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Development and Use of AI-Assisted Case-Based Learning in Dental and Medical Education.

Desarrollo y uso del aprendizaje basado en casos asistido por inteligencia artificial en la educación médica y odontológica.

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Abstract: Clinical reasoning and diagnostic competencies are widely recognized as essential components in dental and medical education yet remain difficult to achieve effective outcomes. Case-Based Learning (CBL) has been adopted as a structured pedagogical approach to address several challenges in engaging students in real clinical scenarios. In recent years, Artificial Intelligence (AI)-assisted tools, particularly those designed for clinical case development and information curation, have been introduced to support CBL without displacing traditional instructional methods. This narrative review synthesizes current literature to examine the role of AI-assisted approaches in enhancing undergraduates' learning experiences, in terms of engagement, motivation, knowledge integration, and improvement of diagnostic reasoning within CBL frameworks. The present review further highlights the practical consideration for dental and medical educators, and curriculum designers to focus on the integration of AI-assisted tools as a means of strengthening clinical education practices while maintaining educational integrity and learner-centered outcomes in higher education.

Keywords: Artificial intelligence, case-based learning, dental, medical, curriculum, education.

Resumen: El razonamiento clínico y las competencias diagnósticas se reconocen ampliamente como componentes esenciales en la educación médica y odontológica, aunque continúan siendo difíciles de desarrollar con resultados eficaces. El Aprendizaje Basado en Casos ha sido adoptado como un enfoque pedagógico estructurado para abordar diversos desafíos al involucrar a los estudiantes en escenarios clínicos reales. En los últimos años, se han introducido herramientas asistidas por inteligencia artificial, especialmente aquellas diseñadas para el desarrollo de casos clínicos y la curación de información, con el fin de apoyar el sin sustituir los métodos de enseñanza tradicionales. Esta revisión narrativa sintetiza la literatura actual para examinar el papel de los enfoques asistidos por AI en la mejora de la experiencia de aprendizaje de los estudiantes de pregrado, en términos de participación, motivación, integración del conocimiento y fortalecimiento del razonamiento diagnóstico dentro del marco del. La presente revisión también destaca consideraciones prácticas para los educadores médicos y odontológicos, así como para los diseñadores curriculares, en cuanto a la integración de herramientas asistidas por como un medio para reforzar las prácticas educativas clínicas, preservando la integridad educativa y los resultados centrados en el estudiante en la educación superior.

Palabras clave: Iinteligencia artificial, aprendizaje basado en casos, odontología, medicina, plan de estudios, educación

1. Introduction

Competency in the dental and medical professions relies heavily on excellent practice of problem-solving and critical thinking skills, which are essential for clinical decision-making. Case-Based Learning (CBL) is a student-centered, active learning method in which learners analyze real clinical case studies, often in small groups, to apply their knowledge, develop solutions, and deepen their understanding under the guidance of the instructor. The activity promotes critical thinking, problem-solving, guided learning, interactive discussions, and teamwork analysis through structured inquiry centered around specific situations and medical problems. In dental and medical education, CBL is known to be an effective pedagogical approach that fosters analytical reasoning among students, empowering them with actual medical scenarios.

The traditional CBL is facilitated by human instructors who guide students through patient cases to encourage discussion and deduction of possible examinations to come out with the final diagnoses. However, with the advancements in AI technologies such as machine learning (ML) and NLP, it allows more opportunities to transform the CBL learning experience with AI technologies, by offering personalized feedback, automated assessments, and adaptive difficulty levels (1). As of now, the integration of AI-assisted CBL continues to evolve, adapting to the needs of dental and medical education.

One of the most significant transformations has been the implementation of AI-driven decision support systems that assist students in diagnosing complex cases by analyzing symptoms, medical history, and diagnostic images (2). The advanced systems are particularly beneficial in environments where direct faculty supervision may not be readily available, ensuring students still receive structured guidance. AI-based simulation has now emerged as an essential tool in CBL, allowing students to engage in lifelike clinical scenarios without the immediate pressure of real-world patient interactions. AI-powered models can also analyze student inputs, identify areas where they encounter difficulties, and provide targeted interventions to enhance comprehension (1, 3).

