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Artificial Intelligence in Restorative Dentistry Education: Implications for Community Oral Health and Equity

Toleen Mazloum[1*], Tia Mazloum[2], Jeremiah Daniel Ghodsi[3], Abdo Abuharbeed[4], Betti Shahin[5]

[1*] Dental Student, College of Dentistry, University of Illinois Chicago, USA. Email: dr.toleen.mazloum@gmail.com

[2] No current affiliation

[3] Student of Loyola University Chicago, USA.

[4] Dental Student, College of Dentistry, University of Illinois Chicago, USA.

[5] Clinical Associate Professor, Restorative Department, College of Dentistry, University of Illinois Chicago, USA. Email: bshahi4@uic.edu

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***Corresponding Author:** Dr. Toleen Mazloum, College of Dentistry, University of Illinois Chicago, IL, USA.

Abstract

Oral diseases remain among the most prevalent chronic conditions worldwide, disproportionately affecting underserved and socioeconomically disadvantaged populations. Dental education plays a critical role in preparing future practitioners to address restorative treatment needs within community-based clinical settings. Recently, artificial intelligence (AI) has emerged as a transformative tool in dentistry, offering novel opportunities to enhance diagnostic accuracy, treatment planning, and educational delivery. This literature review explores the potential community impact of integrating AI-supported diagnostic and decision-support technologies into restorative dentistry education. Evidence suggests that AI applications in radiographic interpretation, caries detection, and risk assessment can improve students' clinical competence and support early identification of restorative needs in outreach environments. Furthermore, AI-enabled teledentistry and digital diagnostic systems may strengthen community oral health programs by facilitating remote screening, triage, and continuity of care. From an educational leadership perspective, the responsible incorporation of AI into dental curricula requires careful attention to

ethical considerations, data governance, faculty development, and preservation of professional clinical judgment. While technological integration presents challenges related to infrastructure, cost, and algorithmic bias, strategic implementation may contribute to reducing oral health disparities and expanding access to restorative care. Ultimately, AI-enhanced restorative dentistry education represents a promising pathway toward developing socially accountable practitioners capable of delivering equitable, prevention-oriented oral health services in diverse community settings.

Keywords: Artificial Intelligence (AI), community oral health, dental education, restorative dentistry, teledentistry.

Introduction

Oral diseases remain among the most prevalent non-communicable conditions globally, with untreated dental caries continuing to impose substantial functional, psychosocial, and economic burdens on affected populations. [1,2] Despite significant advancements in restorative materials, preventive strategies, and digital technologies, marked disparities in access to oral healthcare persist across socioeconomically disadvantaged populations, rural communities, migrants, and individuals with limited health literacy. [3] These inequities highlight the growing responsibility of dental education systems to prepare graduates capable of addressing restorative treatment needs within complex community contexts.

Community-based clinical training has therefore emerged as a cornerstone of contemporary dental curricula, emphasizing experiential learning, social accountability, and population-oriented care delivery. [4] However, variability in students' diagnostic competence, confidence in treatment planning, and exposure to advanced disease presentations can influence the quality and consistency of care delivered during outreach placements. [5] In response, artificial intelligence (AI) technologies are increasingly being explored as adjunctive tools capable of enhancing clinical reasoning, reducing diagnostic variability, and supporting evidence-based decision-making in restorative dentistry education. [6]

The integration of AI into restorative dentistry training also reflects broader digital transformation trends in healthcare systems. Machine learning-based diagnostic systems, predictive analytics platforms, and teledentistry technologies offer new opportunities to improve early identification of restorative needs and facilitate access to care in underserved populations. [7] Nevertheless, the educational implications of AI adoption extend beyond technological capability, encompassing ethical governance, curricular reform, and leadership strategies aimed at ensuring that digital innovation contributes to reducing oral health disparities. This review critically synthesizes current evidence regarding the role of AI in restorative dentistry education, with particular emphasis on its potential community impact and implications for socially responsible workforce development

Artificial intelligence applications in restorative dentistry

Artificial intelligence has rapidly emerged as a transformative innovation in restorative dentistry, particularly in diagnostic imaging and treatment planning domains. Deep learning algorithms trained on large radiographic datasets have demonstrated high sensitivity and specificity in detecting early carious lesions, restoration defects, and periapical pathology. [5] Such diagnostic support tools have the potential to standardize lesion detection and reduce inter-examiner variability among dental students, thereby improving clinical decision-making during both simulated and real patient encounters. [6]

