

## NARRATIVE REVIEW

## Impact of Artificial Intelligence and Generative AI on Dental Education

## تأثیر هوش مصنوعی و هوش مصنوعی مولد بر آموزش در رشته دندانپزشکی

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**Background:** Artificial intelligence (AI), particularly generative AI (GenAI), is fundamentally transforming dental education by enabling highly personalized learning and refining clinical decision-making. However, the rapid adoption of tools like ChatGPT has outpaced the establishment of formal educational guidelines, thereby introducing novel ethical and practical concerns.

**Method:** A comprehensive narrative review was conducted, synthesizing current literature and authoritative reviews published since 2020, with a focus on the integration of GenAI integration in dental education. Additional sources were identified from key bibliographies. This review critically evaluates the impacts, challenges, and optimal strategies for incorporating AI across undergraduate and postgraduate dental curricula.

**Results:** AI tools, especially GenAI, are increasingly being integrated into teaching, learning, and assessment. Documented benefits include personalized feedback, realistic clinical case simulations, and improved diagnostic reasoning. These technologies promote educational efficiency, pedagogical innovation, and student engagement. However, significant risks remain, including threats to academic integrity (e.g., AI-generated assignments), algorithmic bias, and data privacy issues. Most dental institutions currently lack discipline-specific AI policies, though broader university and global guidelines emphasize ethical use, transparency, and critical thinking. Successful integration depends on comprehensive faculty development, clear ethical frameworks, and student literacy regarding the capabilities and limitations of AI.

**Conclusion:** The integration of AI and GenAI into dental education not only offers transformative potential but also introduces unique challenges. Proactive curriculum development and institutional policies are essential to harness these technologies effectively while upholding academic integrity and ethical standards.

**Keywords:** Artificial Intelligence, Generative AI, Dental Education, Curriculum, Ethics, ChatGPT, Guidelines

**الخلفية:** يُحدث الذكاء الاصطناعي، ولا سيما الذكاء الاصطناعي التوليدي، تحولاً جذرياً في تعليم طب الأسنان، إذ يُتيح تعلمًا شخصيًا للغاية ويحسن عملية اتخاذ القرارات السريرية. مع ذلك، تجاوز الانتشار السريع لأدوات مثل ChatGPT وتيرة وضع المبادئ التوجيهية التعليمية الرسمية، مما أدى إلى ظهور مخاوف أخلاقية وعملية جديدة.

**الطريقة:** أجريت مراجعة سردية شاملة، جمعت الأدبيات الحالية والمراجعات الموثوقة المنشورة منذ عام ٢٠٢٠، مع التركيز على دمج الذكاء الاصطناعي التوليدي في تعليم طب الأسنان. كما تم تحديد مصادر إضافية من قوائم المراجع الرئيسية. تُقيم هذه المراجعة بشكل نقدي تأثيرات الذكاء الاصطناعي وتحدياته واستراتيجياته المثلى في مناهج طب الأسنان الجامعية والدراسات العليا.

**النتائج:** تتزايد عمليات دمج أدوات الذكاء الاصطناعي، ولا سيما الذكاء الاصطناعي التوليدي، في التدريس والتعلم والتقييم. تشمل الفوائد الموثقة تقديم ملاحظات شخصية، ومحاكاة واقعية للحالات السريرية، وتحسين الاستدلال التشخيصي. تُعزز هذه التقنيات الكفاءة التعليمية والابتكار التربوي ومشاركة الطلاب. مع ذلك، لا تزال هناك مخاطر كبيرة، بما في ذلك تهديدات النزاهة الأكاديمية (مثل الواجبات المُولَّدة بواسطة الذكاء الاصطناعي)، والتحيّز الخوارزمي، وقضايا خصوصية البيانات. تفتقر معظم مؤسسات طب الأسنان حاليًا إلى سياسات خاصة بالذكاء الاصطناعي في هذا التخصص، على الرغم من أن التوجهات الجامعية والعلمية الأوسع نطاقًا تُشدد على الاستخدام الأخلاقي والشفافية والتفكير النقدي. يعتمد التكامل الناجح على تطوير شامل لأعضاء هيئة التدريس، وأطر أخلاقية واضحة، وتوعية الطلاب بقدرات الذكاء الاصطناعي وحدوده.

