prompts: cost, lack of infrastructure, lack of faculty training, resistance to change.*
- How equipped is the dental school/ dental education with the knowledge and skills necessary to teach with or about AI?
- **Ethical Concerns:** What are the main ethical or legal concerns you have about using AI in education and eventual practice?
- **Curriculum Gap:** How should the dental curriculum be updated to ensure future graduates are competent to work alongside AI systems in their clinical careers?

**Section 4: Future Vision and Recommendations**

- **Objective:** To elicit actionable suggestions and summarize the future trajectory of AI in the field.
- Imagine an **"ideal" dental school** in 5–10 years. How would AI be integrated into the teaching and learning processes?
- What are **the key steps** that institutions or national dental bodies should take **right now** to prepare for this AI-driven future?
- Any other suggestions

# Understanding the Role of AI in Dental Education:

## A Rapid Evidence Assessment for Regulatory Insight

## Appendix 5: Bibliometric Snapshot of Studies Included in the Review

| ID | Title of article/document | Author(s) | Year of publication | Country | Journal/ Publishing organisation | Study design | Sample size | Data collection method | AI category | Outcomes measured | Main results/conclusion | Recommendations of the paper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Exploring dental faculty awareness, knowledge, and attitudes toward AI integration in education and practice: a mixed-method study | Saeeda Abdullah, Syeda Rabbab Hasan, Muhammad Adil Asim, Ambreen Khurshid, Ali Waqar Qureshi | 2025 | Pakistan | BMC Medical Education | Mixed-method study | 400 | Survey; Focus Group Discussions | Diagnostic; Simulation | Knowledge; Awareness | General awareness and positive attitudes towards AI; Limited knowledge in advanced AI concepts | Integration of AI in curriculum; Training and capacity building; Infrastructure development; Need of longitudinal studies to enhance generalisability of AI adoption |
| 2 | Awareness and Approaches Regarding Artificial Intelligence in Dentistry: A Scoping Review | Sultan Aldakhil, Khalid Alkhurayji, Shug Albarrak, Abdulaziz Almihbash, Rayan Aldalan, Khaled Alshehri, Salman Alrusaini, Ali Asiri | 2024 | Global | Cureus | Scoping Review | 7688 | Database search; PRISMA guidelines | Diagnostic | Knowledge; Awareness | Low awareness of AI in dentistry; need for curriculum integration | Integrate AI into dental curricula |
| 3 | ChatGPT— A double-edged sword for healthcare education? Implications for assessments of dental students | Kamran Ali; Noha Barhom; Faleh Tamimi; Monty Duggal | 2024 | Qatar | European Journal of Dental Education | Exploratory study | 50 assessment items | Web-based assessment using ChatGPT | Generative | Knowledge | Generative AI applications have potential in education but require adaptation to mitigate dishonest use | Adapt teaching and assessments to integrate AI benefits while preventing misuse |
| 4 | Artificial Intelligence in Endodontic Education | Anita Aminoshariae, Ali Nosrat, Venkateshbabu Nagendrababu, Omid Dianat, Hossein Mohammad-Rahimi, Abbey W. O'Keefe, Frank C. Setzer | 2024 | Global | Journal of Endodontics | Scoping review | 35 articles | Electronic search; manual search; grey literature | Diagnostic; Simulation; AI Tutor | Knowledge; Skills; Competency | AI will transform endodontic education; educators must be aware of AI's limitations | Introduce AI in clinical and didactic pedagogy |
| 5 | Diagnostic competence of senior dental students in detecting caries on panoramic radiographs with and without artificial intelligence assistance: a cross-sectional study | Oyun-Erdene Batgerel, Melda Pelin Akkitap, Rafat Sasany | 2025 | Turkey | BMC Medical Education | Cross-sectional study | 132 | Evaluation of panoramic radiographs | Diagnostic | Competency | AI-assisted tools enhance diagnostic accuracy and should be integrated into dental education | Develop standardized AI-integrated educational modules |
| 6 | Artificial intelligence-assisted full-mouth radiograph mounting in dental education | Jennifer Chang; Logan Bliss; Nikola Angelov; Aaron Glick | 2024 | USA | Journal of Dental Education | RCT | 40 | Pre- and post-study surveys; performance evaluation | Diagnostic | Skills; Competency | AI enhances efficiency but may reduce accuracy; balance is needed | AI should complement clinical skills; further research needed |

