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Artificial Intelligence in Oral Health: bridging technology and human touch for smarter, inclusive, and compassionate dental care

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Abstract
Background: The ageing population faces a dual burden of oral health decline and social isolation, both of which significantly affect quality of life and systemic wellbeing. Conventional healthcare models treat these issues separately, but the rise of Artificial Intelligence (AI) offers new opportunities for integrated solutions.
Objective: To review how AI-driven technologies can simultaneously enhance oral health and social wellbeing among older adults through holistic, synergistic approaches.
Methods: A narrative review was conducted across interdisciplinary databases focusing on AI applications in geriatric oral health, tele-dentistry, and psychosocial engagement. Studies highlighting digital inclusion, ethical design, and implementation challenges were also examined.
Results: AI tools such as remote oral monitoring systems, conversational agents, and personalized health education platforms demonstrate potential to improve self-care, social engagement, and early disease detection. These innovations promote autonomy and reduce care barriers. However, limitations persist due to digital illiteracy, affordability constraints, and ethical concerns regarding data privacy and algorithmic bias.
Conclusion: AI holds transformative potential in uniting oral and social healthcare for older adults. Sustainable impact requires co-design with end-users, equitable access, and culturally adaptive frameworks. Future research should focus on longitudinal outcomes, participatory design, and policy integration to realize AI's dual role in promoting health and human connection.

Keywords: Artificial intelligence (AI), oral health, older adults/ageing population, dental care, social wellbeing, compassionate healthcare

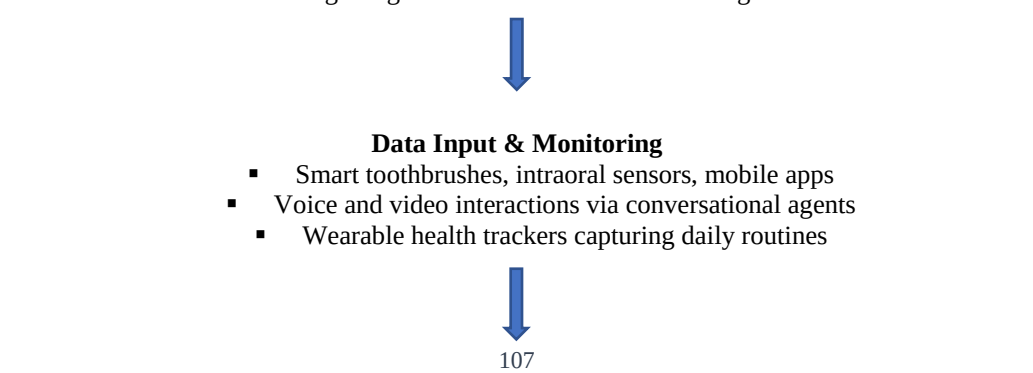
Introduction

The global demographic shift toward an ageing population presents major public health challenges, particularly in maintaining oral and psychosocial wellbeing. Older adults often experience cumulative biological, functional, and social changes that predispose them to oral diseases and isolation. Deteriorating oral health not only impairs mastication, speech, and aesthetics but also affects self-esteem and social participation [5, 6]. Conversely, loneliness and social withdrawal can diminish motivation for oral hygiene and reduce healthcare-seeking behaviour, forming a self-perpetuating cycle of neglect [6].

Traditionally, oral and social health domains have been addressed independently—dental professionals focusing on clinical outcomes and social services managing emotional wellbeing. However, with the advent of digital and intelligent health systems, there is increasing recognition that these aspects are deeply interconnected. Artificial Intelligence (AI), through its data-driven precision and adaptive interactivity, has emerged as a promising bridge between physical and psychosocial health.

Building on the synergistic framework proposed by Qi and Wu[7], this review examines how AI technologies can be applied to manage oral health while fostering social engagement in older adults. AI-enabled innovations—such as remote monitoring tools, conversational agents, and personalized health education systems—offer possibilities for patient empowerment, behavioral reinforcement, and companionship. Furthermore, by integrating AI into tele-dentistry and community-based services, oral healthcare can become more inclusive, continuous, and culturally responsive.

This article explores current applications, implementation barriers, ethical concerns, and future directions, emphasizing the importance of patient-centric and equitable AI design for sustainable oral health in ageing populations.