Studies indicate that the use of AI-driven simulations in medical education enhances both diagnostic accuracy and procedural confidence among students (4). Similarly, in dental education, AI-driven radiographic interpretation software has proven effective in training students to identify caries, fractures, and periodontal diseases with greater precision compared to traditional teaching methods (2). The application of adaptive learning algorithms in CBL also holds significant promise. These AI-powered platforms analyze student performance and adjust case difficulty accordingly, ensuring that each learner receives a personalized educational experience. Students exposed to AI-assisted adaptive CBL demonstrated a higher rate of knowledge retention and improved critical thinking skills than those taught using conventional methods (1). Additionally, AI can also facilitate collaborative learning by enabling virtual group discussions where students interact with intelligent tutors that provide real-time feedback (3).

Looking toward future developments, AI-assisted CBL is poised to incorporate immersive learning technologies such as Virtual Reality (VR) and Augmented Reality (AR) (3). These tools will enable students to engage with virtual patients in realistic clinical scenarios, enhancing their ability to apply theoretical knowledge to practice. Furthermore, AI-powered chatbots and virtual assistants will improve personalized learning by offering instant responses to student inquiries, delivering supplemental materials, and guiding learners through diagnostic processes (5). As AI continues to advance, its role in CBL will likely expand, improving accessibility and standardizing training for dental and medical students worldwide.

However, integration of AI into Case-Based Learning (CBL) must address the long-standing challenges in dental and medical education, such as a lack of training in digital skills among faculty staff, shortages of faculty members, the requirement for standardized patient case studies, and the lack of ability to assess student performance in real time (6). A better understanding of the fundamental requirement of clinical teaching and the limitations of AI assistance may allow for full efficiency of the module being developed for implementation. The present study explores the development and evolution of AI-driven CBL, comparing its implementation in dental and medical education while evaluating its benefits and potential drawbacks to prepare academia on the reality of using AI for clinical teaching and assessment. To ensure comprehensive analysis, peer-reviewed journals, conference proceedings, and validated case studies are gathered, focusing on best practices, existing challenges, and emerging trends in AI-driven CBL

The present review criticizes findings from both qualitative and quantitative data reported in previous established studies. Qualitative data is obtained through expert interviews and thematic content analysis of prior studies, providing insights into the pedagogical impact and reception of AI-assisted CBL among educators and students. In contrast, quantitative data is sourced from statistical assessments of AI-driven CBL platforms, evaluating performance metrics such as student engagement, knowledge retention, and diagnostic accuracy. These parameters enable a direct comparison between AI-assisted and traditional CBL models, highlighting their respective strengths and limitations. The employment of dual approach in the present study ensures a well-rounded evaluation of AI integration in dental and medical curriculum, especially on the effectiveness of the module.

2. Methods

A comprehensive, non-systematic search was conducted across several electronic databases, including PubMed, Google Scholar, and SCOPUS. The search strategy employed a combination of keywords and free text words, including, but not limited to: (“artificial intelligence” AND “case-based learning”) AND (“dental curriculum” OR “medical curriculum”) AND (“dental education” OR “medical education”). The search was restricted to publications from the year 2020 onwards with specific inclusion and exclusion criteria.

2.1. Article selection and eligibility criteria

Articles were selected based on their relevance to the research topic and their contribution to understanding the integration of AI in CBL for dental and medical education. The following general criteria guided the selection process; as the inclusion criteria encompassed (1) articles published in English, (2) articles published between 2020 and 2025 to ensure current application of the technological data, and (3) research specifically addressing AI applications in dental and medical education. Articles were excluded if found lacked full-text availability or did not pertain to the specific intersection of AI and case-based pedagogical models. A minimum of two authors independently reviewed titles and abstracts to determine initial eligibility. The full texts of potentially relevant articles were then retrieved and assessed for final inclusion in the review. A flow diagram, similar to the PRISMA format, was used to document the number of studies identified, screened, and included at each stage to ensure transparency in reporting.

2.2. Data extraction and synthesis

Information from the selected articles was extracted and organized by key themes, as this allowed for a structured and logical presentation of the diverse findings. The primary information extracted included the study's main findings, research methods used (e.g., qualitative, quantitative, mixed methods), key variables (e.g., module structure, discipline, tools used, context, evaluation method), and identified strengths or limitations. A qualitative, narrative approach was used to analyze and synthesize the information. Findings from the included articles were compared and contrasted to identify patterns, agreements, contradictions, and emerging trends in the literature. The synthesis was performed beyond simply summarizing individual studies; it involved critiquing the sources and interpreting the collective significance of findings to address the research objective.