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| 7 | Artificial Intelligence in Dental Education: Opportunities and Challenges of Large Language Models and Multimodal Foundation Models | Daniel Claman; Emre Sezgin | 2024 | USA | JMIR Medical Education | Viewpoint | N/A | N/A | LLM; Generative | N/ A | Integration of LLMs and FMs can improve dental education by creating interactive and personalized learning experiences. | Gather empirical evidence for feasibility and utility of LLMs or FMs; Expand AI guidelines for dental education. |
| 8 | Evaluating and comparing student responses in examinations from the perspectives of human and artificial intelligence (GPT-4 and Gemini) | Kübra Yıldız Domaniç; Şükran Baycan | 2025 | Turkey | BMC Medical Education | Exploratory study | 30 questions | Standardized questions; AI model responses | Generative | Knowledge | ChatGPT outperformed Gemini in accuracy and consistency; AI tools can enhance teaching and educational assessments. | Use AI as a supplementary tool; develop ethical guidelines |
| 9 | ChatGPT and dental education: Opportunities and challenges | Mohammed H. Elnagar; Sumit Yadav; Shankar Rengasamy Venugopalan; Min Kyeong Lee; Maysaa Oubaid; Sankeerth Ram; Veerasathpurush Allareddy | 2024 | USA | Seminars in Orthodontics | Narrative review | N/A | Review | Generative | N/ A | AI tools like ChatGPT present both challenges and opportunities in dental education, requiring responsible integration. | Develop tailored AI models for dental education; Establish ethical guidelines. |
| 10 | Benefits and challenges of the integration of haptics-enhanced virtual reality training within dental curricula | Szabolcs Felszeghy, Murat Mutluay, Mikko Liukkonen, Nicla Flacco, Mahmoud M. Bakr, Sarah Rampf, Simona-Georgiana Schick, Faisal Mushtaq, Maria F. Sittoni-Pino, Kristin Ackerman, Santiago Arias-Herrera, Ben Audsley, Kinga Bágyi, Santiya Bell, Tamás Bistey, Samantha Byrne, Giorgia Carpegna, Esther Carramolino-Cuéllar, Juliana B. da Costa, Mark R. Durham, Sónnica Galán-Gil, Gábor Gerber, Diego González-Carrasco, Kandace Gourley, Péter Hermann, Outi Huhtela, Hanna Hytönen, Antti Kämppi, Michael Lampe, Carlos López-Roig, Rita Marincsák, David Morton, Masako Nagasawa, Katalin Nagy, László Nagy, Marit | 2024 | Global | Journal of Dental Education | Literature review; Educator survey | 42 articles; 228 educators | Literature review; Electronic survey | VR; Simulation | Skills; Competency | VR-haptics can enhance dental education but requires further validation and integration | Further research; Curriculum integration; Faculty training |

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| | | Øilo, Cesar Orsini, Ulla Palotie, Mihaela Pantea, Damiano Pasqualini, Anita Pétercsák, Daniela Pino-Valenzuela, Edgar Quenta-Silva, Amitha Ranauta, Gitana Rederiene, Pere Riutord-Sbert, Ewa J. Rodakowska, María P. Rodríguez-Hopp, Mauricio Saenz-Laguna-Saavedra, Anna L. Suominen, Jorge Tricio, Ülle Voog-Oras, Michael D. Wolcott, Sila Nur Usta, Peter Lingström, Muhammad A. Shazib, Maria C. Manzanares-Céspedes, Thomas J. Greany, Margrit Maggio, Rebecca Stolberg, Gül Gülsün, Sompop Bencharit, Barry Quinn | | | | | | | | | | |
| 11 | Shaping future practices: German-speaking medical and dental students' perceptions of artificial intelligence in healthcare | Sebastian Fitzek; Kyung-Eun Anna Choi | 2024 | Austria/Germany/Switzerland | BMC Medical Education | Cross-sectional survey | 409 | Online survey | N/ A | Knowledge | Need for comprehensive AI education in medical and dental curricula | Implement inclusive, comprehensive AI education programs |
| 12 | Evaluating the Accuracy and Performance of ChatGPT-4o in Solving Japanese National Dental Technician Examination | Hikaru Fukuda; Masaki Morishita; Kosuke Muraoka; Shino Yamaguchi; Taiji Nakamura; Manabu Habu; Izumi Yoshioka; Shuji Awano; Kentaro Ono | 2025 | Japan | International Dental Journal | Scientific Research Report | 400 questions | Analysis of JNDTE questions using ChatGPT-4o | LLM | Knowledge | Potential application as a supplementary tool; need for advancements in image recognition | Enhance AI-driven image recognition and simulation-based learning |
| 13 | Effect of artificial intelligence-assisted personalized feedback on radiographic diagnostic performance of dental students: a controlled study | Busra Nur Gokkurt Yilmaz; Furkan Ozbey; Birkan Eyup Yilmaz | 2025 | Turkey | BMC Medical Education | Randomized controlled study | 110 | Pre-test and post-test; survey | LLM | Knowledge; Skills | AI-supported personalized feedback enhances diagnostic performance and student satisfaction | Integrate AI-supported feedback systems into dental curricula |
| 14 | Transforming undergraduate dental education: the impact of artificial intelligence | Molly Harte; Barbara Carey; Qingmei Joy Feng; Ali Alqarni; Rui Albuquerque | 2025 | Global | British Dental Journal | Review | N/A | Review | Diagnostic; Generative | N/ A | AI should be integrated into dental curricula with a focus on ethical use. | Transition curriculum to include AI; Emphasize ethical implications. |

