

Artificial intelligence in dental hygiene education: a narrative review on ethical challenges and preliminary pathways

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ABSTRACT

Objective: Artificial intelligence (AI) is transforming health professions education and patient care, making it imperative to examine the ethical considerations surrounding its responsible use. This review study explores ethical issues related to the integration of AI in dental hygiene (DH) education and examines the implications for student learning and professional practice. **Method:** A narrative review was conducted using Medline, PubMed, CINAHL, and SCOPUS. Articles were identified using keywords: “artificial intelligence,” “AI,” “dental hygiene education,” “dental education,” “health sciences,” “ethical considerations,” “ethics,” and “implementation.” Relevant literature addressing ethical or educational implications of AI in DH or dental education were screened and analyzed. **Results:** From 46 articles identified, 12 met the inclusion criteria. Five key ethical concerns emerged: overreliance on AI with potential impacts on critical thinking; algorithmic bias and data integrity issues; AI-related anxiety and resistance among learners and educators; risks to human interactions and patient-centered care; financial and logistical barriers to equitable AI adoption; and limitations to AI competence and confidence in its utilization. **Discussion:** This narrative review highlights the need for intentional, ethically sound approaches to AI integration. A preliminary conceptual framework based on the Canadian Dental Hygienists’ Association Code of Ethics is proposed, emphasizing beneficence, autonomy, integrity, accountability, and confidentiality through digital literacy, transparency, human oversight, and ongoing evaluation. **Conclusion:** Ethical, learner-centered frameworks are essential to support critical thinking, professional judgement, and patient-centered values as AI continues to

evolve within health sciences education. Further research is also needed to evaluate long-term educational outcomes and guide curriculum development.

Keywords: artificial intelligence; curriculum; dental, education; dental hygiene; education; ethics; learning

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INTRODUCTION

Over the last several decades, artificial intelligence (AI) has evolved from an abstract concept, and a topic of science fiction, to a tool that is deeply integrated into many aspects of modern daily life, to the extent that even local drugstores sell AI-powered toothbrushes.¹ AI is rapidly emerging as not only a pivotal force, but a subtle one that is becoming ingrained in our daily habits and thus, for educators, affecting learning outcomes and skill-development in health sciences education for students.² From Large Language Models (LLMs), to adaptive learning platforms and AI-driven clinical transcription and generation of clinical notes, these AI tools promise to significantly change how students learn and prepare for their professional practice.³

Dentistry, in particular, has placed a significant emphasis on digital workflows, with AI becoming increasingly ubiquitous in its application to these digital tools.⁴ These workflows include diagnosis support, treatment planning, image analysis, patient administration, prognosis analysis and the automation of tasks. Dentistry has seen the integration of AI-powered applications in specialties including operative dentistry, periodontics, orthodontics, oral and maxillofacial pathology, and prosthodontics.⁵

More recently, AI has become increasingly integrated into many facets of dental and dental hygiene (DH) education. Four core areas have emerged in dental and DH education, in which AI is being actively integrated and evaluated: (1) AI-based diagnostic

imaging, (2) digital dentistry, (3) treatment planning using AI-driven diagnostic technologies, and (4) implant dentistry.⁶

As AI becomes more integrated into dental practice and dental education, it presents complex ethical issues that need attention from educators, students, and professionals. Although these issues ideally would be addressed prior to broad adoption, the reality is that many stakeholders, including educators and regulators, are implementing and refining these approaches while simultaneously developing frameworks and safeguards. That said, early enthusiasm for the application of AI has given way to critical evaluations of its impact on human judgement, data integrity, and the quality of interpersonal interactions.⁷

Two key questions that arise:

1. What are the primary ethical concerns with using AI in DH education?
2. How can these concerns be mitigated to ensure responsible implementation of this technology?

This review aims to evaluate the existing literature in search to answer these questions. It intends to provide a narrative review⁸ that explores current applications of AI in DH education, and emerging ethical issues. Based on the findings, a preliminary conceptual framework for the ethical use of AI in DH education will be developed. This framework will integrate core ethical principles relevant to Canadian dental hygienists and propose suggestions for educators and policymakers to responsibly leverage AI in both pre-professional and adult education.

METHODS

This literature review followed a narrative approach⁹ designed to capture and analyze the current state of research about integrating artificial intelligence in DH and dental education, where the two pre-professional programs overlap. The methodological details are described below:

Search strategy

A search was conducted in September 2024 through four major databases: Medline, PubMed, CINAHL, and Scopus to ensure inclusion of literature from all health professional education. The search strategy employed a combination of specific keywords, including “artificial intelligence”, “AI”, “dental hygiene education”, “dental education”, “health sciences”, “ethical considerations”, “ethics”, and “implementation”. These keywords were selected to ensure that the search captured a broad enough spectrum of studies related to both the technical and ethical dimensions of AI in DH educational contexts.

