

Environmental Sustainability in Periodontal Practice: A Narrative Review with Perspectives from Saudi Arabia

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ABSTRACT

Background: Healthcare contributes roughly 4.4% of global greenhouse gas emissions, and dentistry is a measurable part of this burden through energy and water use, materials, and single-use waste. Periodontal practice is particularly resource-intensive, involving repeated visits, instrumentation, irrigation, sterilization, PPE, and single-use materials across non-surgical, surgical, and maintenance care.

Aim: This narrative review synthesizes evidence on environmental sustainability in periodontal practice and offers context-specific perspectives for Saudi Arabia, where Vision 2030 links sustainability to health-system transformation.

Methods: A comprehensive search of PubMed, Scopus, Web of Science, and CINAHL, supplemented by manual reference screening, identified literature on periodontal sustainability, green dentistry, dental waste, biodegradable polymers, carbon footprint, and Saudi-specific sustainability, synthesized thematically.

Results: Periodontal care generates substantial carbon, water, and plastic burdens, with clinic audits reporting periodontal plastic waste among the highest per patient. Systemic barriers include limited sustainability literacy, cost perceptions, and absent institutional policy. Emerging solutions include biodegradable polymers (PLA, PHA), recyclable vitrimers, and chemical upcycling, alongside practical strategies such as appointment consolidation, teledentistry, reusable PPE, digital workflows, and waste segregation. A five-dimensional framework—environmental, clinical, behavioral, economic, and policy—is proposed. For Saudi Arabia, water scarcity, Vision 2030, and the Saudi Green Initiative create both urgency and opportunity, though curricular and clinical integration remains limited.

Conclusion: Environmental sustainability is increasingly integral to responsible periodontal care, requiring coordinated action from clinicians, educators, and policymakers. Periodontology-specific evidence remains limited, warranting future life-cycle assessments and standardized sustainability indicators, particularly within Saudi Arabia's healthcare and educational context.

Keywords: Environmental sustainability; Periodontal practice; Green dentistry; Carbon footprint; Biodegradable polymers; Dental waste management; Saudi Arabia; Vision 2030.

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INTRODUCTION

Environmental degradation driven by human activity has placed healthcare systems under scrutiny for their ecological impact. The healthcare sector contributes around 4.4% of total global greenhouse gas emissions, highlighting its substantial role in climate change. Within healthcare, dentistry represents a measurable contributor through high energy and water consumption, extensive material use, and large volumes of single-use and non-recyclable products^{1,2,3}. Dentistry's environmental footprint is driven by electricity-intensive equipment, water-demanding procedures, travel by patients and staff, and widespread reliance on disposable plastics and packaging^{3,4}. Periodontal practice presents a particularly relevant context for sustainability because treatment frequently involves repeated clinical visits, instrumentation, irrigation, sterilization, personal protective equipment (PPE),

and the use of single-use materials across non-surgical, surgical, and maintenance phases of care. Waste audits in dental and educational settings have also demonstrated substantial quantities of packaging and non-infectious disposable waste, highlighting opportunities for improved resource efficiency and waste reduction³.

The environmental relevance of periodontal care is compounded by the high global burden and chronic nature of periodontal disease. Global Burden of Disease estimates indicate that more than one billion people worldwide are affected by severe periodontitis, with prevalence projected to rise substantially by 2050 as population's age and grow⁵. Unlike many episodic dental interventions, periodontal care commonly follows a long-term disease-management model involving repeated non-surgical periodontal therapy, supportive periodontal

maintenance, and, where indicated, surgical or regenerative procedures. Consequently, relatively modest environmental impacts associated with individual visits may accumulate substantially over the course of long-term patient care.

The environmental burden of periodontal practice therefore extends across multiple domains, including water and energy consumption, single-use plastics and packaging, sterilization, PPE, transportation, and the production and disposal of dental materials^{3,4,6,7}. At the same time, emerging digital workflows and additive manufacturing may reduce paper consumption, physical impressions, and some forms of travel-related burden, while potentially generating new polymer and electronic waste streams that require consideration within broader life-cycle assessments^{3,8}. Sustainability interventions must therefore balance environmental benefits with infection-control requirements, clinical effectiveness, patient safety, and regulatory standards. Despite growing recognition of these issues, environmental sustainability remains inconsistently embedded in dental and periodontal education, with curricular gaps in structured training, faculty preparedness, and policy support^{2,6}.

The broader global gaps have particular relevance for Saudi Arabia, where Vision 2030 has placed sustainability and health-system transformation at the center of national policy, creating both an impetus and an opportunity to align periodontal and broader dental practice with wider environmental and developmental goals⁹. Nevertheless, the extent to which sustainability principles have been incorporated into periodontal syllabuses, clinical protocols, procurement practices, and waste-management systems within the Kingdom remains insufficiently characterized. This highlights the need for a context-sensitive synthesis that connects international evidence with the healthcare, educational, infrastructural, and policy landscape of Saudi Arabia.