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| 15 | The role of artificial intelligence in enhancing personalized learning pathways and clinical training in dental education | Chengchen Hu, Fang Li, Shengguo Wang, Zhi Gao, Shan Pan, Maofeng Qing | 2025 | Global | Cogent Education | Review | N/A | Review | VR; Simulation | Enhanced clinical competence | AI holds promise for revolutionizing dental education through tailored learning experiences, but careful integration is essential. | Refine AI technologies and establish comprehensive guidelines for effective and ethical use. |
| 16 | Exploring the Application Capability of ChatGPT as an Instructor in Skills Education for Dental Medical Students: Randomized Controlled Trial | Siyu Huang; Chang Wen; Xueying Bai; Sihong Li; Shuining Wang; Xiaoxuan Wang; Dong Yang | 2025 | China | Journal of Medical Internet Research | Randomized Controlled Trial | 187 | Questionnaires; Eye-tracking; VR assessments | AI Tutor; Generative | Skills; Competency | ChatGPT effectively assists in dental skill learning and reduces cognitive load | Integrate ChatGPT into skills teaching |
| 17 | Adopting artificial intelligence in dental education: A model for academic leadership and innovation | Nadim M. Islam, Lory Laughter, Ramtin Sadid-Zadeh, Carlos Smith, Teresa A. Dolan, Geralyn Crain, Cristiane H. Squarize | 2022 | USA | Journal of Dental Education | Model proposal | N/A | N/A | N/ A | N/ A | AI can enhance educational experiences and delivery of care in dental education. | Use Bolman and Deal's Four Frames model for AI implementation. |
| 18 | Dental Students' Learning Experience: Artificial Intelligence vs Human Feedback on Assignments | Chantha K. Jayawardena, Yuvika Gunathilake, Dhammika Ihalagedara | 2025 | Sri Lanka | International Dental Journal | Comparative study | 194 | Archived data from Moodle; Online survey | AI Tutor; Generative | N/ A | AIT can complement human tutors by providing detailed feedback quickly | Further research and improvements needed for AI feedback |
| 19 | Artificial intelligence in dental education: ChatGPT's performance on the periodontic in-service examination | Arman Danesh; Hirad Pazouki; Farzad Danesh; Arsalan Danesh; Saynur Vardar-Sengul | 2024 | Canada | Journal of Periodontology | Original Article | 311 questions | Multiple-choice questions from the 2023 in-service examination | LLM | Knowledge | ChatGPT shows potential but has limitations in accuracy for periodontology | Residents should scrutinize ChatGPT's outputs |
| 20 | ChatGPT in Dental Education: Enhancing Student Proficiency in Informed Consent | Les Kalman; Arman Danesh | 2025 | Canada | Medical Science Educator | Short Communication | N/ A | Qualitative feedback; Readability tests | Generative | Knowledge; Skills | Supervised learning is important for safe AI use in dental practice | Use supervised learning; Explore advanced models |
| 21 | Evaluation of ChatGPT's Real-Life Implementation in Undergraduate Dental Education: Mixed Methods Study | Argyro Kavadella; Marco Antonio Dias da Silva; Eleftherios G Kaklamanos; Vasileios Stamatopoulos; Kostis Giannakopoulos | 2024 | Cyprus | JMIR Medical Education | Mixed Methods | 77 | Questionnaire; Knowledge Examination | LLM | Knowledge | ChatGPT enhanced educational outcomes; Students adapted well | Integrate ChatGPT into curriculum; Educate on limitations |
| 22 | Evaluating ChatGPT and Google Gemini Performance and Implications in Turkish Dental Education | Ipek Kinikoglu | 2025 | Turkey | Cureus | Original Article | 240 questions | Analysis of AI model performance on exam questions | Generative | Knowledge | AI models can surpass human performance in dental exams; potential for educational tools | Further research on AI in education; improve AI reasoning and interpretive capabilities |

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| 23 | Leveraging AI in Periodontal Reflective Portfolios: A Tool for Learning or a Crutch for Students? | Navid N. Knight; Kavitha Parthasarathy; Josef Huang | 2025 | USA | European Journal of Dental Education | Commentary | N/A | N/A | Generative | N/ A | AI should support, not replace, reflective processes in dental education. | Incorporate AI literacy and responsible use into curricula. |
| 24 | A Scoping Review of Large Language Models in Dental Education: Applications, Challenges, and Prospects | Mengjie Kong; Elise Hoi Wan Fok; Cynthia Kar Yung Yiu | 2025 | Global | International Dental Journal | Scoping Review | 37 studies | Literature search in PubMed, Web of Science, and Embase | LLM | Knowledge; Skills | LLMs have potential in dental education but face challenges that require coordinated efforts for effective integration. | Develop guidelines for LLM integration; Focus on expanding applications; Address ethical and technical challenges |
| 25 | Performance of large language artificial intelligence models on solving restorative dentistry and endodontics student assessments | Paul Künzle; Sebastian Paris | 2024 | Germany | Clinical Oral Investigations | Analysis | 151 | Question pool analysis | LLM | Knowledge | ChatGPT-4 models are most performant; cautious use recommended | Further studies with diverse question sets |
| 26 | Exploring the Ethical Dimensions of Artificial Intelligence and Robotics in Dental Education | Galvin Sim Siang Lin; Jia Yee Foo; Shu Meng Goh; Mohammad Khursheed Alam | 2024 | Global | Bangladesh Journal of Medical Science | Review Article | N/A | N/A | VR; Diagnostic; AI Tutor; Simulation | N/ A | AI and robotics offer advantages in dental education but require addressing ethical challenges. | Integrate ethics into curricula; foster collaboration with AI/robotics experts; prioritize ethics training. |
| 27 | Digital and artificial intelligence-assisted cephalometric training effectively enhanced students' landmarking accuracy in preclinical orthodontic education | Jiayu Lin, Zhihao Liao, Jingtao Dai, Manyi Wang, Ruixue Yu, Hong Yang, Chufeng Liu | 2025 | China | BMC Oral Health | Experimental study | 40; 24 | Objective evaluation of landmarking scores | Diagnostic | Skills; Competency | Digital and AI-assisted cephalometric training enhances landmarking accuracy and reduces performance disparities. | Further multicenter validation and long-term assessments needed. |
| 28 | Artificial intelligence: Friend or foe in the assessment of dental students? | C. Louca, I. Tonni, A. Leung, P. Fine | 2025 | UK | Journal of Dentistry | Mixed methods | 51 | Live online polling system; qualitative feedback | Generative | Knowledge; Competency | Need for investment in AI training for educators | Universities should provide contemporary, affordable, and accessible AI training |
| 29 | The use of artificial intelligence and game-based learning in removable partial denture design: A comparative study | Ahmed Mahrous, David L. Botsko, Amira Elgreatly, Akimasa Tsujimoto, Fang Qian, Galen B. Schneider | 2023 | USA | Journal of Dental Education | Comparative study | 73 | Survey; Mock practical test | Simulation; AI Tutor | Skills; Competency | AiDental software improved student grades and was well-liked by students | Further research on grading module and clinical setting use |

