Journal of International Education and Development
2025, VOL. 9, NO. 8, 97-100
DOI: 10.47297/wspiedWSP2516-250022.20250908

Innovative Teaching Methods in Oral Medicine in the Age of Artificial Intelligence

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ABSTRACT
The rapid development of artificial intelligence (AI) technology has provided strong support for dental medicine education. AI technology offers unique advantages in areas such as three-dimensional image analysis, virtual simulation training, and personalized learning path planning. However, its practical application also faces challenges such as the risk of students becoming overly reliant on AI tools, insufficient clinical accuracy of AI teaching tools, and difficulties in integrating traditional teaching models with AI technology. Therefore, this paper explores the systematic transformation of teaching methods in dental medicine driven by artificial intelligence, aiming to explore new models for cultivating dental medicine talent adapted to the intelligent era and to facilitate the smart transformation of medical education.

KEYWORDS
Artificial intelligence; Dental medicine education; Human-machine collaboration; Blended learning

1 Introduction

Dental medicine is a highly specialized and practical clinical discipline. With the development of precision medical technologies such as microscopic root canal treatment and digital implant restoration, traditional teaching methods are no longer sufficient to meet the needs of modern dental practitioners for comprehensive skills. The integration of artificial intelligence technology offers a breakthrough solution to this challenge. Machine learning algorithms can deconstruct implicit patterns within vast amounts of clinical data, enhancing learners' understanding of disease progression mechanisms. Virtual reality technology can create high-fidelity oral surgical environments, overcoming the spatial and temporal limitations of physical training. This not only improves teaching efficiency but also redefines the dimensions of clinical thinking development. Based on this, this article aims to systematically outline the integration pathways between artificial intelligence technology and the dental medical education system, exploring teaching strategies and methods that leverage algorithmic advantages while preserving the humanistic characteristics of medical education. This exploration not only facilitates the acceleration of medical students' transition into clinical practitioners, cultivating a new generation of dental healthcare professionals with data-driven thinking and technological innovation awareness, but also promotes the sustainable development of the dental medical talent cultivation system, better aligning it with societal development needs.

2 Characteristics of dental education in the era of artificial intelligence

2.1 Artificial intelligence-assisted disease diagnosis education

The application of artificial intelligence technology in dental medicine education is gradually deepening, not only improving teaching methods but also demonstrating its unique advantages in enhancing learning efficiency. Artificial intelligence can integrate massive amounts of clinical data to identify early signs of demineralization in cavities, bone resorption in periodontal disease, and other issues. This information is broken down into interactive dynamic diagrams, allowing students to observe the pathological progression layer by layer and understand the patterns of disease development [1]. When students input simulated case parameters, the AI system generates corresponding imaging findings and diagnostic recommendations in real time. During the process, the system highlights differences between students' judgments and standard diagnoses, emphasizing overlooked key indicators, thereby effectively reducing the time required for students to learn from mistakes. Additionally, case characteristics from different regions and stages are systematically categorized by the AI system, enabling students to encounter a disease spectrum far exceeding the scope of traditional teaching. This lays the foundation for cultivating a new generation of oral medicine professionals with data sensitivity.

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2.2 Virtual simulation technology enhances operational training

Traditional clinical skills training in dentistry primarily relies on physical models and animal experiments, which suffer from issues such as high operational wear and tear and limited scenarios. With the introduction of high-precision force feedback devices and 3D imaging technology, instructors can create realistic virtual oral environments for students to conduct operational training while wearing specialized equipment. During the process, details such as pressure control and instrument angle adjustments are quantified and recorded, forming a visual skill assessment map. Additionally, the virtual system can break down the operational process into hundreds of parameter metrics, including drill angle deviation rates, support point stability fluctuation curves, and soft tissue protection action integrity, with real-time data generation. After the procedure, students can review the operational video and use the system's annotated error points for self-correction. Through repeated practice, the formation period of muscle memory and conditioned reflexes is significantly shortened, laying a solid foundation for real clinical operations.