This narrative review therefore aims to provide a comprehensive and specialty-focused examination of environmental sustainability in periodontal practice, specifically, It examines (1) the principal environmental challenges associated with periodontal care, including carbon emissions, water and energy consumption, and material and single-use waste; (2) emerging sustainable materials and technological innovations, including digital workflows and additive manufacturing; (3) evidence-based strategies for optimizing clinical workflows, procurement, sterilization, and waste management; and (4) context-sensitive recommendations for Saudi Arabia to support the integration of sustainability into periodontal practice and dental education. By integrating international

literature with regional perspectives, this review aims to move beyond recognition of dentistry's environmental impact toward a practical, specialty-specific framework for more sustainable periodontal care.

METHODOLOGY

A narrative review approach was adopted to critically examine and synthesize the growing body of evidence on environmental sustainability in periodontal practice. Given the broad, multidisciplinary, and evolving nature of environmental sustainability, this approach allowed evidence from diverse fields to be considered and interpreted within the specific context of periodontal care. Narrative reviews are particularly appropriate for complex topics that encompass heterogeneous evidence and require contextual interpretation rather than a narrowly defined systematic approach^{10,11}. The review was designed to provide a broad and critical perspective rather than to answer a single focused clinical question. Accordingly, unlike systematic reviews, which generally employ predefined eligibility criteria and highly structured search and appraisal procedures, narrative reviews permit a more flexible and iterative approach to literature identification and synthesis. This facilitates the integration and interpretation of evidence from diverse sources, including empirical studies, conceptual and theoretical literature, policy and guideline documents, and relevant research from materials science and healthcare sustainability^{10,11}.

LITERATURE SEARCH STRATEGY

A comprehensive literature search was performed across multiple electronic databases including PubMed, Scopus, Web of Science, and CINAHL. Search terms combined Medical Subject Headings (MeSH) and keywords related to environmental sustainability and periodontology, including: "periodontal sustainability," "green dentistry," "dental waste," "biodegradable polymers," "PLA," "PHA," "Covalent Adaptable Networks," "carbon footprint," "water efficiency," "life-cycle assessment," and "Saudi Arabia sustainability." Additional sources were identified through manual screening of reference lists from key studies and relevant review articles.

Inclusion and Exclusion Criteria

Studies and relevant literature were included if they addressed environmental impact, waste management, sustainable clinical workflows, or material innovations relevant to dentistry or periodontal care. Studies from materials science were included when they described sustainable polymer development with potential dental or biomedical applications. Policy documents were included when they provided environmental frameworks applicable to oral healthcare settings. Studies were excluded if they were not available in

English, did not provide substantive discussion of environmental sustainability, or focused solely on clinical outcomes without addressing environmental considerations.

Data Synthesis

Given the narrative nature of this review, data extraction and synthesis followed an interpretive and thematic approach consistent with qualitative narrative reviews in dentistry and sustainability science, which emphasize qualitative synthesis across heterogeneous evidence rather than formal meta-analysis³. Literature was organized into major conceptual domains reflecting recurrent themes in sustainability-in-dentistry literature: the environmental burden of periodontal and dental care^{1,12,14}, material sustainability with emphasis on polymer and plastic use^{15,16}, emerging innovations in biodegradable and recyclable materials, waste management and recycling strategies in dental settings^{1,17,18}, optimization of clinical and practice workflows, including energy, water and travel-related impacts¹², and relevant environmental and professional policies and guidance frameworks^{1,14}.

THE ENVIRONMENTAL BURDEN OF PERIODONTAL PRACTICE

A. CARBON FOOTPRINT AND WASTE GENERATION

Carbon Footprint and Periodontal Workflows

Periodontology is identified as one of the most resource intensive areas of oral healthcare due to full mouth disinfection, frequent non-surgical therapy, regenerative and surgical procedures, and regular maintenance visits³. These protocols require repeated patient attendance, making travel a major emission source, in line with carbon models of general dental practice where patient and staff travel dominate the footprint^{13,14,19}. High use devices in periodontal care like ultrasonic scalers, suction units and sterilization of complex instrument sets, contribute to energy and water consumption, consistent with life cycle analyses of examinations and clinic operation^{3,12,19}.

Periodontal Specific Materials and Procurement

Periodontal therapy makes extensive use of regenerative biomaterials (membranes, bone grafts, collagen scaffolds and multiphasic polymeric constructs) for guided tissue and bone regeneration and defect reconstruction²⁰. These products are often advanced polymer based devices manufactured through energy intensive processes and distributed globally, embedding upstream emissions in periodontal care pathways^{3,15,20}.