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| 30 | Recognising and supporting authentic learning in a changing world: the opportunities and threats of AI | Francesca Mullan; Helen Mather; Heidi Bateman; Alison Cairns; Melanie Nasseripour; Viv Binnie; Luke Dawson; Giles McCracken; Janice Ellis | 2024 | UK | British Dental Journal | Workshop and questionnaire | 71 conference attendees; 27 questionnaire responses | Questionnaire; Workshop discussions | AI Tutor; Simulation | N/ A | AI is here to stay; dental schools must engage with AI; need to understand student use of AI | Engage with AI; co-create AI-focused curricula with students |
| 31 | Automated grading of embroidery assignments: a multi-region deep learning framework with ResNet-50 | Nanzhen Lin; Yuyang Wang; Gaobo Jin; Jingyi Huang; Kedie Zhang; Chenyan Xie; Qing Han; Yueyuan Yu | 2025 | China | BMC Medical Education | Experimental study | 381 | Image collection | Diagnostic | N/ A | ResNet-50 AW model shows potential for automating grading; further validation needed | Improve dataset quality and diversity; enhance system interpretability |
| 32 | Exploring the adoption and utilisation of ChatGPT in everyday academic practices among medical and dental students of Rawalpindi and Islamabad: a study on the impact and perceived effectiveness | Khadija Qamar; Saad Waseem Butt; Mehwish Abaid; Ahmed Rashid; Rafia Tahira; Aarij Sohail Iqbal | 2024 | Pakistan | Journal of the Pakistan Medical Association | Cross-sectional study | 315 | Structured online survey; Printed questionnaire | LLM | Knowledge | ChatGPT improves academic performance and is a valuable tool for students | Further research needed to explore perceptions and risks |
| 33 | Reliability of ChatGPT in automated essay scoring for dental undergraduate examinations | Bernadette Quah; Lei Zheng; Timothy Jie Han Sng; Chee Weng Yong; Intekhab Islam | 2024 | Singapore | BMC Medical Education | Research study | 69 | Essay scoring comparison | LLM | N/ A | ChatGPT shows potential for essay marking but should not be used standalone | Use ChatGPT as an adjunct for self-assessment; ensure proper rubric design |
| 34 | The integration of haptic training into the QMUL dental curriculum | Amitha Ranauta; Ben Audsley; Paul Coulthard | 2023 | UK | European Journal of Dental Education | Commentary | N/ A | N/ A | VR; Simulation | N/ A | Virtual reality haptics trainers have created unique opportunities and challenges for dental schools. | N/ A |
| 35 | Generative Artificial Intelligence–Driven Clinical Case Simulation in Temporomandibular Disorder Education: ChatGPT Versus Real Patients | Paula Rodrigues-Pereira; Maria Amália Pereira Dias-Calças; Alex Moreira Mélo; Melissa de Oliveira Melchior; Lucas Gaspar Ribeiro; Antônio Pazin-Filho; Jardel Francisco Mazzi-Chaves; Laís Valencise Magri | 2025 | Brazil | Journal of Dental Education | Blinded, cross-sectional, crossover study | 30 | Simulated clinical interactions; Google Forms questionnaire | Generative | Clinical reasoning; diagnostic skills | GAI can complement real patient simulations in teaching clinical competencies in TMD/OP | Integrate both GAI and real patient simulations for enhanced learning |

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| 36 | Familiarity with ChatGPT Features Modifies Expectations and Learning Outcomes of Dental Students | Jelena Roganovic | 2024 | Serbia | International Dental Journal | Experimental study | 104 | Survey; Quiz | LLM | Knowledge | Reading ChatGPT features descriptions can alter expectations and attitudes towards technology, and enhance learning performance, but did not increase expectations toward sbelief in superior AI system support | AI features descriptions should be reviewed and verified to consider how they might induce cognitive bias or placebo effect as implications for standardisation of clinical trials and use of AI in public-facing contexts. Future research should investigate psychological aspects associated with AI technology acceptance + task performance in education. |
| 37 | An Open-Source, AI-Supported Teaching Tool in Orthodontic Education—Assessment of Acceptance and Effectiveness | Hisham Sabbagh; Teodora Ribnishki; Linus Hötzel; Leonard von Bronk; Yeganeh Khazaei; Andrea Wichelhaus | 2025 | Germany | Journal of Dental Education | Pilot test study | 150 | Questionnaire; Radiograph analysis | Diagnostic | Skills | MCAT standardisd thes learning process and uniformed student performance on cephalometric tracing skills; AI tool is well-accepted by students compared to hand-tracing | Long-term implementation of MCAT in curricula |
| 38 | Performance of three artificial intelligence (AI)- based large language models in standardized testing; implications for AI-assisted dental education | Hamoun Sabri; Muhammad H. A. Saleh; Parham Hazrati; Keith Merchant; Jonathan Misch; Purnima S. Kumar; Hom-Lay Wang; Shayan Barootchi | 2025 | USA | Journal of Periodontal Research | Comparative cross-sectional | 1312 questions; 2375 residents | Examination score | LLM | Knowledge | GPT-4 shows potential as an educational tool in assisting revision in periodontics | Further development and testing of AI models to meet needs of clinical practice, patient management and decision-making |