Inclusion and exclusion criteria

To address our specific research question, only studies written in English that focus on the implementation of AI in dentistry and dental hygiene, particularly concerning ethical considerations, were included. No filters were applied for the year of publication or article type. Nonetheless, only peer-reviewed full articles were considered. The detailed inclusion and exclusion criteria are provided in Table 1. The articles were screened based on the inclusion-exclusion criteria first by the title and abstract, and then by the full articles. Figure 1 outlines the study selection process.

Data extraction

Data were extracted from the eligible studies focusing on the aims, AI use, and primary ethical considerations (Table 2). Upon extraction, results were synthesized to highlight common themes, ethical dilemmas, practical challenges (Table 2), and corresponding mitigation strategies (Tables 3). This approach enhanced the transparency and replicability of the review,⁹ and also ensured that the final analysis was grounded in evidence, thus supporting the development of a preliminary ethical framework for the integration of AI into dental hygiene education.

RESULTS

After selection and initial screening, 46 articles were eligible for full-text review, of which 12 studies were included in the narrated review. Five primary ethical concerns emerged from the literature (Table 2).

Overreliance on AI with potential impacts on critical thinking, algorithmic bias and data integrity issues

One of the primary ethical concerns identified in the literature is the risk of over-reliance on AI tools. Several studies have highlighted that excessive dependence on AI tools can lead to a reduction in critical thinking skills among students.^{10,11} When learners accept AI-generated feedback or utilize AI-driven outputs for completing academic tasks uncritically, there is a risk that they may forgo developing the deep analytical skills necessary for effective clinical decision-making. In the context of adult learning for professional programs, where self-directed learning and reflective practices are crucial,^{12,13} this over-reliance could undermine the educational process.

Algorithmic biases and concerns over private data security are other significant ethical challenges raised in the literature. AI systems are inherently dependent on the quality and representativeness of the data on which they are trained.¹⁴ Roganovic et al. also

underscore concerns that biases in training datasets can lead to unfair or inaccurate outputs. In dental hygiene education, biased algorithms may result in skewed diagnostic recommendations or assessments that disadvantage certain student groups or patient populations. There is also a clear barrier to the use of AI technology if dental professionals or patients perceived that an AI tool was not fully safeguarded against data security breaches.¹⁰ Maintaining data integrity, ensuring that training datasets are diverse and thoroughly representative, and that private health data is considered safely guarded, is essential to mitigate these risks.

AI-related anxiety and resistance among learners and educators

A recurring theme identified in the literature is the emergence of AI-related anxiety and resistance among dental hygiene students and educators. Findings indicate that the anxiety stems from an awareness of AI's limitations; such as algorithmic biases, data privacy risks, and the potential for reduced human oversight, which in turn lead to resistance in adopting these technologies.^{10,15} For many adult learners in dental hygiene programs, the prospect of implementing AI tools into their educational process may be intimidating, particularly if these tools are perceived as too opaque, not explainable or positioned as a replacement for hands-on clinical training.^{16,17} Müller et al. found that students with a higher digital proficiency sometimes exhibit heightened skepticism towards AI outputs because they may better understand the risks of over-reliance on machine-generated information. This anxiety may be compounded by the fear that excessive dependence on AI might undermine the development of critical thinking and diagnostic skills, which are essential for optimal patient-centred care.

Risks to human interactions and patient-centered care

The integration of AI can potentially alter the dynamics of human interaction in both educational and clinical settings. Concerns about the loss of personal connection are prevalent in the literature from healthcare providers, the public perception of AI tools, educators and students alike.¹⁰ In dental hygiene, personalized care and empathetic communication are fundamental to patient trust and effective treatment;¹⁸ therefore, the potential diminished role of human interaction poses a serious ethical dilemma. Particularly for educational contexts, this loss of connection may impact the influence of mentorship and personalized feedback from an individual instructor.¹⁰

Financial and logistical barriers to equitable AI adoption

Financial costs and logistical challenges associated with implementing AI systems can exacerbate inequalities in educational access. As highlighted by Firincioglugulari, high costs may prevent some institutions from adopting state-of-the-art AI technologies, leading to disparities in educational quality and student preparedness for the “real world”.¹⁹

Limitations of AI competence and confidence in its utilization

Closely related to the issue of AI-related anxiety, is the concern regarding AI competence and confidence among dental hygiene students. While some studies indicate an upward trend of AI knowledge among students, many students still reported moderate to low levels of using AI-driven tools effectively within educational and clinical contexts.^{20,21} Insufficient training and a lack of structured curriculum on AI pre-professional programs can leave learners unprepared to critically evaluate AI outputs.^{15,19} This gap may not only affect competence in leveraging AI for diagnostic and clinical support, but also compromises their ability to integrate these tools into decision-making processes

responsibly.