**الخلاصة:** لا يقتصر دمج الذكاء الاصطناعي والذكاء الاصطناعي التوليدي في تعليم طب الأسنان على توفير إمكانيات تحويلية فحسب، بل يطرح أيضًا تحديات فريدة. يُعد تطوير المناهج الدراسية بشكل استباقي والسياسات المؤسسية أمرًا ضروريًا لتسخير هذه التقنيات بفعالية مع الحفاظ على النزاهة الأكاديمية والمعايير الأخلاقية. **الكلمات المفتاحية:** الذكاء الاصطناعي؛ الذكاء الاصطناعي التوليدي؛ تعليم طب الأسنان؛ المناهج الدراسية؛ الأخلاقيات؛ ChatGPT؛ التوجهات

## دانتون کی تعلیم پر مصنوعی ذہانت اور جنریٹو AI کا اثر

## تأثیر هوش مصنوعی و هوش مصنوعی مولد بر آموزش در رشته دندانپزشکی

**زمینه و هدف:** هوش مصنوعی (AI)، به ویژه هوش مصنوعی مولد (GenAI)، با فراهم آوردن امکان یادگیری شخصی‌سازی‌شده و بهبود تصمیم‌گیری بالینی، سلسله آموزش دندانپزشکی را متحول کرده است. با این حال، پذیرش سریع ابزارهایی مانند ChatGPT، از تدوین دستورالعمل‌های آموزشی رسمی پیشی گرفته و نگرانی‌های اخلاقی و عملی جدیدی را به وجود آورده است.

**روش:** یک مرور جامع روایی با ترکیب متون و مراجع معتبر منتشر شده از سال ۲۰۲۰ به بعد، با تمرکز بر تلفیق هوش مصنوعی مولد در آموزش دندانپزشکی انجام شد. منابع بیشتری نیز از طریق کتاب‌شناسی‌های کلیدی شناسایی شدند. این بررسی به ارزیابی انتقادی تأثیرات، چالش‌ها و راهبردهای بهینه برای گنجاندن هوش مصنوعی در برنامه‌های درسی دندانپزشکی در مقاطع دکترا و تحصیلات تکمیلی می‌پردازد.

**یافته‌ها:** ابزارهای هوش مصنوعی کارایی آموزشی، نوآوری در روش‌های تدریس و مشارکت دانشجویان را تقویت می‌کنند. اما، خطرات قابل توجهی همچنان باقی است، از جمله: تهدیدات علیه صداقت علمی (مانند تکالیف تولید شده توسط هوش مصنوعی)، سوگیری الگوریتمی و مسائل مربوط به حریم خصوصی داده‌ها. در حل حاضر، بیشتر مؤسسات دندانپزشکی فاقد سیاست‌های خاص رشته‌ای در مورد هوش مصنوعی هستند، اگرچه دستورالعمل‌های گسترده‌تر دانشگاهی و جهانی بر استفاده اخلاقی، شفافیت و تفکر انتقادی تأکید دارند. اقدام موفق به توسعه جمع اساتید، چارچوب‌های اخلاقی روشن و سواد دانشجویان در مورد توانایی‌ها و محدودیت‌های هوش مصنوعی بستگی دارد.

**نتیجه‌گیری:** ادغام هوش مصنوعی، به طور خاص هوش مصنوعی مولد در آموزش دندانپزشکی، پتانسیل تحول‌آفرینی دارد اما چالش‌های منحصر به فردی را نیز به همراه می‌آورد. تدوین فعال برنامه‌های درسی و سیاست‌های سازماني برای بهره‌برداری مؤثر از این فناوری‌ها، ضمن حفظ صداقت علمی و استانداردهای اخلاقی، ضروری است.