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| 39 | Scoping review of artificial intelligence and immersive digital tools in dental education | Mohammad Ali Saghiri, Julia Vakhnovetsky, Nader Nadershahi | 2022 | Global | Journal of Dental Education | Scoping review | 31 articles | Literature review | VR; AR; MR; Simulation ; Haptics; AI | Review | Limited studies at the time; Positive perception of AI and virtual teaching models | Further research needed (technology + pedagogical content); Integration of AI, AR, VR, MR, haptics in curriculum |
| 40 | Intelligent Dental Handpiece: Real-Time Motion Analysis for Skill Development | Mohamed Sallam; Yousef Salah; Yousef Osman; Ali Hegazy; Esraa Khatab; Omar Shalash | 2025 | Egypt | Sensors | Experimen tal | 61 | Sensor data collection | Simulation | Skills; Competen cy | IDH offers a scalable solution for improving dexterity and confidence in dental training. | Further research and development of intelligent dental tools. |
| 41 | Artificial intelligence: ChatGPT as a disruptive didactic strategy in dental education | Miguel Ángel Saravia-Rojas, Alexandra Rosy Camarena-Fonseca, Roberto León-Manco, Rocio Geng-Vivanco | 2024 | Peru | Journal of Dental Education | Original Article | 55 | Questionnaire; Writing assignment evaluation | LLM | Skills; Competen cy | Students valued ChatGPT but traditional methods yielded higher scores | Caution in using ChatGPT; Not to fully rely on it; Ethical code |
| 42 | Artificial intelligence for oral and dental healthcare: Core education curriculum | Falk Schwendicke, Akhilanand Chaurasia, Thomas Wiegand, Sergio E. Uribe, Margherita Fontana, Ilze Akota, Olga Tryfonos, Joachim Krois | 2023 | Global | Journal of Dentistry | Curriculum develop ment; Delphi process | 28 | Delphi process (single); Expert interviews | N/A | Knowledg e - curriculum design | Adopting core AI curriculum can increase AI literacy in pral healthcare providers | Adopt core AI curriculum; expand as needed; Call for PSRBs to produce guidelines on granular curricular content and learning outcomes in relation to AI and relevant teaching. |
| 43 | Attitudes and perceptions of dental students towards artificial intelligence | Oadi N. Shrateh; Siwar Al-batat; Ahmad R. Al-Qudimat; Lara I. Ghannam; Lina J. Abuhanoud | 2025 | Palestine | BMC Medical Education | Cross-sectional observatio nal survey | 305 | Online Questionnaire | Diagnostic | Knowledg e | Palestinian dental students demonstrate strong awareness and positive attitudes toward AI in dentistry. | Integrate AI into dental curricula; Address ethical concerns + digital equity; Curriculum reform that combines foundational AI knowledge with practical training. |
| 44 | Using a Virtual Patient via an Artificial Intelligence Chatbot to Develop Dental Students' Diagnostic Skills | Ana Suárez; Alberto Adanero; Víctor Díaz-Flores García; Yolanda Freire; Juan Algar | 2022 | Spain | International Journal of Environment al Research and Public Health | Descriptiv e cross-sectional study | 193 | Survey | Simulation | Skills; Competen cy | AI virtual patients in dental curricula is positively valued by students; higher satisfaction in 5th yr vs 4th yr so must be tailored to experience level of student (e.g. more complex for | Integrate AI virtual patient into dental curricula |

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| 45 | Development of Evidence-Based Guidelines for the Integration of Generative AI in University Education Through a Multidisciplinary, Consensus-Based Approach | Loizos Symeou; Loucas Louca; Argyro Kavadella; James Mackay; Yianna Danidou; Violetta Raffay | 2025 | Global | European Journal of Dental Education | Consensus-Based Framework Development | N/ A | Literature reviews; Consultations; Workshops; Webinars | Generative | Knowledge - curriculum design | Curriculum framework may serve as a model for other HEIs aiming to integrate AI tools while upholding educational quality and ethical standards. | Develop flexible, evidence-based guidelines for AI integration in education. |
| 46 | Performance of ChatGPT-3.5 and ChatGPT-4o in the Japanese National Dental Examination | Osamu Uehara, Tetsuro Morikawa, Fumiya Harada, Nodoka Sugiyama, Yuko Matsuki, Daichi Hiraki, Hinako Sakurai, Takashi Kado, Koki Yoshida, Yukie Murata, Hirofumi Matsuoka, Toshiyuki Nagasawa, Yasushi Furuichi, Yoshihiro Abiko, Hiroko Miura | 2025 | Japan | Journal of Dental Education | Comparative study | 1399 questions | Manual input of questions into ChatGPT | Generative | Knowledge | ChatGPT-4o has advanced clinical reasoning skills and dental knowledge, useful as a supplementary tool in dental education. | Further refinement needed for clinical practice-based reasoning. |
| 47 | Artificial intelligence chatbots and large language models in dental education: Worldwide survey of educators | Sergio E. Uribe; Ilze Maldupa; Argyro Kavadella; Maha El Tantawi; Akhilanand Chaurasia; Margherita Fontana; Rodrigo Marino; Nicola Innes; Falk Schwendicke | 2024 | Latvia | European Journal of Dental Education | Cross-sectional survey | 428 | Online questionnaire | LLM | Knowledge acquisition; Research; Clinical decision-making | AI chatbots have potential in dental education but require clear guidelines for implementation. | Develop clear implementation guidelines; provide training for educators. |
| 48 | Integrating Generative AI in Dental Education: A Scoping Review of Current Practices and Recommendations | Sergio E. Uribe; Ilze Maldupa; Falk Schwendicke | 2025 | Global | European Journal of Dental Education | Scoping review | 31 documents | Scoping review; Thematic analysis | Generative | N/ A | Need for comprehensive guidelines; Emphasized ethical use, transparency, academic integrity | Develop clear AI policies; Offer AI literacy courses; Invest in AI infrastructure |