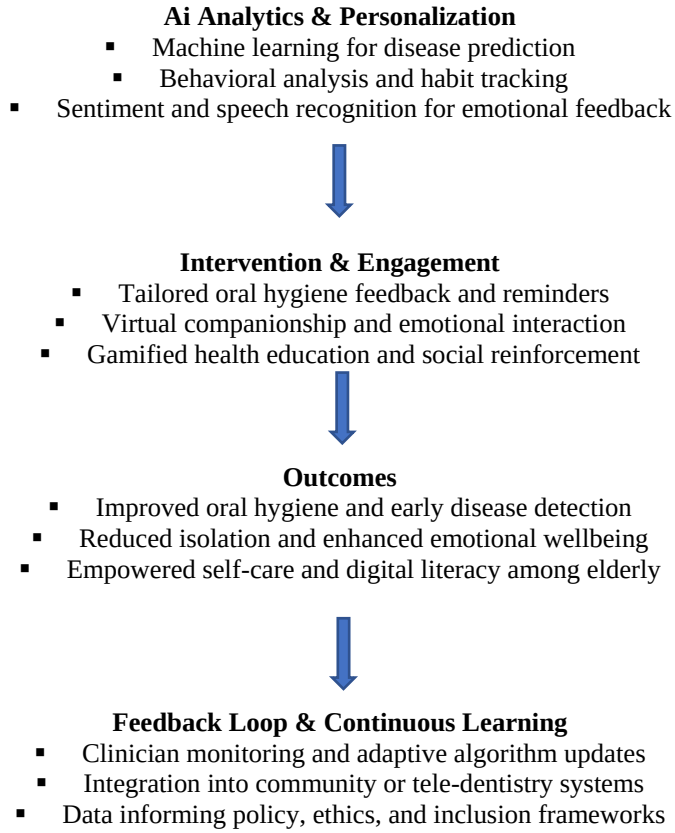


Fig 1: Synergistic Model of AI in Oral and Social Wellbeing for Older Adults

The synergistic model illustrates how Artificial Intelligence (AI) technologies can connect oral health and psychosocial wellbeing in older adults through continuous data monitoring, personalized analytics, and interactive engagement. Feedback loops enable ongoing adaptation, improving both clinical and emotional outcomes.

AI Tools in Practice: Addressing Dual Needs

Artificial Intelligence (AI) in healthcare has evolved from static data processing to adaptive systems that personalize and humanize patient care. Within geriatric dentistry, these technologies address not only clinical requirements but also psychosocial wellbeing—creating a unified framework that supports holistic ageing.

1. Remote Oral Health Monitoring

AI-enhanced mobile applications and smart dental devices enable real-time tracking of oral-hygiene behavior, plaque accumulation, and early signs of disease. Smart toothbrushes equipped with embedded sensors and AI-driven analytics provide individualized feedback and behavioral nudges, empowering older adults to maintain autonomy in oral hygiene [11, 13]. These platforms can also flag early pathological changes and alert dental professionals remotely, improving access to timely intervention, particularly in areas where geriatric dental care is limited.

2. Conversational AI for Social Engagement

Natural-language processing (NLP) technologies underpin conversational agents and robotic companions such as *ElliQ* and *PARO*, which have been shown to mitigate loneliness and stimulate cognitive engagement in older populations [12]. When combined with oral-health prompts—hydration reminders, medication alerts, or daily hygiene check-ins—these AI systems function as both social support and preventive healthcare tools. Integrating multilingual and culturally contextual communication enhances understanding[15] among elderly users.

3. AI-Assisted Tele-dentistry and Triage Systems

Tele-dentistry platforms augmented by AI-based diagnostic models can interpret intraoral photographs, classify lesions, and triage urgent cases for specialist review [13, 10]. Such integration extends the reach of dental professionals to homebound or rural elderly individuals, improving accessibility while reducing clinician workload. AI-supported triage also facilitates accurate prioritization and enhances the quality of remote consultations.