**واژه‌های کلیدی:** هوش مصنوعی؛ هوش مصنوعی مولد؛ آموزش دندانپزشکی؛ برنامه درسی؛ اخلاق؛ چت‌جی‌بی‌تی؛ دستورالعمل‌ها

**پس‌منظر:** مصنوعی ذہانت (AI)، خاص طور پر جنریٹو (GenAI)، AI، انتہائی ذاتی نوعیت کی سیکھنے اور طبی فیصلہ سازی کو بہتر بنا کر دانتون کی تعلیم کو بنیادی طور پر تبدیل کر رہی ہے۔ تاہم، ChatGPT جیسے تولز کو تیزی سے اپنانے نے رسمی تعلیمی رہنما خطوط کے قیام کو آگے بڑھا دیا ہے، اس طرح نئے اخلاقی اور عملی خدشات کو متعارف کرایا ہے۔

**طریقہ:** ڈیٹیل ایجوکیشن میں GenAI انضمام کے انضمام پر توجہ مرکوز کرتے ہوئے، ۲۰۲۰ سے شائع ہونے والے موجودہ ادب اور مستند جائزوں کی ترکیب کرتے ہوئے، ایک جامع بیانہ کا جائزہ لیا گیا۔ کلیدی کتابیات سے اضافی ذرائع کی نشاندہی کی گئی۔ یہ جائزہ انڈرگریجویٹ اور پوسٹ گریجویٹ ڈیٹیل نصاب میں AI کو شامل کرنے کے اثرات، چیلنجز اور بہترین حکمت عملیوں کا تنقیدی جائزہ لیتا ہے۔

**نتیجہ:** AI، تولز، خاص طور پر GenAI، تدریس، سیکھنے، اور تشخیص میں تیزی سے مربوط ہو رہے ہیں۔ دستاویزی فوائد میں ذاتی رائے، حقیقت پسندانہ کلینیکل کیس سمیلیشنز، اور بہتر تشخیصی استدلال شامل ہیں۔ یہ ٹیکنالوجیز تعلیمی کارکردگی، تدریسی جدت طرازی اور طالب علم کی مصروفیت کو فروغ دیتی ہیں۔ تاہم، اہم خطرات باقی ہیں، بشمول تعلیمی سالمیت کو خطرات (مثلاً، AI سے تیار کردہ اسائنمنٹس)، الگورتھمک تعصب، اور فیڈبک کی رازداری کے مسائل۔ زیادہ تر دانتون کے اداروں میں اس وقت نظم و ضبط سے متعلق مخصوص AI پالیسیوں کا فقدان ہے، حالانکہ وسیع تر یونیورسٹی اور عالمی رہنما اصول اخلاقی، شفافیت اور تنقیدی سوچ پر زور دیتے ہیں۔ کامیاب انضمام کا انحصار جامع فیکیٹی ڈویلپمنٹ، واضح اخلاقی فریم ورک، اور AI کی صلاحیتوں اور حدود کے حوالے سے طلباء کی خواندگی پر ہے۔

**نتیجہ:** دانتون کی تعلیم میں AI اور GenAI کا انضمام نہ صرف تبدیلی کی صلاحیت فراہم کرتا ہے بلکہ منفرد چیلنجز کا بھی تعارف کرتا ہے۔ تعلیمی سالمیت اور اخلاقی معیارات کو برقرار رکھتے ہوئے ان ٹیکنالوجیز کو مؤثر طریقے سے استعمال کرنے کے لیے فعال نصاب کی ترقی اور ادارہ جاتی پالیسیاں ضروری ہیں۔

**کلیدی الفاظ:** مصنوعی ذہانت؛ جنریٹو AI؛ دانتون کی تعلیم؛ نصاب؛ اخلاقیات؛ چیت جی بی ٹی؛ رہنما اصول

## INTRODUCTION

The rapid evolution of artificial intelligence (AI) is fundamentally reshaping healthcare education, and dental training finds itself at the forefront of this transformative movement (1). Over the past decade, foundational advancements in digital technology including computer-aided design, three-dimensional imaging, and high-fidelity simulation have established the necessary infrastructure for integrating more sophisticated AI systems in both preclinical and clinical dental education (2).