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| 49 | SDMentor: A virtual reality-based intelligent tutoring system for surgical decision making in dentistry | Narumol Vannaprathip; Peter Haddawy; Holger Schultheis; Siriwan Suebnukarn | 2025 | Thailand | Artificial Intelligence In Medicine | Randomized controlled trial | 36 | Pre-test and post-test; Randomized controlled trial | VR; AI Tutor | Knowledge; Skills; Competency | Integration of high-fidelity VR simulation with intelligent tutoring is promising for teaching surgical decision making | Expand to other areas of dentistry and surgical domains |
| 50 | Exploring Knowledge, Attitude, and Perceptions toward the Artificial Intelligence among Malaysian Clinical-Year Dental Undergraduate Students: A Cross-sectional Survey | Suresh Kandagal Veerabhadrappa, Tilden Ting Chong Hong, Shreyansh Padarha, Aarya Bharadwaj, Than Jing Qian, Teh Kar King, Seema Yadav | 2025 | Malaysia | Journal of Datta Meghe Institute of Medical Sciences University | Cross-sectional survey | 144 | Questionnaire-based online survey | Diagnostic | Knowledge | Students acknowledge AI's potential and support its integration into practice and education. | Address knowledge gaps and accessibility challenges for successful AI adoption. |
| 51 | AI-Powered Problem- and Case-based Learning in Medical and Dental Education: A Systematic Review and Meta-analysis | Hongxia Wei, Yuguo Dai, Kaiting Yuan, Kar Yan Li, Kuo Feng Hung, Elaine Mingxin Hu, Angeline Hui Cheng Lee, Jeffrey Wen Wei Chang, Chengfei Zhang, Xin Li | 2025 | Global | International Dental Journal | Systematic Review and Meta-analysis | 6 RCT studies | Electronic search; Meta-analysis | AI Tutor; Generative | Knowledge; Clinical reasoning capability; Satisfaction | AI-powered PBL/CBL enhances knowledge acquisition and satisfaction | Further high-quality and longitudinal RCTs needed |
| 52 | Development and evaluation of a retrieval-augmented large language model framework for enhancing endodontic education | Xiaowei Xu, Siyi Liu, Lin Zhu, Yunzi Long, Yin Zeng, Xudong Lu, Jiao Li, Yanmei Dong | 2025 | China | International Journal of Medical Informatics | Quality improvement study | N/ A | Systematic collection and integration of educational materials | LLM | Knowledge; Skills; Competency | EndoQ improves educational outcomes and represents a scalable model for AI-enhanced clinical training | Further exploration of AI in medical education; address hallucinations and expand to other specialties |
| 53 | Formative feedback generation in a VR-based dental surgical skill training simulator | Myat Su Yin; Peter Haddawy; Siriwan Suebnukarn; Farin Kulapichitr; Phattanapon Rhienmora; Varistha Jatuwat; Nuttanun Uthaipattanacheep | 2021 | Thailand | Journal of Biomedical Informatics | Randomized controlled trial | 30 | Pre-test/post-test control group design | VR; Simulation | Skills | VR simulators with formative feedback improve skill training effectiveness | Integrate VR simulators with feedback into curricula |
| 54 | Artificial intelligence knowledge, attitudes and application perspectives of undergraduate and specialty students of faculty of dentistry in Turkey: an online survey research | Cemile Yılmaz, Rahime Zeynep Erdem, Latife Altınok Uygun | 2024 | Turkey | BMC Medical Education | Cross-sectional online survey | 397 | Online survey | Diagnostic | Knowledge; Attitudes; Perceptions | AI is seen as a complement to dental practice; Importance of managing AI's role in healthcare | Further research with a larger and more diverse sample |

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| 55 | Artificial intelligence (A.I.) in dental curricula: Ethics and responsible integration | Clara S. Kim, Cheryl S. Samaniego, Saulo L. Sousa Melo, William A. Brachvogel, Krithika Baskaran, Danielle Rulli | 2023 | USA | Journal of Dental Education | Perspective paper (commentary / narrative discussion) | N/ A | N/ A | GenAI; LLM | Conceptual discussion only; no measured outcomes. | AI should be proactively and responsibly integrated into dental education to ensure future dentists can use it safely and ethically in practice. | Introduce AI education in dental curricula, teach ethical and responsible use, develop guidelines/standards, and involve professional organisations in guiding AI integration. |
| 56 | Generative Artificial Intelligence (Gen AI) in dental education: Opportunities, cautions, and recommendations | Rafael Delgado-Ruiz, Amy S Kim, Hai Zhang, Diane Sullivan, Kamran H Awan,Panagiota G Stathopoulou | 2024 | USA | Journal of Dental Education | Perspective / commentary paper | N/ A | N/ A | GenAI; LLM | Mixed (potential benefits and risks) | GenAI integration requires guidelines, oversight, and evaluation of its impact on learning. | Develop policies, AI literacy training, transparency in AI use, and evaluation frameworks for critical thinking. |
| 57 | Artificial Intelligence in Dental Service Provision: A Rapid Evidence Assessment | GDC / Peninsula Dental School | 2025 | Global with UK implications | GDC Website | REA + PRISMA 2000 | 45 included studies; individual study sample sizes ranged from **1 to 289** | Systematic database searches and structured data extraction using a piloted Excel sheet | Implementation of AI and robotics in dental service provision (not education) | Knowledge; Skills; Clinical Competency | AI use in dental service provision is growing, shows promise, but evidence is limited and uneven; further robust research is needed | Larger-scale trials, UK-specific research, focus on regulation, training needs, EDI, ethics, and data protection |
| 58 | Consultation on the review of the Standards for Education | GDC | 2024 | UK | GDC Website | Consultation | N/ A | Online submissions and stakeholders responses | General AI in education | Stakeholder views on educational standards, future workforce requirements, digital and AI readiness | Existing education standards require updating to ensure graduates are prepared for evolving technologies, including digital and AI-enabled healthcare environments. | Update educational standards to support digital literacy, critical appraisal, safe technology use, professionalism, and preparedness for emerging technologies including AI. |
| 59 | Digital Health – Artificial Intelligence and healthcare | Jonothon Key | 2020 | Global | GDC Website | Blog - Overview and discussion of artificial intelligence in digital health and healthcare, including opportuniti | N/ A | N/ A | General AI in digital health | N/ A | AI will continue to impact healthcare; greater public understanding, regulatory awareness, and governance are needed to ensure safe and equitable implementation. | 1. Improve public understanding of AI<br>2. Address trust and consent issues<br>3. Improve data quality, validation, and representativeness<br>4. Prepare |