Waste Streams in Periodontal Settings

Periodontal surgeries and full mouth disinfection require large volumes of single use drapes, suction tips, irrigation sets, barrier films and PPE, adding substantially to clinical waste and plastic use^{3,4,6}. Scoping research in sustainable dentistry has highlighted inadequate segregation of clinical waste and the challenges of recycling contaminated plastic

materials, which increases incineration related emissions and costs, challenges that directly apply to intensive periodontal care^{1,4,6,7}.

Evidence on sustainable dentistry combined with periodontal focused reviews, shows that periodontal practice has a distinct environmental burden driven by intensive, repeated care, high energy equipment, and polymer rich regenerative materials. Travel, procurement of biomaterials, and plastic heavy infection control are key hotspots that should guide targeted sustainability strategies in periodontology.

Water Consumption in Periodontal Practice

Periodontal care relies on continuous water use for ultrasonic scaling, irrigation and cooling. Ultrasonic scalers generate significant heat at the tip; safe operation requires a constant water coolant or sterile irrigant to keep dentin and periodontal tissues below damaging temperatures²¹. Both integrated dental-unit water spray and bulb syringe irrigation with sterile saline can effectively limit temperature rise, highlighting that coolant flow rate and continuity are critical rather than the specific delivery route²¹.

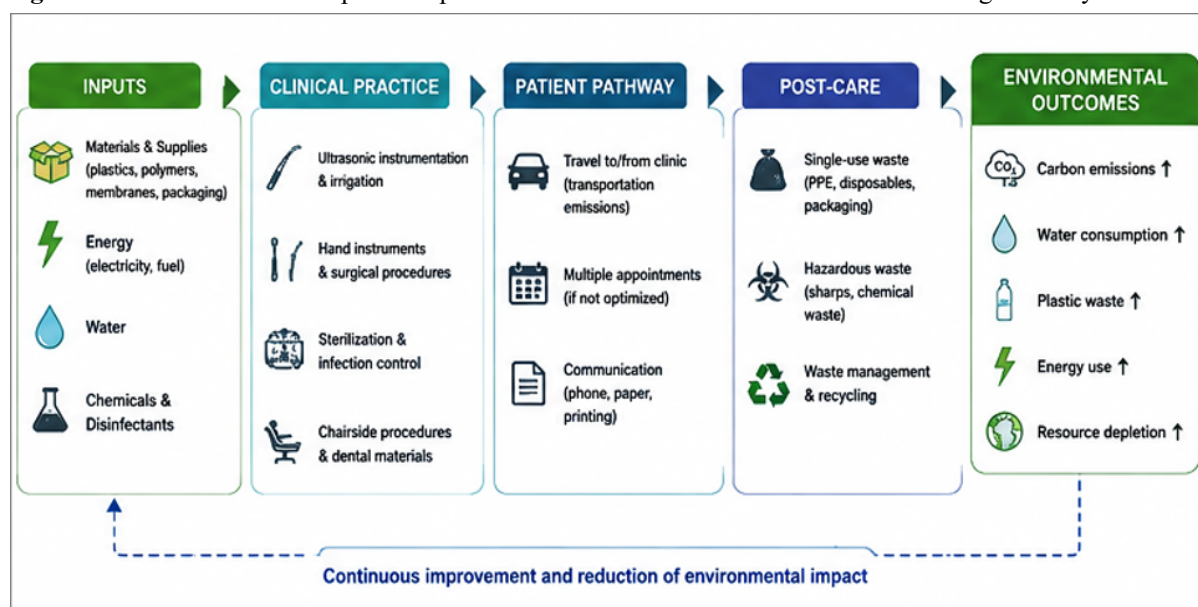
In water scarce or infrastructure poor settings, improvised coolant systems have been developed to allow ultrasonic scaling where piped water is unavailable, demonstrating that simple external water reservoirs can support effective periodontal debridement while maintaining safety²¹. More broadly, sustainability reviews of periodontal practice identify water saving technologies, optimized irrigation, and efficient sterilization cycles as key workplace strategies to reduce overall water use without compromising infection control³.

Polymer Use and Plastic Waste in Periodontal Practice

Periodontal practice is plastic intensive, especially for PPE, barrier protections, suction tips, irrigation syringes, sterilization packaging, and protective films. Quantitative clinic audits show that periodontics can generate among the heaviest plastic waste per patient; in one university clinic, periodontal care produced ~279 g of plastic waste per patient, largely from PPE, sterilization packaging and dental protective film. Across dental practice, approximately 18–21 single-use plastic items may be used per procedure, with personal protective equipment (PPE) representing the largest contributor. Many of these items are composed of complex, multi-layered or heterogeneous polymers, making them difficult to recycle^{22,23}. Systematic review evidence confirms substantial polymer waste in clinics (81–384 g per operator per day) and the presence of polymer micro- and nanoparticles in air and wastewater, indicating pollution risks in addition to solid waste volumes²³.