A pivotal development in recent years has been the emergence and widespread integration of generative AI, including large language models (LLMs) such as ChatGPT (3). These tools represent a significant advancement beyond traditional discriminative artificial intelligence, which primarily serves classification and pattern recognition tasks such as detecting caries on radiographs. In contrast, GenAI can create novel and realistic content including texts, images, and interactive patient simulations, thereby enabling dynamic, adaptive, and highly personalized educational experiences (4).

The potential applications of generative artificial intelligence in dental education are already becoming evident across several critical domains. Regarding personalized learning, AI-driven systems can tailor educational content to individual student needs and learning paces, thereby facilitating a shift toward competency-based education (5). In the realm of enhanced clinical simulation, generative models can create realistic virtual patient scenarios, provide automated feedback, and support clinical decision-making, effectively bridging the gap between theoretical knowledge and practical application (3). For research and academic writing, generative artificial intelligence tools can assist with literature reviews, proposal drafting, and data analysis, accelerating research workflows while simultaneously sparking new debates around authorship and integrity (5). Concerning assessment and feedback, automated essay scoring systems, chatbots, and AI-powered formative assessment tools can deliver timely and individualized feedback, thereby promoting self-directed learning. Finally, in communication and professional skills, AI-powered conversational tools can simulate patient interactions, allowing students to safely develop and refine interpersonal and counseling skills (6).

The COVID-19 pandemic served as a catalyst that accelerated the adoption of virtual and AI-supported learning modalities, thereby exposing both the vast opportunities and inherent challenges of this digital transformation (7). However, a significant gap persists as most dental educators and students receive minimal or no formal training in using AI utilization. This lack of preparedness can

hinder critical evaluation of AI-generated content and the ethical, responsible application of these powerful tools in both education and clinical settings (8).

Significant challenges, particularly those of an ethical nature, remain largely unaddressed. These concerns include issues of algorithmic bias, data privacy, and academic integrity, as GenAI blurs the distinction between original student contribution and AI-assisted creation. At the global level, there exists a notable absence of discipline-specific guidelines or formal institutional policies governing the use of GenAI in dental education, even as its presence becomes increasingly unavoidable (5).

In response to this evolving landscape, this narrative review aims to provide a comprehensive synthesis of the current and potential impact of AI in dental education. It will critically examine key benefits, challenges, and evidence-based strategies for integrating AI into dental curricula. Furthermore, the review will analyze existing global and institutional guidelines, identifying specific gaps relevant to dental education, and will conclude with practical recommendations for educators, curriculum planners, and policymakers on adapting to the era of AI-powered education.

## METHODS

This narrative review was designed to offer a comprehensive, contemporary, and critical synthesis of existing literature concerning the integration and impact of artificial intelligence (AI), with a particular focus on generative artificial intelligence (GenAI), within both undergraduate and postgraduate dental education.

A systematic search was conducted from January 2020 to July 2025 across PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar databases, initially identifying approximately 527 articles relevant to artificial intelligence (AI) and generative artificial intelligence (GenAI) applications in dental education. After a preliminary screening of titles and abstracts by two independent reviewers, 31 studies were found to meet the inclusion criteria. Additionally, a manual review of references from two recent comprehensive reviews identified 2 foundational studies published prior to 2020, considered essential for context. In total, 33 peer-reviewed studies and authoritative documents were ultimately included and synthesized in this narrative review. The search strategy incorporated terms related to general AI ("artificial intelligence," "AI," "machine learning," "deep learning," "dental informatics") and specific GenAI technologies ("generative AI," "large language model," "LLM," "ChatGPT," "DALL-E," "Midjourney"). These terms were combined using Boolean operators with keywords reflecting educational contexts ("dental education," "dentistry curriculum," "teaching,"

"assessment," "clinical simulation," "student learning," "faculty development") to ensure maximum sensitivity and specificity in retrieving relevant studies.