In viewing these pressing concerns laid out in this way, it's clear that a proactive approach is necessary to ensure that the implementation of AI supports, rather than undermines educational and clinical practices. Thus, the following proposed framework aims to serve as a guide to balance technological innovation with the essential ethical principles that guide today's Canadian dental hygiene providers.

DISCUSSION

Proposed ethical framework for AI integration in dental hygiene education

Dental hygienists in Canada are governed by a few common ethical principles, from the Canadian Dental Hygienists' Association Code of Ethics.²² Based on the synthesized findings from the limited existing literature, dental hygiene educators can be further guided by these principles when integrating AI into their curriculum, in order to set their learners up for academic and professional success. This proposed preliminary framework is designed to address the ethical concerns identified in the existing literature (Table 2) while enhancing the clinical and educational utility of AI, and utilizing the mitigation strategies proposed in the existing literature (Table 3).

Beneficence

The key objective of the first principle of this framework is to improve the clinical outcomes of patients and foster the holistic development of skills for dental hygiene students. AI tools should be implemented with the goal of providing personalized feedback and simulating clinical scenarios and clinical conversations. It could, for example, provide opportunities for students to enhance their skills of motivational interviewing and patient-centered communication. However, educators should be mindful

of utilizing AI tools, such as patient simulators or chatbots, which have a complexity tailored to the student's level of knowledge.²³ To mitigate ethical concerns and ensure competency, educators should ensure that AI developers and industry partners regularly update and utilize clinician oversight to validate their AI models to ensure they deliver accurate, evidence-based recommendations that contribute positively to patient care and student learning.^{11,15} Educators should also prioritize assessing student needs and knowledge gaps about AI technology,^{19,21} and based on needs, integrating AI training modules into dental hygiene curriculum that emphasize the complementary role of technology in supporting, rather than replacing human expertise.^{10,15,20} The introduction of AI into adult learning environments requires careful attention to digital literacy levels. Studies by Halat et al. and Firinciogullari indicate that many students possess only a moderate level of readiness for AI integration, highlighting the need for comprehensive training programs.^{19,21}

By improving learning outcomes, confidence in technology, and clinical decision-making aided by additional diagnostic tools, AI has the potential to enhance patient care, fulfilling the principles of beneficence, autonomy, and integrity by actively contributing to the well-being of both students and patients. (Figure 2)

Autonomy

The key objectives of the second principle of the framework is to firstly respect the autonomy of both dental hygiene students and patients by ensuring transparent and informed use of AI technologies, as well as to mitigate the “black box” phenomenon. This is where the internal workings of an AI system are opaque to its’ users and sometimes even its developers, therefore contributing to a lower level of confidence and a reduced ability to trace the decision-making process of the system.²⁴ To embody this principle

and mitigate this phenomenon, educators and clinicians should develop clear communication protocols and disclosures that explain how AI tools operate, including the data sources (where available), algorithms, and inherent uncertainties involved in AI-generated outputs.^{10,11,15,25} In the spirit of transparency, educators can also allow students to opt-in or opt-out of AI-enhanced modules, ensuring they remain active participants in their learning.¹⁰

Incorporating digital literacy programming into the curriculum can help ensure that students understand the benefits, limitations, and ethical implications of AI tools. There should be an emphasis on informed consent practices when using patient data for educational purposes, in line with ethical standards.²⁰ Respecting autonomy ensures that students have control over their learning and patients over their treatment decisions. Transparent AI practices, the ability to opt in or out, and increased digital literacy training empowers students and patients to make informed choices, thereby upholding their right to self-determination, and maintaining the principles of beneficence while embedding accountability in the use of these tools. (Figure 2)

Integrity

The key objective of the third principle of this framework is to uphold the integrity of dental hygiene education standards by ensuring that AI-generated information that students utilize is accurate, trained on varied data to mitigate bias, and reflective of current evidence-based practices. In collaboration with industry partners, educators should prioritize software that has established rigorous validation protocols for their AI tools, including routine audits, cross-references with established clinical and regulatory guidelines. Leading AI tool developers should ensure that tool training datasets are

diverse and representative to reduce bias and promote data integrity.¹⁴ According to this framework (Figure 1), and the existing literature, collaboration between educators, clinicians and AI developers will be required to refine and update AI models continuously.