Beyond diagnostic enhancement, AI-driven predictive models are increasingly being utilized to guide restorative treatment planning. By integrating patient-specific risk

indicators, material performance data, and clinical outcome predictors, these systems can support minimally invasive treatment strategies aligned with contemporary preventive philosophies. [8] Importantly, AI integration within digital restorative workflows, including intraoral scanning analytics and CAD/CAM fabrication processes, may further improve prosthetic accuracy and procedural efficiency. [9] However, while these technologies offer substantial educational and clinical benefits, their effectiveness depends on appropriate interpretation and contextualization by clinicians.

Concerns regarding algorithm transparency, dataset representativeness, and potential treatment bias highlight the importance of positioning AI as an adjunct rather than a replacement for professional expertise. [10] Consequently, dental education programs must emphasize critical appraisal skills that enable students to evaluate AI-generated recommendations within patient-centered frameworks.

Impact of artificial intelligence on dental education

The integration of artificial intelligence into dental education has been associated with significant pedagogical shifts toward competency-based and data-driven learning models. AI-supported diagnostic platforms provide real-time feedback on radiographic interpretation and treatment planning decisions, allowing students to engage in iterative learning processes that enhance clinical reasoning. [11] Compared with traditional apprenticeship models, these technologies may accelerate skill acquisition and improve confidence in managing complex restorative cases.

Simulation-based learning environments enhanced by AI analytics have further contributed to innovations in restorative training. Virtual reality and haptic simulation systems equipped with performance tracking capabilities enable objective assessment of operative skills, including preparation design accuracy and handpiece control. [12] Such tools support reflective learning by allowing students to monitor their progress through digital dashboards and adaptive feedback mechanisms. [13] Nonetheless, the educational benefits of AI integration are contingent upon faculty readiness and institutional support for curricular reform. [14]

Critically, while AI technologies may enhance technical competence, their influence on the development of independent clinical judgment remains a subject of debate. Overreliance on automated decision-support systems may risk diminishing diagnostic autonomy if not balanced with reflective pedagogical approaches that encourage critical thinking and ethical reasoning. [15]

Artificial intelligence in community-based restorative care training

Community-oriented clinical education represents a key context in which the potential societal impact of AI-enhanced restorative training can be realized. Outreach settings often involve high disease burden, limited specialist supervision, and constrained resources, creating opportunities for AI-supported diagnostic tools to assist students in identifying untreated caries and restoration failure more effectively. [16] By facilitating early detection and risk stratification, these technologies may contribute to improved treatment prioritization and more efficient allocation of public health resources.

Furthermore, AI-enabled predictive analytics can support population-level oral health planning by identifying high-risk groups and guiding preventive restorative strategies. Such data-driven approaches align with minimal intervention dentistry principles, emphasizing disease management and preservation of tooth structure. [17] However, the implementation of AI technologies in underserved populations must be approached cautiously to avoid exacerbating disparities associated with digital infrastructure limitations and algorithmic bias. [18]

Experiential learning opportunities involving AI-supported outreach initiatives may also foster students' awareness of social determinants of oral health and encourage the adoption of culturally sensitive care practices. As a result, integrating AI into community-based restorative training has the potential to enhance both clinical competence and professional commitment to health equity.

Teledentistry, AI- enabled outreach, and access to restorative care

The convergence of artificial intelligence and teledentistry represents one of the most significant developments in expanding access to restorative dental care, particularly in underserved and geographically isolated communities. AI-supported remote diagnostic systems capable of analyzing intraoral photographs and radiographic data have demonstrated potential to improve early detection of untreated caries and restoration failure, thereby facilitating timely referral and intervention. [16, 19] These technologies may enable dental students participating in outreach programs to contribute meaningfully to large-scale screening initiatives while gaining experience in digital care delivery models.

From a public health perspective, AI-enabled teledentistry can enhance continuity of care by supporting follow-up consultations, treatment monitoring, and preventive counseling through virtual platforms. [20] Such approaches are particularly relevant in communities where transportation barriers, workforce shortages, and socioeconomic constraints limit access to conventional clinical services. [21] Importantly, digital triage systems powered by predictive analytics may allow more efficient prioritization of patients with urgent restorative needs, improving resource allocation within community oral health programs.

