Commentary

Are Digital Dental Systems Designed With Frail Older Adults in Mind?

Introduction

A globally ageing population, rising demand for oral health care, and persistent workforce shortages are placing unprecedented pressure on dental systems worldwide. Concurrently, advances in data-driven health care are reshaping care delivery. In response, dentistry has undergone a rapid digital transformation. Technologies such as digital imaging, computer-aided design and manufacturing (CAD-CAM), artificial intelligence (AI), and virtual care platforms are becoming deeply integrated into both clinical practice and dental education. While these innovations are fundamentally changing how oral health services are delivered, planned, and managed,[1] their specific application to vulnerable demographics, particularly frail older adults, remains a critical challenge.

This growing demographic shift presents profound challenges for oral health care systems worldwide. Older adults frequently present with multimorbidity, polypharmacy, frailty, cognitive impairment, reduced mobility, sensory deficits, and an increasing dependency on caregivers,[2] factors that heavily complicate both the provision and accessibility of care. Furthermore, the rising prevalence of retained dentition, implant-supported rehabilitations, and complex restorative histories has amplified the technical and interdisciplinary demands of geriatric dentistry. Consequently, conventional models of care are increasingly inadequate for addressing the needs of contemporary ageing populations. While digital technologies offer promising solutions, such as streamlining workflows, facilitating domiciliary care, and enabling highly individualised treatment planning for medically compromised patients,[3] a critical gap exists. Despite the rapid adoption of these technologies, it remains unclear whether modern digital workflows are truly designed with frail older adults in mind or if they are genuinely accessible and beneficial for patients with such complex functional needs.

Simultaneously, dental education has undergone a substantial pedagogical transformation.[4] While traditional teaching models, predominantly centred on lectures and phantom-head clinical simulations, remain foundational, they are increasingly supplemented by immersive simulation technologies, digital learning environments, and remote educational platforms. Consequently, contemporary dental graduates are expected to demonstrate competency not only in manual clinical procedures but also in digital literacy, data interpretation, and technology-assisted clinical decision-making. Crucially, these newly required digital competencies are uniquely positioned to address the profound complexities of geriatric oral health care. Innovations such as virtual 3-dimensional treatment planning, AI-driven risk assessment, and teledentistry allow practitioners to minimise stressful chairside time, safely navigate the intricacies of multimorbidity and polypharmacy, and facilitate domiciliary care for frail older adults. Furthermore, digital educational environments allow institutions to safely simulate high-risk, medically compromised scenarios, directly bridging the gap between technological proficiency and specialised geriatric care.

Despite the growing integration of digital technologies into dentistry, significant challenges remain regarding accessibility, operational costs, ethical considerations, and educational standardisation. Moreover, the rapid pace of technological advancement frequently outpaces the generation of robust clinical evidence and structured implementation frameworks. It is here that a profound tension emerges: modern digital systems are predominantly optimised for ideal, cooperative, and digitally literate demographics, inadvertently risking the exclusion of those who require specialised care the most. This disconnect is particularly critical in geriatric dentistry, where patient frailty, cognitive impairment, sensory limitations, and a reliance on caregivers present unique barriers to technologies that demand high patient compliance or digital interaction. This growing disparity brings a central, urgent question to the forefront, one that serves as the core focus of this review: *are contemporary digital dental systems genuinely designed with frail older adults in mind?* Consequently, this article examines the digital transformation of dentistry, specifically intersecting dental education and geriatric oral health care, to critically evaluate whether these technological advances are bridging the gap in care for ageing populations or inadvertently widening it.

Evolution of digital pedagogical models

Digital technologies are profoundly reshaping dental education by transitioning curricula towards sophisticated, simulation-based learning environments.[1] High-fidelity haptic simulators, virtual patients, digital typodonts, and extended reality platforms now enable repetitive skills training, objective assessment, and immediate feedback without risking patient safety. Crucially, these digital pedagogical tools offer unprecedented opportunities to develop competencies specific to geriatric care. Scenario-based training with virtual avatars allows students to safely navigate multimorbidity, practise interdisciplinary communication, and manage

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complex clinical decision-making for patients with cognitive impairment or frailty.