Narrative and scoping reviews describe dentistry as locked into a largely linear, single use plastics model, driven by low material cost, sterility assurance, and challenges of decontamination and recycling; they highlight periodontology's frequent surgical and aerosol generating procedures as particularly dependent on disposable polymers^{3,6}. Growing evidence also points to microplastic release from dental polymers during clinical procedures (e.g., grinding resin-based materials) with demonstrated cellular toxicity, reinforcing the need to reduce polymer load and improve capture and waste management in dental and periodontal settings²⁴.

Figure 1. Environmental footprint of periodontal



practice across the care pathway

B. SYSTEMIC BARRIERS TO SUSTAINABILITY IN PERIODONTAL PRACTICE

Beyond the direct environmental impacts of clinical activities, several systemic barriers impede the adoption of sustainable practices in periodontal care. Limited sustainability literacy among dental professionals remains a fundamental challenge, with many clinicians reporting inadequate knowledge of waste segregation principles, carbon footprint considerations, and sustainable material options⁶. This knowledge gap is perpetuated by the absence of environmental content in most dental curricula and continuing education programs^{2,25}.

Economic concerns also influence decision-making, with perceptions that sustainable products are more expensive or less effective than conventional alternatives. While some eco-friendly materials may carry higher upfront costs, evidence suggests that comprehensive sustainability interventions can be compatible with long-term savings and are often constrained more by costs and lack of training than by effectiveness²⁶. However, the lack of transparent cost-benefit analyses specific to periodontal

practice limits informed decision making. Perhaps most critically, the absence of structured institutional and national policies guiding environmental stewardship in dental care contributes to inconsistent implementation of sustainability measures^{6,27}. Few dental regulatory bodies or professional associations have established clear guidelines, benchmarks, or incentives for reducing environmental impact, leaving individual practitioners to navigate sustainability challenges without standardized frameworks or support²⁷.

Despite these barriers, evidence demonstrates that sustainable periodontal practice is both feasible and beneficial. With properly implemented frameworks, dental clinics can significantly reduce

environmental impact without compromising clinical outcomes, suggesting that sustainability is integral to ethical, cost efficient, and future ready periodontal care^{3,6,15}.

INNOVATIONS IN SUSTAINABLE MATERIALS

Biodegradable Polymers

Recent advances in polymer science offer promising pathways to reduce the environmental burden of periodontal practice. Biodegradable polymers, particularly polylactic acid (PLA) and polyhydroxyalkanoates (PHA), present viable alternatives to conventional petroleum-based plastics for various medical and dental applications^{28,29}. PLA, derived from renewable resources such as cornstarch or sugarcane, is a biodegradable, biocompatible polymer that has gained attention as an environmentally friendly alternative to traditional plastics and is already used in multiple dental applications. PLA's biodegradability and bio-based origin reduce dependence on fossil resources, though its degradation is primarily via controlled hydrolysis/composting rather than rapid breakdown in all-natural environments²⁸.

PHAs are bio-based and biodegradable polyesters produced and degraded by microorganisms; some PHAs show properties similar to conventional plastics and are considered promising alternatives for medical devices and potential dental applications [29]. Their biocompatibility, bioresorbability, and tunable mechanical performance make them attractive for future oral and periodontal devices²⁹.

Recyclable and Reprocessable Materials

Beyond biodegradability, recyclable and reprocessable polymers based on covalent adaptable networks (CANs), often termed vitrimers, offer pathways toward circular material flows. Vitrimers are permanently cross-linked networks with dynamic covalent bonds that provide thermoset-like mechanical performance while allowing reshaping and reprocessing at elevated temperature³⁰. These properties suggest potential for durable, repairable, and recyclable dental devices, although dental-specific implementations are still largely prospective.

Chemical Upcycling

Chemical recycling and upcycling of polymers aim to close material loops more effectively than conventional mechanical recycling by depolymerizing plastics to monomers or other feedstock suitable for high-quality re-synthesis. Reviews on bio-based and vitrimeric systems highlight that dynamic covalent networks and bio-based architectures are being developed with recyclability and circularity explicitly in mind, positioning them as candidates for future high-performance, chemically recyclable materials³⁰.

STRATEGIES FOR SUSTAINABLE PERIODONTAL PRACTICE

Sustainable periodontal practice encompasses a range of practical approaches aimed at reducing the environmental footprint of periodontal care while preserving clinical effectiveness and patient safety. Figure 2 illustrates the key differences between conventional and sustainable periodontal

workflows, highlighting opportunities to reduce resource consumption, waste generation, and environmental impact across the continuum of care.