Quality assurance measures can monitor the quality of AI outputs, particularly in diagnostic and prognostic applications, better preparing students to critically assess the quality and accuracy of its outputs.^{11,21,26} Maintaining integrity in dental hygiene educational content and future dental hygienists' clinical decision-making is critical to preserving trust, maintaining confidentiality, and maintaining the principle of beneficence, in addition to integrity. (Figure 2) An evidence-based approach ensures that AI tools enhance rather than compromise the educational process and corresponding patient care.

Accountability

The key objective behind this principle of the framework is to ensure that responsibility for AI-driven decisions is clearly defined and that mechanisms are in place to address biases and errors. There is a need to define specific roles and responsibilities for educators, administrators, and developers in monitoring AI systems and their outputs.

Institutions should consider establishing an AI ethics board, composed of interdisciplinary experts to oversee AI implementation, address concerns, and recommend corrective actions if needed.^{14,25} With the help of the ethics board, transparent error-reporting systems and structured review processes can work to address any discrepancies in AI outputs, simultaneously encouraging the development of critical thinking skills in students. Encouraging regular feedback from students and faculty to inform iterative improvements in AI tools can also be a helpful accountability tool.^{14,16} Clear accountability safeguards protect both students and patients by ensuring

that any adverse outcomes or challenges can be promptly and effectively addressed. In the framework below, this is illustrated in the overlapping traits between the principles of confidentiality, accountability, and autonomy. (Figure 2) Accountability fosters a culture of responsibility, thereby reinforcing trust in the AI tool and trust in the institution responsible for its implementation.

Confidentiality

The key objective of this final pillar of this framework is to uphold the principle of confidentiality by ensuring that all data used in AI systems is securely managed and protected from unauthorized access. Institutions must do their due diligence and ensure that any AI tool they implement utilizes robust data security measures, including encryption, anonymization, and strict access controls. It must be ensured that all patient and student data used for AI training and application complies with relevant legal frameworks. Institutions and educators alike must also develop policies that govern data use, along with the use of tools such as generative AI and establish regular audits to ensure compliance with these standards. These practices maintain the integrity of the institution, providers and embed accountability in the use of any AI-driven tool. (Figure 2)

Students and faculty should undergo training about the importance of data protection, and the ethical handling of safe information.^{19,20} Confidentiality is an intersecting principle of ethical healthcare, dental hygiene care, and education. By safeguarding sensitive information, and ensuring that patient and student data is not fed into AI tools without consideration to broader privacy and health data protection regulations, the framework protects individual privacy and maintains the trust essential to both effective learning and clinical practice. The successful implementation of AI requires careful

analysis of the ethical concerns, and the intentional development of a framework that aligns with the core principles of the Dental Hygienists' Code of Ethics. The ethical concerns found in the literature consisting of the risk of over-reliance on technology, algorithmic bias, loss of human interaction, financial barriers to implementation, and data privacy concerns must all be addressed to ensure the responsible and effective use of AI in educational settings.

One of the central tensions in the integration of AI is the balance between leveraging technological advances, while maintaining human oversight. This is illustrated in Figure 2, where the principles of integrity and confidentiality intersect; human oversight to safeguard patient and student data is paramount to the ethical implementation of AI technologies. While AI has demonstrated the ability to improve diagnostic accuracy and streamline administrative tasks, over-reliance on these tools may hinder the development of critical thinking skills and potentially diminish the quality of clinical judgment.^{10,15} In adult learning contexts, where learners benefit from reflective practices and mentorship, it is essential to preserve the “human touch” of interactions.¹⁰ This ethical framework addresses these concerns by promoting a balanced approach to AI implementation – using AI tools to aid, not replace, human decision-making. Educators should be encouraged to learn about AI tools, systems, and their regulatory oversight so they can implement AI tools into the curriculum in a way that fosters independent analysis, and critical evaluation, rather than blind trust in an algorithm. This is visualized in Figure 2, where autonomy and accountability intersect, highlighting transparency in AI algorithmic processes and their use.