However, while these immersive technologies enhance learner engagement and visualise complex treatment needs, significant limitations persist.[5] A critical question arises regarding the fidelity of these systems: do current haptic simulators accurately replicate the tactile reality of the ageing mouth, such as mobile teeth, altered salivary flow, or restricted mouth opening? Furthermore, integrating these advanced systems introduces challenges related to technical usability, ergonomic constraints, and an increased cognitive burden for the student. Therefore, while digital pedagogy has the potential to better prepare clinicians for an ageing demographic, the educational tools themselves must be critically evaluated to ensure they accurately model the realities of geriatric care.

Digital competencies and curriculum reform

The rapid digitalisation of dentistry necessitates substantial curricular restructuring. Contemporary dental programs are increasingly integrating training in intraoral scanning (IOS), digital radiography, CAD-CAM workflows, additive manufacturing, and AI-assisted diagnostics.[6,7] However, true digital competency extends far beyond technical operation. Future curricula must ensure graduates are equipped not only to utilise these systems but also to critically evaluate their clinical validity, cybersecurity risks, and ethical implications.

This expanded definition of digital literacy is absolutely paramount when addressing geriatric vulnerability. Older adults with complex care needs frequently experience cognitive impairment and reduced decision-making capacity, complicating the process of obtaining informed consent for AI-driven diagnostics or digitally simulated treatment plans. Furthermore, the use of teledentistry, virtual consultations, and remote monitoring often necessitates caregiver mediation. This reliance on third parties introduces profound ethical and legal challenges regarding patient autonomy, privacy, and the secure transmission of sensitive health data. Consequently, ensuring robust data protection in cognitively impaired populations must become a core component of digital dental education. Ultimately, accreditation and regulatory bodies must revise educational standards so that future clinicians are trained to navigate the unique, highly sensitive intersection of emerging technologies and vulnerable ageing populations.

Educational institutions, therefore, face a dual challenge: integrating advanced technological literacy while safeguarding foundational clinical reasoning and evidence-based decision-making. While cloud-based platforms, virtual seminars, and interdisciplinary digital modules support a necessary structural shift towards hybrid education, realising this vision requires a substantial, sustainable infrastructure.[8]

However, the rapid commercialisation of digital dentistry threatens to create a profound “digital divide” across educational institutions. Financial constraints, infrastructural disparities, and variations in faculty expertise frequently result in inconsistent implementation. These institutional inequities are not merely academic concerns; they have direct, downstream consequences for vulnerable patient populations. If digital innovations, such as teledentistry for homebound seniors or efficient CAD-CAM workflows that minimise stressful chair time for frail adults, are only taught in well-resourced, elite institutions, the benefits of digital dentistry will remain inaccessible to the broader public. Consequently, educational disparities risk compounding existing geographic and socioeconomic inequalities in geriatric oral health care.

As digital technologies become permanently embedded within dental curricula, accreditation bodies and policymakers must intervene to ensure that innovation does not exacerbate the health care divide. The long-term success of dentistry’s digital transformation cannot be measured solely by the sophistication of its technology but by its equitable distribution. To truly serve the growing ageing demographic, the profession must prioritise scalable, cost-effective, and standardised educational models, ensuring that all future clinicians, regardless of where they train, are fully equipped to deliver advanced, digitally supported care to the frail older adults who need it most.[7]

AI in dental education

While AI is increasingly integrated into dental education to support diagnostic interpretation and treatment planning, its application must be critically evaluated through the lens of geriatric care. A primary concern is that if educational AI models are trained on datasets lacking sufficient representation of frail older adults, future clinicians may develop an overreliance on automated systems that fail to account for complex, age-related physiological change.[9] To prevent algorithmic bias from translating into clinical disparities for ageing populations, AI in dental curricula must be positioned as a supportive adjunct. It should be used to enhance, rather than replace, educator oversight, clinical reasoning, and the nuanced professional judgement required to manage vulnerable demographics.[6]