Figure 2. Conventional vs. sustainable periodontal workflow

- Consolidating appointments, improving care logistics, and using remote/virtual consultations (including tele dentistry) are highlighted as key strategies to reduce travel related emissions and unnecessary visits^{3,6,31}.
- Providing high quality, preventive, patient centred care reduces the need for repeated interventions and associated carbon emissions^{6,7,15}.

Infection control and reusables

- Waste reduction and reuse (e.g., durable equipment, reusable PPE, cloth barriers) are identified as key opportunities, provided infection control requirements are met [1,3,6]
- Energy and water efficient sterilization and decontamination processes are promoted as part of sustainable dentistry^{3,32}.

Digital workflows

- Digital records and radiography reduce paper use and chemical waste, and can lower travel emissions when combined with remote care^{3,16,32}.
- Digital technologies also create new waste streams; circular economy and lean approaches are recommended to manage materials and process waste efficiently^{8,33}.

Waste Management and Recycling

- Correct segregation of infectious versus non-infectious/recyclable waste, with clear bin labelling and staff training, is repeatedly emphasized as a cornerstone intervention^{6,7,17}.
- Recycling of uncontaminated paper, cardboard, metals, glass and some plastics, plus partnerships with specialist recyclers, are identified as practical strategies; bin labelling and supplier engagement support this^{6,15,17}.
- Dental clinics generate large volumes of non-infectious plastics and packaging; audits show substantial potential for recycling and waste

ASPECT	CONVENTIONAL APPROACH	SUSTAINABLE APPROACH
 Appointment Scheduling	Multiple separate visits	Consolidated appointments where clinically appropriate
 Disposables & Plastics	High use of single-use plastics	Reduce unnecessary disposables; use recyclable/biodegradable alternatives
 Water Use	High-volume water consumption	Water-efficient instrumentation and protocols
 Materials	Virgin polymer & conventional materials	Sustainable, recyclable, biodegradable materials
 Records & Communication	Paper-heavy records and printing	Digital records and paperless communication
 Waste Management	Mixed waste; limited segregation	Segregation at source; recycling and proper disposal
 Procurement	Cost-focused purchasing without life-cycle view	Life-cycle-based procurement; support sustainable suppliers

reduction, including metal instrument and packaging recycling schemes^{3,7,17}.

Educational Imperatives

- Reviews highlight a lack of structured sustainability content in dental curricula and call for integration of environmental competencies, including waste management, resource optimization, and carbon footprint awareness^{2,3,31}.
- Continuing education and targeted interventions significantly improve knowledge of biomedical waste management and recycling, though knowledge may decay without reinforcement³⁴.
- Consensus groups and professional associations are identified as key actors in embedding sustainability into learning outcomes and clinical culture^{6,31}.

Policy and Regulatory Frameworks

- International and national professional bodies are urged to develop guidance, benchmarks, and policy to reduce emissions, address decontamination and waste, and support greener procurement^{3,7,31}.
- Incentives for green procurement, waste segregation, energy efficient devices (e.g., optimized ultrasonic units), and digital charting are specifically recommended³.

REGIONAL CONTEXT: SUSTAINABILITY IN SAUDI ARABIA

Recommendations for Saudi Periodontal Practice

Periodontal clinics in Saudi Arabia should prioritize water and energy efficient technologies, such as efficient sterilization systems, dental units that minimize water use, and LED lighting, alongside broader green dentistry measures^{3,16,32}. Travel-related emissions can be reduced through teledentistry and virtual follow up where clinically appropriate, consistent with sustainable practice frameworks that highlight travel as a major emissions source^{6,31}.

Dental schools and residency programs in Saudi Arabia currently show limited formal integration of environmental sustainability content, despite strong interest and perceived importance among students and faculty³⁶. Monitoring of indicators such as water, energy, and waste is recommended as part of quality systems to support data driven improvement in sustainable care^{3,6}.

A Five-Dimensional Framework for Green Periodontal Practice

Green periodontal practice requires a multidimensional approach that extends beyond individual clinical interventions to encompass