The review's inclusion criteria prioritized peer-reviewed articles, systematic or scoping reviews, narrative reviews, empirical research, conference papers, guidelines, and policy documents published from January 2020 to July 2025. Both English and non-English language publications were considered; non-English articles were included if an English abstract or summary was available. Foundational works predating 2020 were also reviewed if they were widely cited or deemed essential for contextual understanding.

A subsequent stage involved a manual review of the reference lists from two recently published and highly relevant reviews (1, 5). This process aimed to uncover additional primary studies, policy papers, and authoritative reports that might not have been captured in the initial electronic database searches. Where feasible, primary source documents referenced within these reviews were traced and evaluated for eligibility and relevance. Articles were included if they addressed the integration, implementation, impact, challenges, perceptions, or policy aspects of AI or GenAI within dental education. Articles exclusively focused on clinical applications of AI without educational relevance were excluded.

The study selection process commenced with an initial review of titles and abstracts to ascertain potential relevance, followed by the retrieval and in-depth reading of full texts for studies meeting the inclusion criteria. To enhance reliability, at least two reviewers independently assessed each article for inclusion, resolving any disagreements through discussion and consensus. For non-English articles, translation support was utilized as necessary to extract critical data. Policy documents and guidelines were analyzed with specific attention to their scope (institutional, national, or international), intended audience, stated principles or rules, and thematic content such as academic integrity, transparency, equity, and ethical AI use.

Findings were clustered into major domains pertinent to dental education: the types and roles of AI/GenAI, documented benefits and transformative impacts, identified risks and challenges (including ethical, legal, and practical considerations), approaches to curriculum integration, institutional and global guidance, and projections for future trends. Where possible, findings from disparate studies addressing similar issues were compared, and areas of consensus or divergence were highlighted. Emphasis was placed on evidence derived from recent, high-impact reviews and empirical studies, as well as authoritative statements from academic institutions and international organizations. This narrative review,

therefore, provides a rigorous and transparent qualitative synthesis of current knowledge, challenges, and best practices for integrating AI into dental education, with the aim of supporting evidence-informed curriculum innovation and responsible educational policy development.

## RESULTS

The integration of AI in dental education now encompasses both traditional (discriminative) AI and the emerging paradigm of generative AI. AI has been predominantly utilized for classification tasks, including radiographic interpretation, caries detection, and predicting student performance (9). These machine learning and deep learning-based systems, have demonstrated significant improvements in diagnostic precision, standardized assessment processes, and provided valuable insights into student learning patterns (10).

In contrast, GenAI represents a transformative approach to dental education. Large language models (LLMs) like ChatGPT, DALL-E, and Midjourney have shown remarkable capabilities in generating novel content, simulating patient scenarios, creating diverse visual and textual teaching materials, and facilitating interactive, conversational learning experiences (4). These tools can produce realistic patient histories, provide tailored responses to student inquiries, and generate assessment questions on demand. This technological advancement has fundamentally reshaped educational experiences, fostered more adaptive, student-centered approach and enabled previously unattainable forms of simulation and self-directed learning (1, 5).

GenAI exhibits particular strength in enhancing clinical reasoning skills by enabling students to engage in "virtual conversations" with simulated patients or expert tutors, develop comprehensive treatment plans, and receive immediate, context-sensitive feedback (11, 12). Beyond language generation, multimodal GenAI tools are increasingly proficient at interpreting images, radiographs, and even 3D models, thereby expanding their applicability in both didactic instruction and clinical training (13).

The integration of AI, particularly GenAI, has yielded substantial benefits for both dental students and educators. Multiple studies document improved access to personalized learning pathways, as AI systems can adapt content, pacing, and feedback according to individual learner's specific strengths and deficiencies (6). Adaptive learning platforms and AI-powered tutoring systems have demonstrated effectiveness in supporting remediation, accelerating competency development, and promoting self-directed learning, all of which are central objectives in modern dental curricula (14).