3. Results

3.1 Overview of the Study

From the initial 530 studies identified, only 17 studies are included in the final analysis following the refinement and screening criteria. Studies included in this narrative review comply to ethical guidelines by maintaining student data privacy and ensuring unbiased AI-driven assessments. As summarized in table 1, the selected studies showcase variation in AI-driven module designs. The following narrative reflects on common challenges and educational implications found across these implementations. One of the primary limitations of AI-assisted CBL is the dependency on high-quality datasets for training AI models. Data bias and algorithmic inconsistencies can impact learning outcomes, necessitating continuous monitoring and refinement of AI applications.

A total of 8 module structures has been identified, developed using AI in medical and dental education within the last five years. The AI applications are used primarily in generating automatic feedback as diagnostic tools, and personalization tools. From that amount, only one-third of the AI-assisted learning modules used focus on clinical components (8, 9, 13). Additionally, one of the studies highlights the need for a hybrid of AI-human teaching methodologies to optimize learning outcomes while preserving the essential role of human educators in dental and medical training (13). It is inevitably important that future research should focus on improving AI model transparency, integrating AI-driven tutoring systems, and addressing faculty resistance to AI-based education tools to allow for more usage of AI in healthcare course delivery.

3.2 AI models and technologies used in CBL

The implementation of AI-assisted CBL in medical and dental education relies on several key technologies, including natural language processing (NLP), deep learning models, and adaptive learning systems. AI-based CBL platforms utilize machine learning algorithms to assess student responses, providing real-time feedback and personalized learning paths. A detailed comparison of AI models used in medical and dental CBL is presented in table 2. Basically, the evolution in pedagogical approach evolves with the CBL serves as the starting point, giving students a grounded way to work through real clinical scenarios. From there, AI-driven diagnostic reasoning is introduced to help learners stretch their clinical thinking and explore a wider range of possibilities. The assessments that follow are made more responsive and engaging through adaptive testing and automatically generated items, integrating immersive VR and simulation activities allowing more realistic, supportive learning environment.

Table 1. Summary of studies employing diverse AI-assisted Case-Based Learning (CBL) module designs and implementation approaches in medical and dental education (2020–present).

Module Structure	Discipline	Tools Used	Context	Evaluation Method	Reference
AR-enabled diagnostic CBL	Dental	AI and AR combination	Dental radiography training	Usability analysis and competency evaluation	(7)
Group-based CBL with analytics dashboard	Dental	AI-enhanced LMS	Clinical diagnostics (dental)	Feedback analytics and outcome-based metrics	(8)
Virtual case-based simulations	Medical	AI diagnostic tools	Diagnostic reasoning	Survey and thematic analysis	(9)
Assessment item generation	Medical	ChatGPT	Exam preparation	Item validity and Bloom's taxonomy alignment	(10)
Adaptive difficulty, personalized learning paths	Medical	AI personalization tools	Basic sciences education	Performance tracking and test improvement	(11)
Real-time Q&A in CBL sessions	Medical	AI chatbot tutor	Interactive small group tutorials	Pre-post tests and engagement metrics	(12)
Immersive simulation with instant feedback	Medical	VR + AI tutor	Clinical training simulation	Skill acquisition scores	(13)
Feedback loop integrated in CBL	Medical	AI for automated feedback	Foundational science modules	Cognitive gain and retention scores	(14)

Table 2. Comparison of AI models used in medical and dental CBL.

AI Model	Application in Dental and Medical Education	Module Structure & Tools Used	Evaluation Method
ChatGPT (NLP)	• Generates clinical scenarios for problem-based learning; supports student-driven inquiry (16, 17, 18) • Prompts case discussions; used in tutor-reviewed AI case writing (19, 20)	Chat-based scenario prompts, refined with tutor input	Qualitative feedback survey; item validity checks
AI-generated quizzes	• Auto-generates MCQs aligned with case content for self-study assessments (21, 22)	Real-time quiz creation integrated into CBL platform	Quiz accuracy analysis; time-efficiency metrics
AI diagnostic tools	• Virtual clinical simulations with automated diagnostic feedback (9, 23, 24)	Simulation engines with diagnostic models	Thematic survey; performance tracking
AI-powered adaptive systems	• Adjust case complexity per learner using performance metrics (8, 11, 25) • Adaptive case progression in blended format	Personalized learning pathways	Test score improvements; retention analysis
AI-enhanced LMS	• Supports AI-driven personalized learning pathways for performance (8, 26, 27)	Platform with real-time insights for facilitators	Review of competency and engagement outcomes
AI chatbot tutor	• Provides on-the-fly Q&A during CBL sessions for small groups (24, 28, 29, 30, 31)	Embedded chatbot in case discussions	Pre/post knowledge assessment; engagement logs
VR + AI tutor	• Immersive tutor-guided VR clinical simulations (13)	VR environment with AI feedback overlays	Skill acquisition scores; simulation analytics
AI automated feedback	• Integrated audio/text feedback loops in foundational science cases (12, 29, 32)	Continuous feedback embedded in CBL (LMS/ plugin)	Cognitive gain and retention testing
VR simulation tools	• VR-based diagnostic CBL (7, 19)	AR viewer with guided imaging annotations	Usability study; diagnostic competency testing