However, the effectiveness of AI-supported outreach models is influenced by infrastructural readiness, patient digital literacy, and regulatory frameworks governing telehealth reimbursement and data security. Without equitable distribution of technological resources, there is a risk that digital innovations could inadvertently widen existing disparities in oral healthcare access. [22] Therefore, integrating AI-enabled teledentistry into restorative dentistry education requires careful alignment with community engagement strategies and policy development initiatives.

Ethical governance and educational leadership in AI integration

The responsible incorporation of artificial intelligence into restorative dentistry education necessitates robust ethical governance and proactive educational leadership. While AI diagnostic systems offer opportunities to enhance clinical decision-making, concerns regarding algorithmic bias, data privacy, and transparency remain central to debates surrounding digital healthcare innovation. [10] Training datasets that inadequately represent diverse populations may lead to variations in diagnostic accuracy across demographic groups, potentially reinforcing oral health disparities rather than mitigating them.

Dental schools therefore play a critical role in preparing future practitioners to use AI technologies responsibly. Curriculum reform efforts should emphasize digital literacy, critical appraisal of algorithm outputs, and ethical considerations related to patient consent and data management. [14] Faculty development programs are equally essential to ensure that educators can guide students in integrating AI tools within patient-centered treatment planning frameworks.

Educational leadership must also engage with accreditation bodies and regulatory organizations to establish standards for AI implementation in clinical

training environments. Interdisciplinary collaboration with experts in public health, health informatics, and policy development can support the design of educational models that align technological advancement with societal oral health priorities. Ultimately, institutional commitment to social accountability will determine whether AI integration contributes to equitable improvements in restorative care delivery.

Challenges and limitations of AI-enhanced restorative education

Despite growing enthusiasm for artificial intelligence applications in dental education, several challenges may limit their widespread adoption and effectiveness. Technological infrastructure requirements including hardware costs, software maintenance, and cybersecurity measures pose significant barriers for institutions operating in resource-constrained environments. Moreover, variability in faculty acceptance and resistance to curricular change may slow the integration of digital innovations into established educational frameworks. [23]

Another critical limitation relates to the current evidence base supporting AI-assisted educational interventions. Many studies focus primarily on short-term outcomes such as diagnostic accuracy or procedural performance, with limited investigation into long-term impacts on community oral health indicator. [11] Furthermore, the heterogeneity of study designs and evaluation metrics complicates efforts to compare findings across different educational contexts.

Ethical and legal uncertainties surrounding AI deployment in clinical training also warrant consideration. Variability in data governance policies and regulatory standards across jurisdictions may influence the scalability and sustainability of AI-enabled educational programs.

Addressing these limitations requires longitudinal research, multi-center collaborations, and policy frameworks that balance innovation with patient safety and equity considerations.

Future directions for research and educational innovations

Future research should prioritize longitudinal evaluation of AI-supported restorative dentistry education to determine its effectiveness in improving population-level oral health outcomes. Studies examining reductions in untreated caries prevalence, restoration failure rates, and treatment delays in underserved communities would provide valuable evidence regarding the societal impact of digital training models. Additionally, integrating AI analytics with electronic health record systems and public health surveillance platforms may enable more comprehensive risk assessment and targeted preventive interventions. [24]

Innovations in immersive simulation technologies and virtual mentorship platforms also hold potential to transform clinical training by enabling remote supervision and collaborative learning across geographic boundaries. Such developments may facilitate global partnerships aimed at addressing disparities in dental education resources and oral healthcare access. Importantly, interdisciplinary collaboration involving data scientists, public health professionals, and health economists will be essential to ensure that AI adoption is both evidence-based and economically sustainable.

Conclusion

Artificial intelligence has the potential to significantly reshape restorative dentistry education by enhancing diagnostic competence, supporting competency-based training, and enabling innovative community outreach strategies. When integrated responsibly, AI-supported learning tools may improve early identification of

restorative needs and expand access to care among underserved populations. However, realizing these benefits requires thoughtful educational leadership, ethical governance, and sustained investment in research evaluating long-term community health outcomes.

Ultimately, the successful incorporation of AI into dental curricula should be guided by a commitment to social accountability and health equity. By aligning technological innovation with preventive care principles and population health priorities, dental education institutions can contribute to the development of practitioners capable of delivering high-quality restorative services in diverse community settings. Continued collaboration among educators, policymakers, and technology developers will be essential to ensure that advances in artificial intelligence translate into meaningful improvements in global oral health.

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