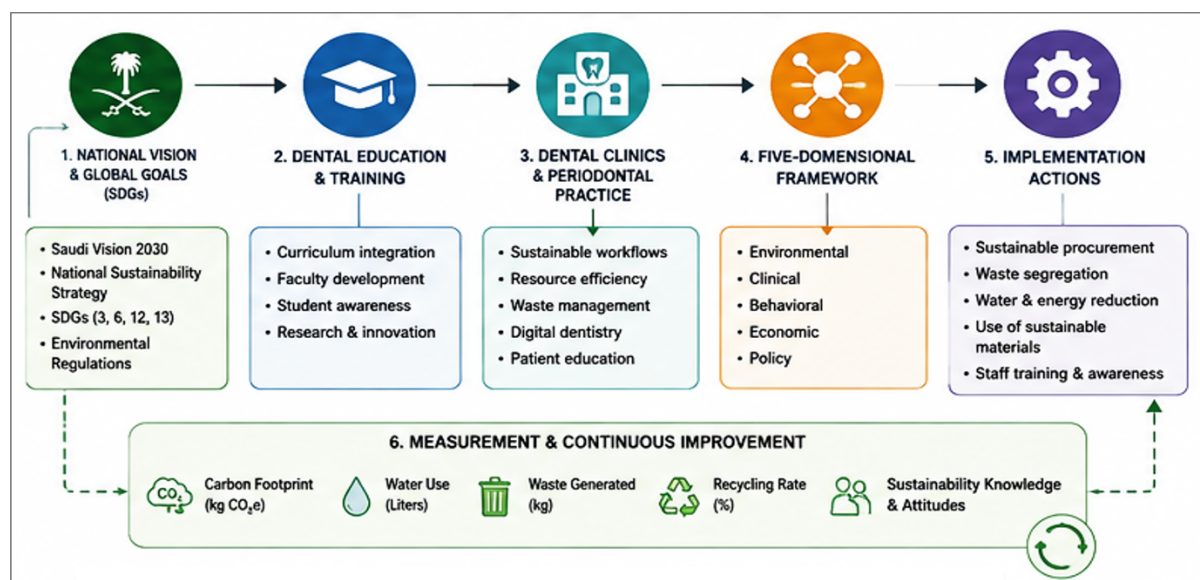


Figure 3. Saudi Arabia-specific implementation framework for sustainable periodontal practice

Environmental Challenges and Opportunities

Environmental sustainability in periodontal practice holds particular relevance in Saudi Arabia due to factors such as high energy demand, water scarcity, and the environmental burden of dental care, including travel and resource use^{7,35,36}. These challenges align with wider national and regional sustainability initiatives, including the Saudi Green Initiative and Vision 2030, which emphasize renewable energy, waste reduction, and low carbon development in health and other sectors³⁶.

environmental, clinical, behavioural, economic, and policy-related considerations. These five interrelated dimensions provide a comprehensive framework for integrating sustainability into periodontal care and for identifying practical strategies to reduce environmental impact while maintaining quality of care (Figure 4).

Figure 4. Five-dimensional framework for sustainable periodontal practice integrating environmental, clinical, behavioural, economic, and policy dimensions.

1. Environmental dimension

Innovation in materials, including biodegradable or lower impact options and improved waste to resource strategies, is a key pillar in green dentistry, though dental specific evidence for many novel polymers remains limited¹⁶.

2. Clinical dimension

Sustainable practice emphasizes prevention, non-surgical and low impact interventions where appropriate, reusable instruments, and digital records/radiography to cut paper, chemical waste, and some travel^{3,6,16,31}.

3. Behavioral dimension

Scoping reviews and regional surveys identify lack of awareness, habits, and resistance to change as major barriers; leadership, education, and local champions are highlighted as key enablers for behavior change in dental teams^{6,37}.

4. Economic dimension

Reviews note that sustainability interventions (e.g., energy efficient equipment, reusable instruments, and digitalization) can reduce long term operating costs while lowering environmental impact^{7,16,32}.

5. Policy and regulatory dimension

International and national calls to action stress the need for guidelines, benchmarks, accreditation criteria, and integration of Sustainable Development Goals into routine oral healthcare and education, including in Saudi Arabia^{6,7,35,36}.

Knowledge Gaps and Future Research Directions

Significant gaps remain in quantitative assessment of the environmental impact of specific dental and periodontal procedures, as well as life cycle comparisons of conventional versus “green” materials and technologies^{3,6}. Saudi and regional studies highlight limited curricular coverage, the awareness implementation gap in clinics, and the need for research on effective sustainability education, patient attitudes, and cost benefit analyses of interventions^{35,36,37}.

CONCLUSION

Environmental sustainability is an increasingly important component of responsible periodontal practice. Periodontal care contributes to environmental burden through resource-intensive procedures, single-use materials, water and energy consumption, transportation, and waste generation. Key opportunities to reduce this burden include optimizing clinical workflows, minimizing unnecessary resource use, adopting sustainable materials and digital technologies, improving waste management, and integrating sustainability into dental education and procurement.

Meaningful progress will require collaboration among clinicians, educators, researchers, manufacturers, and policymakers. Prevention-focused, patient-centered care and efficient use of appointments, water, energy, and digital

technologies can support sustainability without compromising clinical quality. However, periodontal-specific evidence remains limited, highlighting the need for life-cycle assessments, standardized sustainability indicators, and evaluation of sustainable interventions and emerging technologies.