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| | | | | | | es, risks, and regulatory considerations | | | | | | healthcare systems for increased AI integration |
| 60 | Artificial intelligence (AI) and machine learning - NHS England guidance | NHS England | 2025 | England/UK | NHS England Website | NHSE Guidance | N/ A | Regulatory and implementation guidance development; evidence review and expert input | Guidance on understanding, developing, implementing, evaluating, and governing AI in NHS healthcare settings | AI governance, implementation, safety, and compliance | AI must be carefully regulated, validated, ethically implemented, and supported by strong governance, clinical involvement, and patient-centred design | Robust validation, clinician involvement, governance frameworks, patient engagement, ethical safeguards, workforce education, and ongoing evaluation |
| 61 | Planning and implementing real-world artificial intelligence (AI) evaluations: lessons from the AI in Health and Care Award | NHS England / NHS AI Lab | 2024 | England/UK | NHS England Website | Mixed-method designs, including quasi-experimental pre-post implementation studies and some randomised controlled trials. | 23 AI technologies/projects | Programme evaluation, document review, stakeholder engagement, and implementation case study analysis | AI used in planning, designing, implementing, and evaluating real-world AI deployments in healthcare. | AI implementation, adoption, evaluation, barriers and facilitators | Real-world AI evaluations require flexible, mixed-method approaches, strong stakeholder engagement, robust governance, and sufficient time and resources to generate meaningful evidence. | 1. Use pragmatic, mixed-method evaluation designs<br>2. Allow sufficient time (≥2 years)<br>3. Ensure early stakeholder and site engagement<br>4. Include health economic modelling<br>5. Monitor data quality and technology uptake<br>6. Assess equity, fairness, and clinician experience |
| 62 | Understanding Healthcare Workers' Confidence in AI | NHS AI lab / HEE | 2022 | England/UK | NHS England Website | Review of academic literature and semi-structured interviews | 31 interviews | Literature review and interview | General AI technologies/non-specific | Knowledge, confidence, and preparedness | Confidence in AI depends on governance, implementation and context-dependent clinical judgement and that understanding these influences is vital for education | Report implies education and training are needed to support confidence (detailed in subsequent Report 2). **Implementation:** Strategy and |

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| | | | | | | | | | | | and training. | culture (organisational readiness and attitudes towards AI); Technical implementation (how AI systems are integrated technically into existing systems)' Local validation (verifying AI performance in the specific local clinical environment); Systems impact (understanding effects on workflows and wider system processes) |
| 63 | AI and Digital Healthcare Technologies Capability Framework | Health Education England (HEE) | 2023 | England/UK | NHS England Website | Curriculum: AI Capabilities Framework: Literature review, stakeholder workshops x 3 (Nominal Group Technique) and wider participation survey (n=49) | 49 | Survey | Artificial Intelligence and digital healthcare technologies | Knowledge - curriculum design | The framework presents intended use and future application rather than conclusions | Use of the framework to support workforce development, education, and planning in AI and digital healthcare technologies |
| 64 | AI Knowledge Repository | NHS England / Digital Health Technology News | 2025 | England/UK | NHS England Website | Policy and guidance repository | N/ A | N/ A | | | | |
| 65 | Artificial intelligence and innovative technologies | GMC | 2024 | UK | GMC website | Professional regulatory guidance | N/ A | Regulatory guidance development informed by stakeholder engagement, evidence | AI used to support imaging interpretation, wearable devices, | N/ A | GMC: Innovative technologies will significantly affect healthcare; GMC professional standards apply when AI is used; | GMC recommends: Professionals use judgement applying GMC principles when using AI; |

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| | | | | | | | | review, and expert consultation | augmented/virtual reality, and remote monitoring. | | Doctors/associates are responsible for decisions when using AI; They should report adverse incidents involving AI tools like other medical devices | Professionals keep up to date, undertake training, and improve competence; Report adverse incidents involving AI like other medical devices. |
| 66 | Understanding doctors' experiences of using artificial intelligence (AI) in the UK | GMC | 2024 | UK | GMC website | Qualitative research study based on follow-up interviews with doctors | 17 doctors | Qualitative interviews | To explore doctors' experiences and perceptions of using AI in clinical practice and interests such as risks, responsibilities, and training | Knowledge; Skills; Competencies e.g. Views on AI potential for efficiency, supporting tasks, and managing risks, rather than measured improvement in competency | Doctors view AI as assistive, acknowledge benefits and risks, and see the need for clarity in responsibilities and more guidance | Doctors recommended improved education and training, ethical guidance, and regulators clarifying responsibilities and risks |
| 67 | Good medical practice 2024 | GMC | 2024 | UK | GMC website | Statutory Regulatory Standards | N/ A | N/ A | N/ A | N/ A | N/ A | N/ A |
| 68 | Russell Group principles on the use of generative AI tools in education | Russell Group Advisory Group | 2023 | UK | Russell Group Advisory Group | General Principles | N/ A | N/ A | Ethical and responsible use of generative AI tools in education | Principles and their Outcomes | Universities should adopt principles guiding ethical and responsible use of generative AI, supporting AI literacy, adaptation of teaching and assessment, academic integrity, and collaboration. | Russel Group Principles: 1. Support AI literacy for staff and students;m 2. Equip staff to guide appropriate AI use, 3. Adapt teaching, learning and assessment with equal access, 4. Uphold academic rigour and integrity, 5. Share best practice across universities |