In clinical skills development, AI-driven simulators

and assessment tools empower students to practice diagnostic and procedural tasks within realistic, low-risk environments (14). For instance, AI-powered radiographic analysis platforms can present learners with diverse, annotated cases and provide instant accuracy assessments, effectively bridging the gap between theoretical knowledge and practical clinical application (15). Generative AI has further expanded simulation capabilities through facilitating open-ended dialogue, scenario variations, and real-time "what-if" explorations, resulting in more authentic and engaging learning experiences (11).

Another significant impact of GenAI lies in its contribution to research, academic writing, and administrative efficiency. Large language models can assist in literature synthesis, manuscript drafting, research proposal development, and even creating patient education materials. These capabilities potentially reduce language barriers and democratize access to scholarly and clinical resources, particularly for students and educators in non-English-speaking contexts (16).

AI-powered assessment and feedback tools enable both formative and summative evaluation of student progress. These systems can automate grading, provide immediate feedback, and track longitudinal learning outcomes with high reliability, supporting both self-regulated learning and programmatic assessment approaches (17).

Despite these advantages, AI adoption in dental education presents several complex challenges. A primary concern revolves around academic integrity, as GenAI's capacity to generate essays, answer assessment questions, or even "ghostwrite" research proposals raises fundamental questions about originality, authorship, and the distinction between legitimate assistance and academic misconduct (18).

Ethical concerns extend beyond plagiarism to include risks of algorithmic bias, data privacy issues, and transparency problems. GenAI models trained on extensive, sometimes unfiltered, data sources may inadvertently introduce or perpetuate biases in the information presented to students. Significant concerns exist regarding student and patient data privacy, particularly when using cloud-based or third-party AI services (19).

Practical barriers also remain prevalent. Many educators and students lack formal training in the proficient AI tool usage, leading to limited digital literacy, inconsistent application, and potential over-reliance on algorithmic outputs. The rapid pace of technological advancement often means that curricula, accreditation standards, and faculty development programs struggle to keep pace with current practices (20).

The integration of AI and GenAI into dental curricula shows considerable global variability. While some dental schools have initiated pilot

programs incorporating AI-based modules in radiology, prosthodontics, or research methodology, others are only beginning to introduce digital literacy and ethical topics (21). However, there is a clear consensus that dental curricula must evolve to address not only the technical competencies required for AI tool usage but also the critical thinking, ethical reasoning, and reflective skills essential for responsibly appraising and management (22).

Recent evidence indicates that effective integration requires a multi-faceted approach, encompassing faculty development, interdisciplinary collaboration, continuous curriculum review, and active involvement of students in co-designing AI-enhanced learning activities. Simulation-based learning, case-based discussions, and problem-based learning formats are particularly well-suited for embedding AI and GenAI, as they allow learners to dynamically interact with complex, authentic scenarios (23).

Despite the rapid GenAI proliferation, most dental schools and academic organizations have yet to formulate formal, discipline-specific usage policies or guidelines. A recent international survey revealed that less than 10% of dental schools had implemented GenAI policies or recommendations even as faculty and students report frequent and increasing engagement with these tools in their daily educational activities (5).

The future trajectory of AI in dental education will largely depend on the institutions' capacity to effectively address both opportunities and challenges. Key priorities include developing robust digital literacy programs for both students and faculty, establishing dental-specific AI and GenAI guidelines, and continuously assessing educational and ethical outcomes associated with these technologies. There is also a recognized need to cultivate critical engagement cultures, where AI tools are perceived as learning partners rather than unquestioned authorities (24). Emerging evidence suggests that successful integration will require ongoing dialogue among educators, technologists, ethicists, and students, underpinned by a steadfast commitment to transparency, reflection, and adaptability as technologies and educational contexts continue to evolve (1, 5, 6, 14, 24). analysis.

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## DISCUSSION

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The integration of artificial intelligence (AI), particularly generative AI (GenAI), is fundamentally reshaping the landscape of dental education, influencing pedagogical approaches, assessment methodologies, and the very development of professional values. While this review clearly demonstrates the practical benefits of GenAI, including personalized learning, instant feedback, and enhanced simulations, its long-term

success in dental education will ultimately depend on the institutional, pedagogical, and ethical frameworks that guide its implementation (24).

