Advancing Sustainable Dentistry Through Material Innovation and Machine Learning Synergy

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Amid global carbon neutrality commitments, the dental sector confronts critical environmental challenges posed by conventional materials, including excessive life-cycle energy consumption, low recyclability, and waste-related ecological hazards. Our study evaluates the environmental impact of traditional dental materials and proposes a dual-pathway strategy integrating sustainable material development with machine learning (ML)-enabled technological innovation. By transitioning to bio-derived, recyclable alternatives for non-degradable composites and mercury-based alloys, the industry can substantially mitigate its ecological footprint. Parallelly, ML applications emerge as pivotal tools for enhancing operational sustainability—intelligent diagnostic systems enable early disease detection to minimize invasive procedures and material waste, while predictive analytics optimize supply chain efficiency and clinical workflows. A comprehensive review of interdisciplinary literature underscores ML's capacity to refine treatment personalization and diagnostic precision, thereby reducing resource overuse. However, challenges such as data privacy risks, ethical dilemmas in algorithm deployment, and the lack of standardized metrics for assessing material sustainability require urgent resolution. Our study advocates for a collaborative framework uniting material scientists, clinicians, and data experts to harmonize green chemistry principles with transparent ML architectures. Regulatory policies must evolve to incentivize circular economy models and cross-sector innovation. By synergizing material sustainability with intelligent technologies, dentistry can transition toward an eco-conscious paradigm that balances clinical efficacy with planetary health imperatives, ultimately contributing to a resilient, low-carbon healthcare future.

Biography

Yuanyuan Lu received her Dphil degree in Physical and Theoretical Chemistry at the University of Oxford in 2022. Presently, she is a postdoctoral researcher in the College of Environmental and Resource Sciences at Zhejiang University. In 2023, she has successfully obtained the grant from National Natural Science Foundation of China (Young Scientists Fund) and China Postdoctoral Science Foundation. Her present focus of research interests is to explore the environmental behavior and fate of nanomaterial of potential nanotoxicity and mobility.