In Saudi Arabia, sustainability initiatives should reflect national environmental priorities and Vision 2030 while addressing local healthcare and waste-management contexts. Embedding sustainability into routine periodontal practice can help reduce environmental impact while maintaining safe, effective, and ethically responsible patient care.

References

1. Duane B, Harford S, Ramasubbu D, et al. Environmentally sustainable dentistry: a brief introduction to sustainable concepts within the dental practice. *British Dental Journal*. 2019;226:292 - 295. doi:10.1038/s41415-019-0010-7
2. Bamedhaf O, Salman H, Teggimani S, Guraya S. Environmental sustainability in the dental curriculum: a scoping review. *BMC Medical Education*. 2025;25. doi:10.1186/s12909-025-07441-y
3. Di Spirito F, Giordano F, Di Palo MP, De Benedetto G, Aulisio L, Boccia G. Sustainable Dental and Periodontal Practice: A Narrative Review on the 4R-Framework—Reduce, Reuse, Rethink, Recycle—And Waste Management Rationalization. *Dentistry Journal*. 2025;13. doi:10.3390/dj13090392
4. Mulligan S, Smith L, Martin N. Sustainable oral healthcare and the environment: challenges. *Dental update*. 2021;48:493-501. doi:10.12968/denu.2021.48.6.493
5. Nascimento GG, Alves-Costa S, Romandini M, et al. Burden of severe periodontitis and edentulism in 2021, with projections up to 2050: The Global Burden of Disease 2021 study. *Journal of Periodontal Research*. 2024. doi:10.1111/jre.13337
6. Martin N, Sheppard M, Gorasia G, Arora P, Cooper M, Mulligan S. Awareness and Barriers to Sustainable Dental Practice - A Scoping Literature Review: Sustainable Dental Practice: Awareness and barriers.. *Journal of dentistry*. 2021. doi:10.1016/j.jdent.2021.103735
7. Khurshid Z, Alqurashi H, Ashi H. Advancing Environmental Sustainability in Dentistry and Oral Health. *European Journal of General Dentistry*. 2024. doi:10.1055/s-0044-1787099