4. Behavioral Reinforcement and Gamified Learning

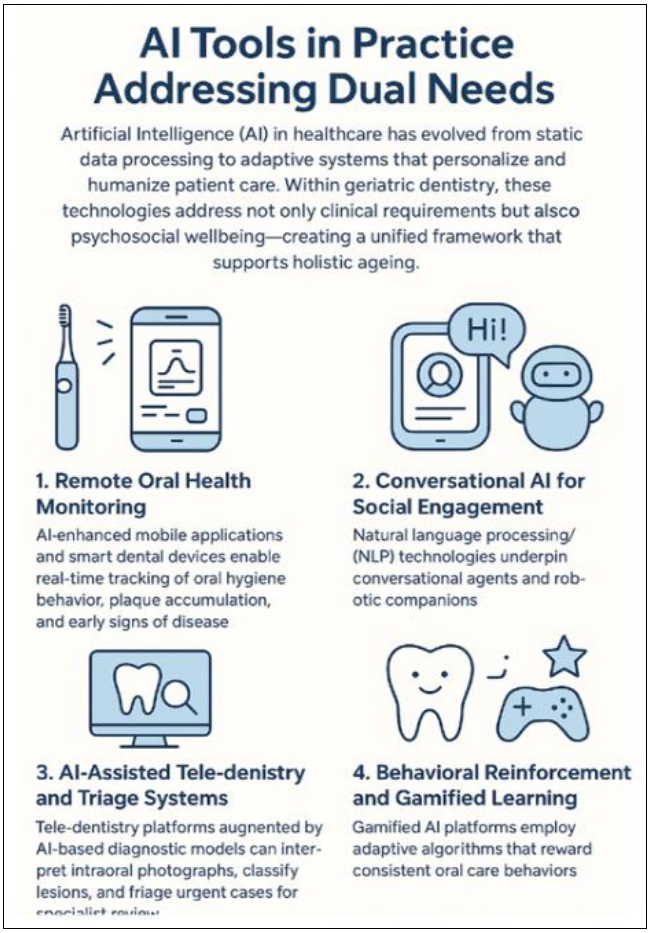
Gamified AI platforms employ adaptive algorithms that reward consistent oral-care behaviors, reinforcing motivation through virtual recognition and social engagement. These tools have been associated with increased adherence and improved hygiene routines among older adults [14]. The combination of digital education and positive feedback contributes to both cognitive stimulation and behavioral stability in long-term care.

5. Multilingual and Culturally Adaptive AI Systems

Older adults represent a heterogeneous population with differing linguistic, cognitive, and cultural profiles. AI systems designed with multilingual interfaces and localized content demonstrate greater usability and trust, particularly in low- and middle-income countries [15, 16]. Such inclusivity ensures that emerging technologies remain equitable and ethically sound, reducing disparities in digital healthcare adoption.

Table 1: Applications of AI for Oral and Social Wellbeing in Older Adults

AI Domain	Application	Primary Function	Expected Outcome	Reference(s)
Remote Monitoring	Smart toothbrushes, intraoral sensors	Disease detection, feedback	Improved hygiene, early diagnosis	[11], [13]
Conversational AI	Social robots, chat-based companions	Emotional engagement, reminders	Reduced loneliness, enhanced compliance	[12], [15]
AI Tele-dentistry	Automated triage, imaging interpretation	Diagnostic prioritization	Increased accessibility, efficient case management	[13], [10]
Behavioral Platforms	Gamified oral-care apps, adaptive feedback	Motivation, routine adherence	Improved self-care, digital literacy	[14]
Culturally Adaptive Systems	Multilingual interfaces, localized content	Inclusion and usability	Higher adoption among diverse older populations	[15], [16]



Implementation Barriers and Ethical Considerations

While the integration of Artificial Intelligence (AI) into geriatric oral healthcare offers substantial promise, real-world implementation remains constrained by socio-technical, ethical, and infrastructural challenges. These barriers must be addressed to ensure inclusivity, safety, and sustainable impact across diverse populations.

1. Digital Literacy and Accessibility

A major obstacle to effective AI adoption is the digital divide. Many older adults—particularly in rural or low-income regions—lack familiarity with digital interfaces or access to stable internet infrastructure [16]. Even when devices are available, difficulties in navigating applications or interpreting voice commands can impede consistent use. Without tailored onboarding, training, and technical support, AI-driven innovations risk excluding those most in need of assistance.

2. Affordability and Scalability

The majority of commercial AI platforms rely on advanced smart devices, subscription models, or costly digital infrastructure. These requirements often place them beyond the reach of elderly populations in resource-constrained settings [17]. To overcome this limitation, integration into national health schemes, public–private partnerships, and cost-sharing models is crucial for equitable access and scalability.

3. Privacy, Consent, and Data Ethics

AI applications in healthcare frequently depend on continuous data collection involving sensitive medical, behavioral, and emotional information. Informed consent becomes complex when cognitive decline or low health literacy is present. Additionally, few regulatory frameworks specifically address the vulnerabilities of elderly users in data privacy or algorithmic transparency [18]. Ethical AI design must therefore ensure clarity in data use, secure storage, and explainable decision-making processes.