Compared to the traditional learning approaches, AI-powered platforms offer adaptive learning experiences by the ability to adjust the complexity of cases in response to individual student performance. The AI-powered systems facilitate real-time progress tracking and personalized feedback, ensuring a more tailored and effective learning process while In addition, the ability of AI-driven CBL to refine analytical reasoning and enhance decision-making skills is well supported by empirical data, showing that students exposed to AI-assisted learning exhibit a deeper understanding of clinical concepts and improved problem-solving abilities (1, 6). Overall, findings from established studies also highlight the transformative potential of AI-driven methodologies in dental and medical training, reinforcing AI-assisted CBL as a valuable supplement to traditional pedagogical approaches.

3.3 The positive impact of AI-assisted CBL on learning activities

The present section highlights the transformative impact of AI-assisted CBL in dental and medical education. The impact of AI-assisted CBL on student performance is illustrated in Table 3, which compares key learning outcomes between AI-driven and traditional CBL approaches based on qualitative and quantitative performance metrics. The data synthesizes findings from multiple studies that evaluated student engagement, diagnostic accuracy, and learning efficiency across different AI-assisted learning environments. The integration of AI into CBL sessions demonstrated significant improvements in multiple aspects of medical and dental education. For instance, a study indicates that AI-assisted CBL enhances student engagement, increases diagnostic accuracy, and promotes knowledge acquisition and skill performance (15).

The gathered evidence from previous studies postulates that AI-driven CBL platforms significantly enhance knowledge retention as compared to traditional approaches. The ability of AI to provide real-time feedback, personalize learning paths, and simulate complex clinical scenarios demonstrates its value in bridging the gap between theoretical knowledge and practical application. Therefore, previous studies suggested that AI-driven tools improve students' confidence in clinical decision-making, making them better prepared for real-world dental and medical practice (15, 35). The students using AI-assisted CBL platforms also exhibit higher engagement levels and improved clinical-based competency as compared to those relying on traditional methods. Such improvement can be attributed to the adaptive nature of AI, which personalizes learning pathways and provides instant corrective feedback. Additionally, knowledge retention scores were also found to be higher in collaborative AI-assisted environments due to the interactive nature of the learning process (36).

Another crucial aspect of AI-assisted CBL implementation in dental and medical education is its ability to bridge the gap between theoretical knowledge and clinical application. AI-powered simulations enable students to interact with virtual patients, analyze case histories, and formulate diagnostic hypotheses in a risk-free environment (24, 35). Research conducted by Moro et al. (3) also suggests that AI-driven simulations improve students' confidence in decision-making and enhance their ability to apply theoretical knowledge to clinical scenarios. In dental education, AI-based radiographic analysis tools demonstrated substantial efficacy in training students to identify abnormalities with higher precision, thereby improving clinical competency (2).

Further comparison made on AI implementation in dental and medical CBL shows distinct advantages tailored to each discipline. In medical education, AI-driven simulations and virtual patient interactions allow students to practice clinical decision-making in a controlled environment (36), with significant improvement observed on patient history-taking process, diagnostic scores and application of knowledge in case analysis. Therefore, AI-assisted systems not only improve diagnostic accuracy but also provide guided feedback to improve knowledge retention and engagement in lessons. In addition, AI-assisted CBL also promotes collaborative discussion among students, as well as interaction with the virtual chatbot. On the other hand, in dental education, AI models such as convolutional neural networks (CNNs) are employed to aid in caries detection, radiographic interpretation, and prosthodontic planning (2). Such applications ensure that students gain exposure to a wide range of diagnostic challenges, surpassing the limitations of traditional textbook-based learning which forms the baseline in dental education.