Digital Innovation in Geriatric Oral Health Care

Among the most clinically relevant innovations in geriatric dentistry is the adoption of digital prosthodontic workflows.[10] IOS is increasingly replacing conventional impression techniques, which, despite general tolerability, are often physically demanding for frail older adults with complex health statuses. By eliminating impression materials, IOS substantially improves patient comfort, reduces procedural stress, and generates permanent digital records that simplify communication across interdisciplinary care teams. When paired with CAD-CAM manufacturing, these workflows enable rapid fabrication and high reproducibility. These logistical advantages are particularly beneficial for care-dependent patients who struggle to endure prolonged or multiple appointments, and emerging evidence confirms that older adults generally favour the comfort and efficiency of digital impressions. However, current digital systems are not yet fully optimised

for the clinical realities of frailty. Significant technical limitations persist when attempting to scan patients with severe ridge resorption, restricted mouth opening, excessive salivation, involuntary movement disorders, or limited cognitive cooperation. Furthermore, high implementation costs and a lack of equipment portability remain substantial barriers to deploying these technologies in long-term care facilities and community-based geriatric services.

Teledentistry and domiciliary dental care

Teledentistry has emerged as a critical modality in geriatric oral health care, particularly for institutionalised, medically compromised, or geographically isolated older adults.[11] By utilising digital communication platforms, clinicians can conduct remote triage, monitor oral hygiene, and provide essential caregiver training. Furthermore, integrating cloud-based records and digital photography facilitates seamless interdisciplinary collaboration among dentists, physicians, and nursing home staff, thereby improving continuity of care. Clinically, this remote oversight is highly effective for preventive maintenance; the early identification of mucosal abnormalities or denture complications can significantly reduce the need for stressful emergency interventions and hospital transfers.[12] However, assessing whether these systems are truly designed for frail older adults reveals significant limitations. Beyond the inherent lack of tactile examination, teledentistry interfaces rarely accommodate the sensory or cognitive declines of frail patients, forcing a heavy reliance on caregivers with varying levels of digital literacy. Coupled with reimbursement uncertainties and data privacy concerns, these usability barriers dictate that teledentistry must currently serve as an adjunct to, rather than a replacement for, direct in-person care.

AI and functional assessment

AI-assisted diagnostic systems represent a rapidly advancing frontier in geriatric dentistry. Machine learning algorithms currently demonstrate high efficacy in identifying caries, periodontal disease, mucosal lesions, and peri-implant pathology from radiographic and intraoral imaging.[4] Beyond structural diagnostics, AI technologies are being adapted for functional geriatric care, offering potential pathways for frailty-based risk assessment and individualised preventive planning. Crucially, emerging digital tools now enable the objective evaluation of masticatory performance and swallowing disorders.[13] Furthermore, thermographic imaging and automated face coding have shown significant promise for the noninvasive detection of inflammatory processes and pain-related facial patterns.[14] These modalities are particularly invaluable for cognitively impaired or aphasic older adults who can no longer reliably self-report discomfort.

Despite these promising clinical applications, the design of current AI systems exposes a critical vulnerability: algorithmic bias. AI models are strictly dependent on the quality and diversity of their training datasets. Frail older adults present highly individualised, complex anatomies, often modified by decades of wear, tooth loss, and polypharmacy, that are frequently underrepresented in standard normative data. If digital systems are not purposefully trained on geriatric-specific datasets, their diagnostic validity for these vulnerable populations remains compromised. Consequently, AI must remain an adjunctive tool, strictly guided by the interdisciplinary judgement and patient-centred expertise of the clinician.

Challenges and future perspectives

Digital transformation is undeniably reshaping both dental education and clinical practice. Technologies such as intraoral scanning, teledentistry, and AI-assisted diagnostics offer unprecedented opportunities to alleviate workforce pressures and manage the escalating complexity of ageing populations.[15] However, the true measure of technological success is not computational sophistication but clinical equity. Currently, the uncritical adoption of digital dentistry risks exacerbating health disparities. Algorithmic biases, high implementation costs, and user interfaces that ignore cognitive and sensory declines actively threaten to marginalise frail older adults. To ensure these innovations protect rather than exclude vulnerable demographics, technology must remain an adjunct to, never a replacement for, empathetic, patient-centred clinical judgement. Ultimately, the central challenge is no longer whether dentistry will digitise but whether it will be inclusive. Moving forward, the dental profession must demand a paradigm shift: developers, researchers, and policymakers must stop retrofitting general digital systems for geriatric care and instead actively codesign these technologies with frail older adults in mind.

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Declaration of generative AI in scientific writing

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