3 Practical challenges of integrating artificial intelligence into dental education

3.1 The risk of student dependence on ai tools

In the process of deeply integrating AI tools into dental education, AI systems provide students with overly simplified learning paths through instant feedback and standardized conclusions. When faced with actual cases, intelligent algorithms directly present diagnostic results and treatment recommendations, leading students to view AI outputs as the only correct answers gradually. The formation of this dependency is closely related to the design logic of AI systems. Most educational tools aim to lower the operational threshold by transforming complex medical decision-making into multiple-choice-style interactive interfaces. While this approach can quickly enhance beginners' operational proficiency, it leads to a decline in students' critical thinking abilities [2]. In real clinical scenarios, ambiguous symptoms and conflicting signs are common, requiring physicians to make risk assessments even when information is incomplete. AI teaching systems, in pursuit of certainty, often filter out noise from raw data through algorithms. Over time, students develop a cognitive inertia toward "clear boundaries," with their tolerance for probabilistic conclusions steadily decreasing. When faced with common intermediate-state cases in real clinical practice, students struggle to make accurate judgments. Additionally, some students equate the AI system's knowledge base with the dynamic advancements of medical science, neglecting the necessity of continuous learning, ultimately leading to a structural decline in clinical decision-making capabilities.

3.2 Insufficient clinical accuracy of ai teaching tools

In the diagnosis of oral diseases, doctors need to comprehensively consider the effects of physiological and pathological changes in the human body, environmental factors, and other aspects. However, intelligent algorithms diagnose and predict diseases by analyzing fixed, static image data and clinical data, ignoring the dynamic changes in living organisms. The standardized case databases used to train AI systems simplify individual patient immune responses, disease progression fluctuations, and environmental factors into fixed parameters. Dynamic features such as the evolutionary cycle of oral mucosal diseases and the alternating active and quiescent phases of periodontitis are difficult to capture within the algorithm's time-slicing analysis framework, leading to low diagnostic accuracy. Furthermore, the decision-making logic of most AI systems is based on correlation analysis. The frequent co-occurrence of specific calcification lesions and cavities in images is misjudged by algorithms as inevitable pathological indicators, ignoring the risk of false positives caused by individual anatomical variations. Once AI models are trained, they form a fixed framework. They are unable to actively integrate newly discovered pathogenesis mechanisms and diagnostic standards, resulting in clinical recommendations from the tool that are inherently flawed.

3.3 Challenges in integrating traditional teaching models with AI technology

In traditional dental education, instructors guide students through manual techniques using gestures and force perception to develop muscle memory; AI technology, however, breaks down clinical skills into visual operation trajectories and mechanical parameters, lacking the intuitive training process inherent in manual skill development. In traditional teaching, instructors and students collaborate to analyze, discuss, and practice procedures related to oral diseases. However, virtual simulation systems convert operational interfaces into digital projections, which cannot fully replicate all the details of a real clinical environment, thereby affecting students' perception and understanding of actual procedures. Additionally, traditional assessments of learning outcomes in dental programs emphasize holistic clinical decision-making, while AI breaks down diagnostic and treatment capabilities into hundreds of independent scoring

points. When optimizing parameters in the virtual system, students may overlook the importance of analyzing non-quantifiable factors such as the patient's overall condition and psychological state [3]. Overall, while the digital twin environment created by the virtual system can simulate visual scenarios, it cannot replicate the subtle tactile sensations patients experience during treatment. The coexistence of these two teaching scenarios exacerbates cognitive load for learners.