Table 3. Impact of AI-assisted CBL on student performance

Type of Learning Approach	Impact on Student Engagement	Impact on Diagnostic/ Clinical Skills	Impact on Knowledge Retention	Reference (s)
AI Instructional Tools	High acceptance and motivation for digital curriculum updates	Facilitates integration of complex clinical topics	Supports continuous curriculum updates and review	(23)
AI-Assisted CBL	Active interaction with Virtual Patient Chatbot	Significantly improved diagnostic scores vs. traditional methods	Enhanced clinical reasoning skills	(32)
AI-Assisted CBL	Increased engagement through collaborative discussion	Improved application of knowledge in case analysis	Higher knowledge acquisition scores in collaborative groups	(33)
AI-Assisted CBL	Positive feedback on chatbot usability	Improved patient history taking completeness	Pilot data supports efficacy in pre-clinical training	(24)
Traditional CBL	Standard engagement (Baseline)	Gaps identified in current AI integration	Highlights challenges in traditional adoption	(34)
Traditional CBL	Effective for foundational understanding	Standard competency development	Established baseline for dental education	(2, 35)

4. Discussion

4.1 Challenges and Limitations

Despite the significant advantages of AI-assisted CBL, the selected studies also highligted several barriers which hinder its widespread adoption in dental and medical education. A primary concern is the risk of algorithmic bias and data quality. AI models rely on historical datasets for training; if these datasets are incomplete, unrepresentative, or biased, the predictive accuracy of the system may be compromised, leading to skewed learning outcomes and unreliable evaluations (11, 14). Ensuring that training datasets are comprehensive and diverse is essential for preventing these disparities and maintaining the integrity of student assessments.

Another significant challenge mentioned is faculty resistance and the preservation of the human element in teaching. Integrating AI-driven tools requires a paradigm shift in pedagogical approaches, which some educators may view as a disruption to established curriculum delivery (11). Furthermore, AI lacks human intuition, empathy, and ethical reasoning necessary for patient-centered care, limiting its ability to fully replace human instructors in complex clinical scenarios (1). Therefore, a hybrid approach is recommended, where AI only serves to supports rather than replaces human judgment in teaching and evaluation (1, 11).

Finally, ethical and regulatory considerations regarding student data privacy and the dependability of automated systems must also be prioritized. The presence of "black box" nature in AI algorythm especially in AI/deep learning, resulted in unexplainable, complex decision-making process, raising concerns about transparency and accountability of the assessment (14). To ensure student trust and regulatory compliance, educational institutions must establish clear guidelines for data governance and continuously monitor AI performance to ensure that it enhances, rather than hinders, the learning process in dental and medical program (11, 14).

4.2 The future of AI in dental and medical curriculum

Overall, the findings suggest that AI-assisted CBL is a transformative tool in dental and medical education, significantly enhancing learning experiences, engagement, and diagnostic proficiency. While challenges exist, continued advancements in AI technology and improvements in data diversity and transparency will likely resolve many existing concerns, paving the way for widespread adoption of AI-driven educational methodologies (5). Future research should focus on improving the interpretability and transparency of AI algorithms to mitigate issues related to the "black box" nature of some AI systems (1). Meanwhile, a hybrid AI-human teaching model, where AI complements human instruction rather than replacing it, may offer a balanced approach that integrates the best of both methodologies.

Collective evidence gathered from the analysis of selected studies further recommend several strategies to optimize the implementation of AI-assisted CBL. First, educational institutions should invest in the development of diverse and representative training datasets to minimize biases in AI-driven assessments (14). Second, faculty training programs should be established to familiarize educators with AI tools and methodologies, promoting acceptance and effective integration into curricula (11). Third, a hybrid teaching model that combines AI-driven instruction with human mentorship should be explored to maximize the benefits of both AI and traditional teaching approaches (1). Finally, future research should also focus on expanding AI-assisted CBL beyond diagnostic training to include interdisciplinary applications, surgical simulations, and patient-centered care models (4, 13). By addressing these recommendations, AI-assisted CBL can be further refined and leveraged as a powerful tool for advancing dental and medical education in the years to come.

5. Conclusions

- The comparative analysis of AI-assisted Case-Based Learning (CBL) for dental and medical undergraduates provides valuable evidence for educators to explore, adapt, and integrate current technological advancements into their teaching practices.
- The integration of AI into CBL sessions offers significant potential to enhance student engagement and facilitate a deeper understanding of clinically relevant topics through interactive and personalized learning experiences.
- Development effective learning modules in higher education, the design of clinically relevant AI-driven teaching tools must align with current technological capabilities while actively addressing limitations such as algorithmic bias and the need for human oversight.

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