To support the ethical integration of AI in dental hygiene education, the proposed

framework prioritizes professional accountability, critical digital literacy skills, and ongoing oversight. Consistent with contemporary Canadian dental hygiene practice guidance, AI-supported tools must be evaluated regularly for accuracy, bias and be in alignment with evidence-based practice.²⁷ AI does not replace clinical judgment; regulated oral healthcare providers (OHCP) retain full responsibility for all assessments, decisions, and documentation generated with the support of AI. Embedding AI and digital literacy into dental hygiene curricula is essential to prepare future OHCPs to critically assess AI outputs, recognize its limitations, assess risk, and apply appropriate oversight. This approach reflects regulatory guidance emphasizing competence, risk management, and appropriate use of AI in oral healthcare settings.²⁷ While the recent guidance from the Alberta College of Dental Hygienists (ACDH), in collaboration with other oral health regulatory bodies in Alberta establishes essential guardrails for the safe and compliant use of AI in practice, the proposed framework extends this guidance upstream into education, providing a structured ethical model to support learner development, critical thinking, and responsible professional identity formation. Rather than duplicating regulatory guidance, this framework aims to complement it by addressing how AI competence is cultivated prior to and alongside clinical implementation.

Limitations and recommendations

This study is limited by its narrative review design, a small and heterogeneous evidence base, and the absence of primary empirical data, underscoring the need for future longitudinal and empirical research to validate the proposed ethical model. Although more comprehensive integrated or systematic reviews would typically be used to

establish the foundation for implementing a theoretical framework, the current approach provides an initial synthesis to guide early discourse in this developing area. We acknowledge that our study only suggests some mitigation strategies of ethical concerns, without providing concrete implementation steps and evaluation indicators.

Although the integration of AI into dental hygiene education is still in its early stages, current evidence suggests that its impact may extend well beyond the educational landscape. Future research should include longitudinal studies that evaluate the long-term effects of AI on learning outcomes and clinical competency. Further work is also needed to assess the effectiveness of enhanced digital literacy initiatives and to refine the ethical framework in response to emerging technologies.

It is essential that educators, students, and experienced clinicians lead this work, shaping how these tools are implemented, how they influence future clinicians, and how they affect public perceptions of dental hygiene providers. Key recommendations for future research are illustrated in Figure 3.

CONCLUSION

The technological advances afforded by AI tools are promising, yet accompanied by ethical challenges that must be addressed by institutions, educators and students alike to ensure that AI serves as a complementary tool, rather than a crutch for human judgement and cognitive skills. Grounding this preliminary conceptual framework in the core ethical principles guiding Canadian dental hygienists provides an initial roadmap for the responsible integration of AI into dental hygiene education.

This narrative literature review has examined the historical evolution of AI, its

current applications in dental and dental hygiene education, and the ethical challenges posed by its use. Drawing on a synthesis table of recent empirical studies and reviews, concerns were identified with respect to potential over-reliance on and lack of confidence/competence in AI technology, algorithmic bias, diminished human interaction, financial barriers, and data privacy concerns. The proposed preliminary conceptual framework addresses these concerns through a multi-pronged approach emphasizing validation, transparent communication, human oversight, and targeted digital literacy training.

As dental hygiene education continues to evolve, educators and policymakers must remain vigilant in balancing innovation with the preservation of core ethical values. The framework proposed here should be understood as an early, ethics-informed model intended to guide discussion, curriculum development, and future research, rather than as a validated framework for implementation. Further empirical research, including longitudinal and practice-based studies, is needed to evaluate, refine, and validate the framework in dental hygiene education contexts. By embracing a proactive and ethically grounded approach, dental hygiene education can remain responsive to innovation while upholding the principles that underpin effective, compassionate, and patient-centred care.

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Table 1: Inclusion and exclusion criteria

	Inclusion	Exclusion
<i>Language</i>	English	Non-English
<i>Year of study</i>	The search was conducted in 2024. A specific time range was not set.	None
<i>Study focus</i>	Dentistry and/or Dental Hygiene	Non-dental practice or education
	AI in education and healthcare applications.	Technical or computational aspects of AI
	AI implementation with relevance to educational or ethical considerations	No clear relevance to ethical considerations
<i>Article type</i>	Peer-reviewed full research articles	Review studies, Opinions, Letters to the editors, Conference proceedings.
<i>Study design</i>	Any	None
<i>Setting</i>	Any	None

Table 2. Synthesis table compiling *primary ethical concerns* with using AI in dental hygiene education based on literature search.