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| 69 | Evaluation of the NHS Artificial Intelligence Lab identifies valuable lessons to shape future AI efforts in health and care. | Cresswell, K., Williams, R., Dungey, S., & Anderson, S. | 2025 | UK | University of Edinburgh | Mixed-Methods Formative Evaluation | 1,021 documents, 85 interviews | Document reviews, interviews, observations, analytics and outputs measurement. **not dental ed** | Health systems AI | Early evidence of benefits (financial, patient outcomes) combined with challenges in broader adoption. Outcomes: Progress on AI development and scaling in healthcare; Evidence of financial and patient care benefits; Cost savings (e.g. a specific project with £44 million savings across 150,000 patients); Challenges in scaling and adoption of AI technologies. | NHS AI Lab has made significant progress, generated valuable lessons and early benefits, but needs sustained support, strategic leadership, and evidence-based decision-making for full potential | 1. Sustained national support and leadership 2. Evidence-based decision-making 3. Collaboration between developers, policymakers, and clinicians to enhance AI adoption. |
| 70 | University AI principles, guidance and policies | QMUL | 2024 | England/UK | QMUL website: student + staff AI use Guides | Student and Staff Guides on AI use | N/ A | Institutional policy development and stakeholder consultation | GenAI;LLM | Knowledge; Skills; Competency | 1. Student guide: Generative AI can be useful but must be used critically and ethically, in line with academic integrity rules 2. Staff guide: Generative AI | 1. Student guide: Use AI critically, verify outputs, follow academic integrity guidance 2. Staff guide: Support AI literacy, adapt assessment, maintain academic |

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| | | | | | | | | | | | presents both opportunities and challenges and must be addressed through pedagogy and assessment design | rigour and integrity |
| 71 | Update on AI regulations | Royal College of Dentists of Canada (RCDC) AI Task Force | 2024 | Canada | Update: RCDC AI Task Force | Position paper / policy statement / consultation response | N/ A | Expert review, policy analysis, and consultation response development | General AI in dentistry | N/ A | AI will reshape dental practice and education; AI governance frameworks, risk mitigation, training, curriculum reform, and monitoring are needed; Regulatory guidance should align with legal and professional obligations. | 1. AI governance frameworks and guiding principles; 2. Mapping and inventory of AI use; 3. Risk mitigation and monitoring policies; 4. Professional guidance on training and competencies; 5Collaboration with regulators and stakeholders. |
| 72 | Artificial Intelligence for Dentistry: White Paper | FDI Artificial Intelligence Working Group | 2023 | Global | World Dental Federation (FDI) | White paper / position paper / expert consensus guidance | N/ A | Review and professional opinion | Machine learning; Image analysis; Data synthesis & prediction; Computer vision; Natural language processing ; Robotics; Virtual reality & simulation | N/ A | AI has transformative potential for dentistry; governance, data protection balance, evidence, literacy, and standardization are needed to realize benefits and mitigate risks | 1. Balancing data protection with AI benefit<br>2. Pursuing data harmonization<br>3. Promoting AI applications with demonstrated benefit<br>4. Strengthening evidence of utility<br>5. Increasing digital/AI literacy<br>6. Broad community engagement and standardization. |
| 73 | What are the standards for AI use in dentistry? | ADA | 2025 | USA | ADA | News piece/over view/guida nce | N/ A | Expert committee input, review of technical evidence | AI standards and guidance for dental AI tools, especially image analysis systems (machine | Standards | AI standards and regulatory frameworks are essential for responsible use in dentistry. | Adherence to and awareness of evolving standards for safety, efficacy, transparency, and fairness |

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| | | | | | | | | | learning/deep learning) and radiographic annotation and datasets | | | |
| 74 | Data Science in the medical curriculum – equipping medical students for the digital age | Medical Schools Council (MSC) and Health Data Research UK (HDR UK) Working Group | 2025 | UK | MSC | Expert consensus guidance / curriculum framework / policy report | N/ A | Expert consensus process, stakeholder consultation, consensus voting/workshops | General AI in healthcare | Knowledge; Skills; Competency | Need to integrate data science (including AI) competencies into medical curricula; importance for the inclusion of structured, accessible data science competencies are needed in medical curricula. | 1. Implement core data science competencies including data governance, health informatics, AI, digital ethics;<br>2. Integrate these into existing modules;<br>3. Provide training on digital identity, data security, responsible AI use;<br>4. Raise awareness of health inequalities, algorithmic bias, and the digital divide;<br>5. Use online resources to supplement teachi |
| 75 | Artificial Intelligence in Medical Education: The 2025 IACAI Vision and Integration Frameworks | International Advisory Committee for Artificial Intelligence (IACAI) | 2025 | Global | Association of American Medical Colleges (AAMC) | Curriculum Framework | N/ A | Expert consultation, workshops, consensus-building process | GenAI;LLM | Knowledge - curriculum design | Concludes with an AI vision and integration framework for medical education; Educator + Learner Focus Matrix of LOs | Detailed recommendations at individual, institutional, national, international levels (Educator Focus Matrix I) and recommendations for competencies and integration planning (Learner Focus Matrix II) |

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