4 Optimized strategies for AI-driven teaching innovation

4.1 Designing "human-machine collaboration" clinical thinking training courses

The design of human-machine collaboration courses focuses on organically integrating the computational advantages of AI with the intuitive judgment of human physicians. Within this framework, AI systems perform information screening and pattern recognition functions, extracting key features from case data in real time while retaining clinical decision-making space for students to make independent judgments. While receiving algorithmic support, learners must still perform cognitive tasks such as hypothesis generation, evidence weight assessment, and treatment plan prioritization. Students must interpret probability data independently by integrating patient background information such as age and allergy history. Through prolonged training, they reinforce their cognitive abilities [4]. The temporal and spatial boundaries of real-world cases constrain traditional clinical education. To address this issue, AI systems can reconstruct the long-term diagnostic and treatment data stream of the same patient, allowing students to traverse key nodes in the progression of the disease over several years within a few hours and observe the delayed effects of specific treatment methods. Students can repeatedly adjust decision points and immediately observe virtual outcomes, gradually establishing multidimensional associations between treatment interventions and biological responses. Additionally, to prevent students from becoming overly reliant on AI technology, human-machine collaborative course instruction should include the following modules: in critical stages such as acute complication simulations, AI support is disabled, forcing students to make independent decisions using the hybrid thinking models formed through prior training, thereby enabling them to make correct judgments and decisions in complex medical scenarios.

4.2 Establish a clinical validation mechanism for AI teaching tools

The oral clinical validation process must cover all stages of the algorithm life cycle. Initial validation mainly verifies the medical rationality of knowledge representation. A multidisciplinary committee reviews whether the disease classification logic is consistent with the cognitive paradigm of oral medicine to ensure that the algorithm's criteria for judging caries staging are isomorphic with the pathological process defined in textbooks. Process validation requires the AI system to demonstrate the reasoning process behind diagnostic conclusions, with educators and experts assessing whether the inference chain aligns with evidence-based medicine principles. Validation results must be compared using the Delphi method to contrast AI recommendations with expert consensus, identifying potential risk points in rare disease diagnosis. As medical knowledge evolves and clinical practices change, the validation mechanism must also be updated. Adaptive modules can be embedded so that when new implant biomechanics research or microscopic root canal treatment guidelines are updated, the validation system automatically triggers a re-evaluation process for the algorithm model: misdiagnosis cases accumulated in teaching scenarios are used to adjust validation standards retroactively, and real clinical data generated in clinical practice continuously optimizes evaluation parameters. The validation process must closely monitor whether the algorithm contains data biases based on gender, race, or region to ensure the fairness of the teaching tool's outputs.

4.3 Promoting a hybrid teaching model combining traditional and AI methods

In the era of artificial intelligence, dental medicine education should adopt a hybrid teaching model that fully leverages the advantages of technology while retaining the wisdom of traditional teaching methods, thereby effectively enhancing students' theoretical knowledge and practical skills. During theoretical lectures, AI knowledge graph visualization tools can be introduced to convert linear text from textbooks into three-dimensional interactive models. Teachers can use augmented reality glasses to annotate students' operational paths, preserving the original tactile quality of hands-on instruction. During tooth preparation exercises, instructors can combine honest tactile feedback with AI visual guidance systems. When students perform procedures, tactile feedback simulates the resistance of actual drilling to help them master the appropriate force [5]; the AI system provides real-time arrow prompts on the screen to indicate whether the cutting angle is correct, allowing students to visually identify errors, feel the difference in tactile feedback, and quickly correct their movements. Instructors can identify common operational issues among students and develop targeted training plans. Traditional teacher evaluations focus on students' humanistic care competencies and clinical

adaptability, while AI systems can quantitatively analyze operational precision and decision-making efficiency. The intersection of these two types of data reveals teaching blind spots, providing a basis for optimizing dental medicine curricula. AI systems can also analyze the skill acquisition trajectories of past outstanding students to generate personalized learning path maps, enabling teachers to design targeted intervention strategies to enhance students' learning outcomes further.

5 Conclusion

In the era of artificial intelligence, the path to reforming dental medicine education includes the following: first, designing "human-machine collaboration" clinical thinking training courses that retain the advantages of physician intuition while leveraging the time-compression capabilities of algorithms to enhance understanding of disease progression; second, establishing a clinical validation mechanism for AI teaching tools to ensure that technological applications remain focused on the essence of education; third, promoting a blended teaching model combining traditional and AI-based approaches to create a complementary and reinforcing effect between the cultivation of tactile sensitivity and virtual reality training. In the future, as brain-computer interfaces and extended reality technologies continue to evolve, dental education professionals must uphold the core values of medical humanism in technological innovation, establish new teacher-student relationships supported by technology, and ultimately cultivate high-quality dental professionals.

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