Author and year of publication	Aim/Brief outline of the study	Primary Ethical Concerns Identified				
		Over-reliance on AI, Potential Algorithmic Bias, Data Integrity, Impact on Critical Thinking Skills	AI-Related Anxiety and Resistance Among Learners and Educators	Risks to Human Interaction and Patient-Centred Care	Financial and Logistic Barriers to Equitable AI Adoption	Limitations of AI Competence and Confidence in its Utilization
Sim et al. 2024 ¹⁵	The primary aim of this study was to investigate dental hygiene students' attitudes towards artificial intelligence (AI) and to assess	Over-reliance on technology can weaken critical thinking skills and encourage uncritical acceptance of AI-generated information, raising concerns about the	Students skilled in digital tools may understand AI's limitations, leading to anxiety or resistance due to concerns about data privacy, algorithmic bias,		Digital literacy disparities exist among learners, especially those who have low interest in their field but high digital proficiency, raising concerns	Research on AI attitudes and digital literacy among dental hygiene students is limited.

	their levels of digital literacy.	accuracy of educational outcomes.	and reduced human oversight.		about equitable access to AI-based educational tools.	
Witkowski et al. 2024¹⁰	The primary aim of this study was to explore how members of the public perceive and feel about the use of AI in healthcare, particularly in relation to patient-centered care.	Concerns about over-reliance on AI may hinder critical thinking and independent decision-making skills.	Concerns over AI algorithms being trained on biased data, leading to unfair educational assessments or recommendations. Needs to be transparency and accountability with AI use.	Loss of human interaction may weaken the personal connection between educators and learners, affecting mentorship and feedback, and raising concerns about conflicts with patient-centred care.	The potential financial burden of implementing AI systems may limit access to AI-enhanced education for lower-income institutions and learners.	Incorporating AI into informed consent could improve patients' self-efficacy and control over their care, which is vital for patient-centred ethics. Transparency about AI is essential for sustaining the therapeutic alliance.
Jeong et al. 2023²⁰	The primary aim of this study was to investigate Korean dental hygiene students' perceptions and attitudes towards AI, and was designed to identify educational needs to strengthen their professional competencies related to AI.		Participants with greater knowledge of AI recognized the need for enhanced AI education in dental hygiene curricula. This was the first survey study on dental hygiene students' perceptions of AI.			Dental hygiene students reported higher AI knowledge than physicians in previous studies. However, most participants did not view dental hygienists as primary users of AI in dental care or as responsible for its accuracy.
Müller et al. 2021¹⁶	The primary aim of this study was to identify barriers and enablers for implementing AI into dental diagnostics, with a specific focus on radiographic diagnostic workflows.	Concern expressed about over-reliance on AI systems, which could diminish clinicians' diagnostic skills and clinical judgement. Questions arose around accountability, particularly in scenarios where AI-assisted diagnostics or reports may lead to errors.	AI decision-making is often viewed as a "black box," leaving clinicians without visibility into its inner workings and data inputs. Dentists express concern about potential misinterpretations and false positives, while data protection issues pose significant barriers for stakeholders.		The complexity of integrating AI into daily workflows poses challenges.	The paper highlights concerns about responsibility in diagnosis, with patients emphasizing the need for dentists to not solely depend on AI, recognizing that AI can err. This raises an ethical dilemma about balancing trust in technology with human oversight in medical decisions.

Lin et al. 2024²⁵	The primary aim of this study was to explore dental students' perceptions regarding the ethical considerations of using AI algorithms in clinical decision-making.		Dental students generally have positive perceptions regarding ethical considerations of AI in clinical decision-making.			The study highlights the need for integrating lessons on patient rights and ethics into dental education.
Bae et al. 2024²⁶	The primary aim of this study was to evaluate the performance accuracy of ChatGPT (a large language model) in answering questions from the Korean National Dental Hygienist Examination.	A study found that LLMs like ChatGPT provide limited evidence-based responses for the dental hygiene board exam, emphasizing caution in interpreting its replies, particularly in Korean contexts.				
Chang et al. 2024¹¹	The primary aim of this study was to evaluate how the use of an AI-assisted tool affects dental students' performance in mounting full-mouth radiograph series.	The study emphasizes AI's ability to boost efficiency in dental education, especially in radiograph mounting. However, it warns that overreliance on AI could jeopardize clinical accuracy.			The findings suggest that inexperienced clinicians might face negative consequences from AI automation in their training.	Students' confidence levels maintained consistent, suggesting that AI's impact on learning may require further investigation.
Roganovic et al. 2023¹⁴	The primary aim of this study was to investigate how experienced dentists and final-year dental undergraduate students perceive and are prepared to accept the use of AI in dental practice.	Concerns about algorithmic bias and inadequate training data for diverse populations are highlighted, as insufficiently representative data can lead to bias.			High costs of AI software present a significant barrier to implementation.	
Firincioglu et al. 2024¹⁹	The primary aim of this study was		Many educational institutions		The expense of AI software is a	Confidence in AI among participants