4. Algorithmic Bias and Equity

AI algorithms are often trained on datasets derived from younger, homogeneous populations, which can produce biased outputs when applied to older adults. For instance, oral pathology recognition systems may misclassify conditions due to age-related anatomical changes or poor representation in training data [19]. Such biases can lead to diagnostic inaccuracies and reinforce inequities in care delivery. Addressing this requires diverse data collection and algorithmic auditing to ensure fairness and reliability.

5. Emotional Dependence and Oversimplification

As AI systems become more interactive and anthropomorphic, concerns about emotional dependence arise. Older adults may develop attachments to AI companions that unintentionally replace, rather than supplement, genuine human contact [20]. Over-reliance on digital interaction risks reducing opportunities for real social engagement. Hence, AI should be positioned as a complementary support mechanism—enhancing human relationships rather than substituting them.

Future Directions and Recommendations

To realize the full potential of Artificial Intelligence (AI) in enhancing both oral and social health among older adults, future research and policy efforts must move beyond proof-of-concept technologies toward sustainable, inclusive, and evidence-based implementation frameworks.

1. Participatory Design Involving Older Adults

AI technologies are often developed with limited input from the very populations they intend to serve. Incorporating older adults into every stage of design—conceptualization, testing, and refinement—ensures that tools are relevant,

usable, and sensitive to their needs [21]. Co-design approaches involving caregivers, dental professionals, and community stakeholders can generate solutions that reflect real-world challenges and preferences, fostering ownership and trust.

2. Integration into Primary and Geriatric Care Systems

AI systems should not exist as isolated digital products but as extensions of existing health infrastructure. Integrating AI-supported oral health tools into community clinics, mobile dental vans, and telehealth platforms can streamline care pathways and reduce redundancy [22]. For instance, AI-assisted screening during routine checkups or home visits can provide early warnings, allowing timely intervention and referral. Such integration enhances continuity between dental, medical, and social services.

3. Longitudinal and Multisite Clinical Trials

There remains a paucity of longitudinal data on the long-term effectiveness, safety, and psychosocial benefits of AI-based interventions in elderly populations. Future research should include multisite clinical trials assessing both clinical outcomes—such as plaque reduction, periodontal stability—and psychosocial parameters, including loneliness, cognitive engagement, and quality of life [23]. Cross-cultural comparisons are also necessary to validate generalizability and identify context-specific barriers.

4. Policy Support and Ethical Governance

Governments and professional bodies must establish comprehensive regulatory frameworks that promote responsible AI development while safeguarding user rights [24]. Policies should mandate transparency, fairness, and explainability in AI systems, with ethical review mechanisms incorporated into product certification. Furthermore, inclusion of AI-based oral health monitoring and social engagement tools within insurance or public health reimbursement models can expand accessibility and drive adoption in low-resource settings.

5. Capacity Building and Digital Education

Bridging the digital literacy gap is critical to ensuring equitable participation in AI-enabled care. Structured training programs tailored for older adults can build confidence in using AI tools, address technophobia, and enhance self-efficacy [25]. These initiatives should also extend to caregivers and healthcare professionals, enabling them to guide and support elderly users effectively. Community-based workshops and senior centers can serve as key hubs for such education, fostering a culture of digital inclusion.

Conclusion

As the global population ages, healthcare must evolve from isolated treatment models toward integrative frameworks that recognize the interdependence of physical, emotional, and social wellbeing. Artificial Intelligence (AI), when applied thoughtfully, represents a transformative opportunity to reimagine oral healthcare—not merely as a clinical service but as a continuous, interactive, and compassionate process.

Building upon the synergistic framework proposed by Qi and Wu [1], this review underscores AI's potential to bridge oral health management with psychosocial engagement, empowering older adults to maintain dignity and independence. Tools such as smart oral-hygiene systems, conversational agents, and AI-assisted tele-dentistry collectively create a supportive ecosystem that enhances self-care and reduces isolation.

However, realizing this vision requires more than technological innovation. Success depends on ethical governance, equitable access, participatory design, and sustained policy commitment. By embedding empathy and inclusivity within digital frameworks, AI can move from automation to augmentation—supporting not just longevity but quality of life in ageing societies.

When human needs align with machine design,
We heal with tech—and help hearts shine.

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