8. Shinkai RSA, Biazevic MG, Michel-Crosato E, De Campos TT. Environmental sustainability related to dental materials and procedures in prosthodontics: A critical review.. *The Journal of prosthetic dentistry*. 2023. doi:10.1016/j.prosdent.2023.05.024
9. Rahman R, Qattan A. Vision 2030 and Sustainable Development: State Capacity to Revitalize the Healthcare System in Saudi Arabia. *Inquiry*. 2021;58. doi:10.1177/0046958020984682
10. Greenhalgh T, Thorne S, Malterud K. Time to challenge the spurious hierarchy of systematic over narrative reviews?. *European Journal of Clinical Investigation*. 2018;48. doi:10.1111/eci.12931
11. Sukhera J. Narrative Reviews: Flexible, Rigorous, and Practical.. *Journal of graduate medical education*. 2022;14 4: 414-417 . doi:10.4300/jgme-d-22-00480.1
12. Suresh P, Crotty J, Tesanovic S, et al. A life cycle analysis of the environmental impact of procurement, waste and water in the dental practice. *British Dental Journal*. 2024;236:545 - 551. doi:10.1038/s41415-024-7239-5
13. Elwan AH, Tantawi M, Fouda AM. Carbon footprint of private dental clinics in Egypt: a cross-sectional study. *BMC Oral Health*. 2025;25. doi:10.1186/s12903-024-05413-0
14. Chalotra R, Shenoy R, Bajaj PD, et al. A scoping review exploring carbon emissions in dentistry—a step towards sustainability. *BMC Oral Health*. 2025;25. doi:10.1186/s12903-025-06952-w
15. Guerra M, Morgado M, Leira Y, Leitão T, Botelho J, Mendes J. Integrating sustainability in dentistry: a pathway towards achieving the UN 2030 agenda. *Frontiers in Oral Health*. 2025;6. doi:10.3389/froh.2025.1549020
16. Sakchhi S, Elbanna L, Chakor M, et al. Green Dentistry: Sustainable Practices and Materials for a Healthier Planet. *International Journal of Dental Materials*. 2025. doi:10.37983/ijdm.2025.7303
17. Yeoh S, Bourdamis Y, Saker A, et al. An Investigation Into Contaminated Waste Composition in a University Dental Clinic: Opportunities for Sustainability in Dentistry. *Clinical and Experimental Dental Research*. 2024;10. doi:10.1002/cre2.70015
18. Duane B, Ramasubbu D, Harford S, et al. Environmental sustainability and waste within the dental practice. *British Dental Journal*. 2019;226:611 - 618. doi:10.1038/s41415-019-0194-x
19. Duane B, Steinbach I. What is the environmental footprint of a dental practice? A life cycle analysis (Part 1).. *British dental journal*. 2024. doi:10.1038/s41415-023-6710-z
20. Alqahtani A. Guided Tissue and Bone Regeneration Membranes: A Review of Biomaterials and Techniques for Periodontal Treatments. *Polymers*. 2023;15. doi:10.3390/polym15163355
21. Nicoll BK, Peters R. Heat generation during ultrasonic instrumentation of dentin as affected by different irrigation methods. *Journal of periodontology*. 1998;69 8: 884-8 . doi:10.1902/jop.1998.69.8.884
22. Martin PN, Mulligan S, Fuzesi P, Hatton PPV. Quantification of Single Use Plastics Waste Generated in Clinical Dental Practice and Hospital Settings.. *Journal of dentistry*. 2022. doi:10.1016/j.jdent.2022.103948
23. Gussgard A, Jokstad A. Polymer waste and pollution in oral healthcare clinics: a systematic review. *BDJ Open*. 2025;11. doi:10.1038/s41405-025-00342-8
24. Ong A, Teo JYQ, Watts DC, Silikas N, Lim JYC, Rosa V. The global burden of plastics in oral health: prospects for circularity, sustainable materials development and practice. *RSC Sustainability*. 2024. doi:10.1039/d3su00364g
25. Dixon J, Field J, Van Harten MV, Duane B, Martin N. Environmental Sustainability in Oral Health Professional Education: Approaches, Challenges, and Drivers-ADEE Special-Interest Group Report.. *European journal of dental education : official journal of the Association for Dental Education in Europe*. 2024. doi:10.1111/eje.13033
26. Volgenant C, Bras S, Persoon IF. Facilitators and Barriers to Implementing Sustainability in Oral Health Care. *International Dental Journal*. 2022;72:847 - 852. doi:10.1016/j.identj.2022.08.002
27. Dyer TA, Mulligan S, Martin N. Sustainability as part of a quality framework for the organisation of oral healthcare. *British Dental Journal*. 2023;235:309-312. doi:10.1038/s41415-023-6269-8
28. Naser AZ, Deiab I, Defersha F, Yang S. Expanding Poly(lactic acid) (PLA) and Polyhydroxyalkanoates (PHAs) Applications: A Review on Modifications and Effects. *Polymers*. 2021;13. doi:10.3390/polym13234271
29. Abdeladhim RB, Reis J, Vieira AM, De Almeida CD. Polyhydroxyalkanoates: Medical Applications and Potential for Use

- in Dentistry. Materials. 2024;17.
doi:10.3390/ma17225415
30. Lucherelli MA, Duval A, Avérous L. Biobased vitrimers: towards sustainable and adaptable performing polymer materials. Progress in Polymer Science. 2022.
doi:10.1016/j.progpolymsci.2022.101515
 31. Duane B, Stancliffe R, Miller FA, Sherman J, Pasdeki-Clewer E. Sustainability in Dentistry: A Multifaceted Approach Needed. Journal of Dental Research. 2020;99:998–1003.
doi:10.1177/0022034520919391
 32. Agrawal SS, Abedeen MZ. Sustainable Dental Practices: Reducing Waste and Energy. International Research Journal of Medicine and Surgery. 2025.
doi:10.47857/irjmeds.2025.v02i03.038
 33. Antoniadou M. Integrating Lean Management and Circular Economy for Sustainable Dentistry. Sustainability. 2024.
doi:10.3390/su162210047
 34. Cayo-Rojas C, Briceño-Vergel G, Córdova-Limaylla N, et al. Impact of a virtual educational intervention on knowledge and awareness of biomedical waste management among Peruvian dental professionals. Scientific Reports. 2023;13.
doi:10.1038/s41598-023-49878-5
 35. Haque S. Sustainable Development Goals and the Dental Profession in Saudi Arabia: A Call to Action. Dental Hypotheses. 2025.
doi:10.4103/denthyp.denthyp_22_25
 36. Jamal H, Marghalani A, Al-Sharif AE, et al. Exploring the Perception of Dental Undergraduate Students and Faculty on Environmental Sustainability in Dentistry: A Cross-Sectional Survey in 26 Dental Schools in Saudi Arabia. Dentistry Journal. 2023;11. doi:10.3390/dj11040103
 37. Alsleem M, Subaya AJA, Ghafli HAA, Alasafirah A, Mahabob M. Knowledge, Attitude, and Practice of Dentists Regarding Green Dentistry - Across-sectional study in Eastern Province of Kingdom of Saudi Arabia. Medical Forum Monthly. 2025.
doi:10.60110/medforum.360503

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