	to assess dental students' knowledge of AI, their attitudes towards AI, and their perceptions of AI and AI-related education, in order to identify educational needs that could enhance their professional competencies.		struggle to integrate AI into teaching due to ethical dilemmas, highlighting the importance of addressing these concerns in dental education. The paper suggests that ethical considerations should be central to developing educational initiatives involving AI.		challenge for educational institutions in adopting AI technologies.	was generally low, indicating a need for better education.
Halat et al. 2024²¹	The primary aim of this study was to assess how prepared dental students feel to engage with AI technologies, how they view AI's role in educational and clinical settings, and what specific knowledge or skills they believe are necessary to support effective AI integration into dental training and practice.		Participants scored an average of 3.43 out of 5 on the ethics domain of the Medical Artificial Intelligence Readiness Scale (MAIRS), suggesting moderate readiness. However, the authors emphasize careful interpretation due to the complexities of AI ethics and highlight legal challenges, including risks of inaccuracies and data breaches that could impact patient care.			

Roganovic 2024¹⁷	The primary aim of this study was to investigate how familiarity with an AI system's features, specifically by reading a description of ChatGPT's features, affects dental students' expectations towards using the technology and their actual learning outcomes.		Highlights ethical concerns about AI performance overestimation due to description manipulation, which may mislead clinical decision-making. Most students expressed reluctance to use ChatGPT, questioning its reliability and effectiveness.			
Suárez et al. 2022²⁴	The primary aim of this study was to evaluate the use of an AI-based virtual patient chatbot as a tool to support the development of dental students' diagnostic skills.		Some students expressed reluctance to accept AI technology-based learning, preferring face-to-face interaction.	Ethical considerations regarding the human aspects of patient care must not be overlooked, according to this study. Utilizing virtual patient interactions may affect the development of essential interpersonal skills in students.	Utilizing virtual patients can afford economic and spatial advantages over traditional simulation methods, such as standardized patient examinations.	Incorporating AI into curricula can enhance student satisfaction and engagement, as shown by positive feedback from this study. However, 4th-year students faced more challenges with diagnostic competence using the virtual patient tool than 5th-year students.

Table 3. Synthesis table of overlapping mitigation strategies for key ethical concerns in AI use for dental hygiene education from literature review.

Author and year of publication	Overlapping Mitigation Strategies to Potentially Address the Identified Ethical Concerns			
	AI and Digital Literacy Education for Bias Prevention <i>Potentially mitigates overreliance on AI technology, AI-related anxiety and resistance, and improves competence and confidence.</i>	Transparency and Student/ Patient Autonomy <i>Potentially mitigates overreliance on AI technology, AI-related anxiety and resistance, the risks to human-centred interactions, and improves competence and confidence.</i>	Human Oversight and Balanced Integration for Ethical Use <i>Potentially mitigates AI-related anxiety and resistance, the risks to human-centred interactions, and financial and logistical barriers to implementation.</i>	Ongoing Research and Continuous Improvement <i>Potentially mitigates AI-related anxiety and resistance, financial and logistical barriers to implementation, and improves competence and confidence.</i>
Sim et al. 2024¹⁵	Integrating digital literacy	Create educational programs	Implement	Conduct qualitative research on the

	and AI training into dental hygiene education can better prepare students for technological advancements through hands-on workshops and practical applications of AI tools.	focused on the ethical use of AI, highlighting data privacy, informed decision-making, and critical evaluation of AI outputs. Promote practices that help students assess the reliability of AI technologies and avoid over-reliance.	guidelines for effective academic use of smart or digital devices, encouraging their use for learning.	factors influencing students' digital literacy and AI attitudes across different interests. Regularly evaluate AI tools in education for equity, accuracy, and inclusivity to prevent biases and maintain high academic standards.
Witkowski et al. 2024¹⁰	Provide educators with training on integrating AI tools responsibly into education while maintaining human interaction and mentorship, and providing personalized feedback.	Allow students to opt in or out of AI-enabled learning tools, providing transparency on how AI is used in their educational experience.	Establish ethical AI guidelines in education focused on transparency, accountability, and data protection. Ensure oversight to prevent algorithmic bias and promote fairness. Additionally, offer medical guidance on leveraging AI for patient-centered care while preserving strong relationships.	Balanced AI usage, for example, as a supportive tool for administrative tasks, grading, and some content delivery, while preserving human involvement in mentorship, feedback, and high-stakes assessments.
Jeong et al. 2023²⁰	Incorporate more AI-focused programming in dental hygiene curricula, while remaining cautious of AI's limitations in clinical settings.			Conduct additional research with dental hygienists and dental hygiene students regarding their perceptions and experiences with AI tools and technology.
Müller et al. 2021¹⁶			Highlights the importance of ethical considerations in using AI for dental diagnostics, stressing the need for safe and explainable AI to reduce bias and ensure transparency.	