A crucial insight emerging from current literature is the pressing need for comprehensive digital literacy programs targeting both students and faculty. Digital literacy in this context extends beyond technical proficiency to encompass critical evaluation skills and ethical reasoning when using AI technologies (25). As AI tools become more common and advanced, simply providing access isn't enough. The genuine educational value emerges from the ability to employ these tools thoughtfully, critically, and responsibly (26). To bridge the gap between AI's potential and its effective implementation in dental education, strategic initiatives including faculty development programs, continuous digital upskilling, and active student involvement in curriculum design are essential (27). A recent global survey revealed that both students and faculty often lack confidence in critically assessing AI-generated content, underscoring the urgent need for digital literacy programs that integrate ethical reasoning and data management (22).

A significant barrier to the responsible integration of GenAI in dental education is the widespread absence of formal, discipline-specific guidelines. Despite the rapidly expanding adoption of GenAI tools, fewer than 10% of dental schools worldwide have established clear policies governing their use in educational contexts (5). This policy vacuum exposes students and educators to risks concerning academic integrity, privacy, and algorithmic bias (28). Existing policies, where present, typically emphasize general principles like ethical use, transparency, security, and academic honesty, but frequently fail to address the unique requirements of dental education (5). Major international organizations have consequently issued for developing comprehensive frameworks that prioritize critical thinking, privacy protection, and equitable access to AI technologies (29).

The dynamic evolution of AI technology necessitates ongoing evaluation mechanisms that assess not only educational outcomes but also ethical and societal implications (21). Responsible implementation requires continuous monitoring of student performance, effectiveness of AI-powered educational support, and AI's impact on the development of students' professional identity (30). Furthermore, educators must remain vigilant in regard to emerging challenges, such as the potential for over-reliance on AI that might undermine independent clinical reasoning, or the risk that complex "black box" algorithms could inadvertently reinforce existing biases (31).

As AI transitions from a supplementary tool to a core component of dental education, a fundamental cultural shift becomes imperative. AI should be

conceptualized not as an infallible authority but as a collaborative learning partner that requires critical scrutiny, contextualization, and open dialogue (32). This perspective aligns with recommendations from both scientific literature and global policy organizations for a thoughtful, human-centered approach that places critical engagement at the heart of digital transformation. Cultivating this mindset requires not only technical training but also creating structured, safe environments where students and educators can openly discuss, debate, and experiment with AI technologies (33).

The successful future integration of AI in dental education will depend on sustained, interdisciplinary collaboration among dental educators, clinicians, computer scientists, ethicists, and policymakers (34, 35). As AI and GenAI capabilities evolve rapidly, curriculum design and institutional policies must maintain flexibility, be grounded in empirical evidence, and remain adaptable to unforeseen challenges and opportunities. A committed focus on transparency, inclusivity, and evidence-based practice will ensure that AI integration in dental education benefits the widest possible range of stakeholders while upholding the fundamental values of academic integrity and social responsibility (36).

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## CONCLUSION

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Artificial intelligence, particularly generative AI, is fundamentally transforming dental education through innovative applications in personalized learning, adaptive feedback mechanisms, and advanced clinical simulations. While these technologies offer considerable advantages, their effective implementation faces significant challenges including insufficient digital literacy, inadequate ethical training, and a lack of specific guidelines tailored to dentistry. Most dental institutions are still in the early stages of creating comprehensive policy frameworks to manage both the opportunities and risks presented by GenAI. For AI to realize its full potential in dental education, institutions must invest in training for both faculty and students, encourage collaboration across different fields, and establish transparent, adaptable policies grounded in evidence and ethical principles. Ultimately, the potential of AI in dental education will be realized not merely through technological progress, but through a dedication to critical engagement, inclusivity, and continuous reflective practice.

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#### Ethical Considerations:

Ethical issues including plagiarism, informed consent, misconduct, data fabrication and/or

falsification, double publication and/or submission, redundancy, etc. have been completely observed by the authors.

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