Lin et al. 2024²⁵		The study highlights the need for integrating lessons on patient rights and ethics into dental education.	Discusses the need to formulate precise rules and ethical guidelines for AI implementation in clinical settings, addressing moral dilemmas arising from AI integration.	Potential biases in AI algorithms pose ethical challenges for patient care. Findings indicate students lack understanding of AI risks in clinical settings, highlighting the need for further research. Exploring students' perceptions can help integrate human judgment with AI in decision-making.
Bae et al. 2024²⁶			The need for human oversight in AI-generated responses was emphasized.	
Chang et al. 2024¹¹		Balancing AI's role as a tool while training students effectively is crucial for future dental education.	Highlights the need to train students to evaluate AI outputs critically to avoid cognitive misdiagnosis.	
Roganovic et al. 2023¹⁴	There is a call for greater representativeness in AI training data to reduce bias. Many educational institutions struggle with AI adoption because teachers lack sufficient training in AI.		The study highlights the absence of regulatory policies for AI use in dentistry, pinpointing an ethical issue related to patient data protection. Dentists see the Ministry of Health as responsible for establishing clear guidelines.	The research emphasizes the importance of ethical considerations in data management, highlighting that using data in harmful ways is unethical. Dentists should prioritize data privacy and comply with regulations like the GDPR to protect patient information.
Firincioglu et al. 2024¹⁹		Most students had limited knowledge of AI and wanted AI-related lectures in their curriculum. They showed low confidence in AI and had little formal education on the subject.		

Halat et al. 2024²¹	Identifying AI benefits, risks, and needs in dental education can enhance curricula and practices.	Highlights the importance of addressing AI knowledge gaps in dental education. Participants expressed a high need for AI-related knowledge and skills in healthcare.	Ready students for AI can enhance their perceptions of its role in health education. However, the lack of benchmarks for AI readiness in dental education complicates curriculum development.	
Roganovic 2024¹⁷	Students familiar with the ChatGPT description scored higher on quizzes, showing that knowledge of its features shaped their expectations and introduced cognitive bias. This highlights the need for accurate AI descriptions in education to prevent overestimating AI capabilities.		The findings highlight the need for careful communication of AI capabilities to avoid overestimation of its effectiveness.	
Suárez et al. 2022²⁴			Need to adjust the complexity of virtual scenarios based on learners' knowledge levels.	

Figure 1. Study selection process

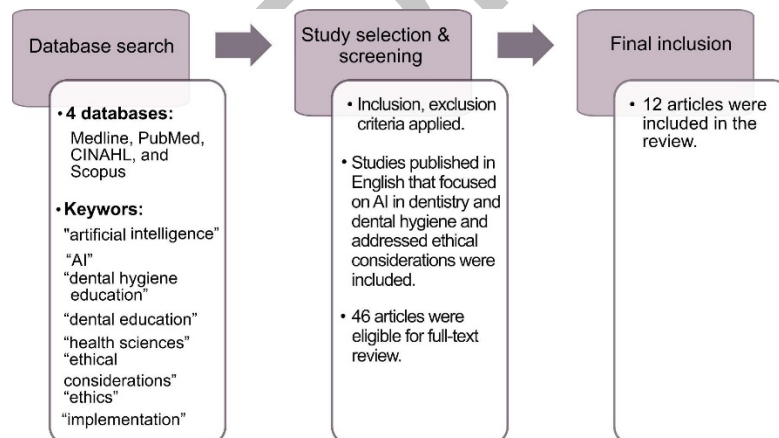


Figure 2. Visual representation of the overlapping themes between the core principles of the proposed ethical framework for the responsible implementation of AI technology into dental hygiene education.

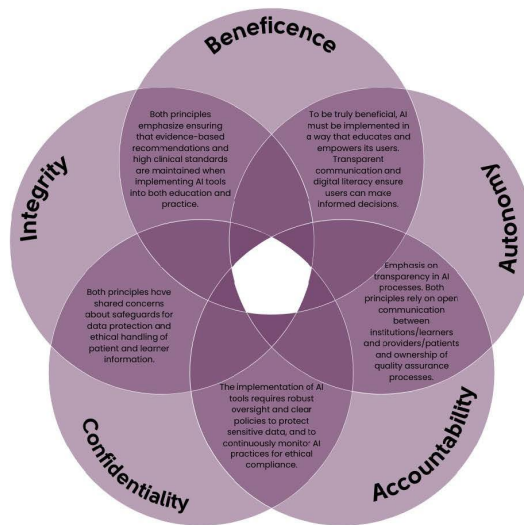


Figure 3. Future considerations for research

