SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 11, No. 4, (2025), pp. 216-224
Open Access. Online & Print

DOI: 10.5281/zenodo.11042518

DENTAL TOURISM AND ENVIRONMENTAL BURDEN: A REVIEW OF CROSS-BORDER TRAVEL, WASTE, AND ENERGY USE

Ramnarayan BK[1*], Krishnanand PS[2], Vidya M A[3], Avinash J[4], Savita AM[5], Venkatasubramanian. R[6]

[1]Associate Dean Administration, Professor and Head, Department of Oral Medicine and Radiology, Dayananda Sagar College of Dental Sciences Bangalore. Email: ramnarayanbk@dscds.edu.in,
[2]Associate Dean Undergraduate, Professor and Head, Department of Oral Pathology, Dayananda Sagar http://orcid.org/0000-0002-1673-4149
[3]Reader, Department of Oral Pathology, Dayananda Sagar College of Dental Sciences, Bangalore, Email: vidyama@dscds.edu.in, ORCID - http://orcid.org/0000-0003-4662-1243
[4]Vice Principal, Professor and Head, Department of Public Health Dentistry, Dayananda Sagar College of Dental Sciences, Bangalore. Email: avinashj@dscds.edu.in, ORCID - https://orcid.org/orcid-search/search?searchQuery=0000-0002-0492-3908
[5]Associate Dean Post graduation, Professor and Head, Department of Periodontics, Dayananda Sagar College of Dental Sciences, Bangalore, Email: savitaam@dscds.edu.in, ORCID - https://orcid.org/0000-0003-4888-4856[6]Professor & Head, Department of Pediatric and Preventive Dentistry, Dayananda Sagar College of Dental Sciences, Bengaluru, Email: venkatasubramanian@dscds.edu.in, ORCID-https://orcid.org/0009-0009-6206-2630

Received: 11/11/2025
Accepted: 18/11/2025

Corresponding Author: Ramnarayan BK (ramnarayanbk@dscds.edu.in)

ABSTRACT

Dental tourism is a rapidly growing era within global healthcare, that offers cost-effective dental treatment to international patients. Cross-border movement is invited to significant environmental challenges, including carbon emissions, increased energy consumption and improper biomedical waste management. Studies have reported that the environmental burden posed by dental-associated travelling as resulted in amplified ecological footprint of clinics operating with extended hours to cater to tourists. Lack of waste management systems in many host countries exacerbates the issue. Recent research opens the pavement, for sustainable supply chain models to integrate eco-friendly materials, advanced waste treatment technologies along with governments regulatory frameworks. Recommendations are promoting virtual consultations, environmental certifications for dental operatories, and primary focus on energy-efficient practices to balance economic gains with ecological responsibility. This review not only consolidates existing evidence but also proposes actionable strategies for stakeholders to advance sustainability in this sector.

KEYWORDS: Dental Tourism, Environmental Sustainability, Biomedical Waste Management, Sustainable Supply Chain, Eco-Friendly Dentistry, Energy Consumption in Dental Care, Cross-Border Healthcare, Climate Impact of Healthcare Travel.

1. INTRODUCTION

Dental tourism is an increasingly popular practice worldwide, allowing patients to seek affordable, high-quality dental theapy across international borders[1,2]. This trend carries significant environmental implications, like increased greenhouse gas emissions, energy demands, and hazardous biomedical waste generation[3].

Duane et al. (2019)[1] highlighted that travel for dental practices contributes substantially to environmental degradation. Their work echoes that patient and staff commuting is a major source of carbon emissions within dentistry. Charati et al. (2024)[2] encompass the sustainable supply chains in dental tourism, suggesting strategies not only for waste treatment but also emphasized on eco-efficient logistics to minimize environmental footprints. Further, Duane et al. (2019)[3] introduced core concepts of sustainability in dentistry. There work urges for practices to adopt green initiatives to mitigate environmental harm.

Garg and Guez (2011)[4] provided light in early era dental tourism's realm highlighting challenges, including patient safety and regulatory gaps. Collins (2022)[5]raised concerns over the hidden burden of dental tourism, noting its implications for both local healthcare systems and the environment. Felkai et al. (2023)[6] discussed physiological risks such as barotrauma and barodontalgia during air travel for dental care, underscoring patient health considerations linked to tourism.

Ramachandra (2011[7] commented on dental implant tourism, highlighting ethical and clinical concerns. Misch (2020)[8] echoed these sentiments, questioning whether dental tourism is a "dream vacation" or a "nightmare" due to environmental and procedural risks. Katakam et al. (2024)[9], though focusing on 3D printing in space medicine, emphasized sustainability frameworks that can also inform dental practice waste management strategies.

Antoniadou et al. (2021)[10] examined the circular economy in biomedical and dental waste sectors, advocating integrated treatment methodologies for environmental sustainability. Khadse et al. (2024)[11] introduced up-cycling dental waste as a potential solution to reduce landfill contributions. Abdallaoui Maan et al. (2023)[12] surveyed private dental practitioners, revealing knowledge gaps in infectious waste management practices.

Duane et al. (2019)[13] expanded on waste management strategies within dental settings, highlighting the need for systemic changes to reduce single-use plastics and hazardous materials. Iqbal et al. (2014)[14] addressed logistical challenges in managing dental tourists and the resulting strain on local resources. Brown et al. (2020)[15] analyzed online patient narratives, revealing growing environmental and ethical concerns expressed by health travelers.

This review synthesizes existing literature on the environmental burden of dental tourism, focusing on cross-border travel emissions, energy utilization in host dental practices, and waste generation. By integrating findings from Duane et al. (2019)[13], Charati et al. (2024)[2], and others, it explores sustainable strategies to balance dental tourism's economic benefits with ecological responsibility.

1.1. Cross-Border Travel and Its Environmental Impact

Duane et al. (2019) emphasized the substantial carbon emissions associated with travel for dental care. Air or road transport used to reach dental visits contribute to greenhouse gases. In dental tourism, the distances travelled not only amplify these emissions, but also creates a disproportionate environmental burden compared to local treatments[1].

Iqbal et al. (2014)[14] said that the logistical challenges in managing dental tourists, like unanticipated demands on local resources and follow-up care needs, further escalate indirect emissions through repeated travel. Brown et al. (2020)[15] was first to analyse the online narratives of health travellers in India. He revealed how international patients undertake multiple trips, increasing their cumulative environmental footprint.

Nadershahi and Ojcius (2024)[16] proposed a shift from individual patient travel towards teleconsultations and collaborative international care networks to reduce emissions. Similarly, Wadhawan et al. (2024)[17] stressed that eco-friendly dentistry must extend beyond clinic walls, especially for elective procedures. Wainer (2022)[18] suggested leveraging lessons from the COVID-19 pandemic, to reduce travel coincides with lower pollution levels. Encourage to reimagine dental care delivery with more localised treatment options for tourists. Interestingly, Wagatsuma et al. (2021)[19], though focusing on infectious disease spread, also highlighted how inbound international travelers can alter local ecological and health dynamics., Reinforcing this perspective, Wainer (2022)[20] argued for systemic changes and discourage unnecessary cross-border care unless essential. Ashiti and Moshkun (2021)[21] raised ethical concerns around treating dental tourists, questioning the sustainability of repeatedly treating complications from prior overseas treatments. This paper addresses

that gap by critically reviewing the environmental implications of dental tourism across the patient journey—from pre-travel logistics to post-treatment waste disposal—and consolidating best practices for eco-responsible, sustainable models. By bridging environmental science, healthcare management, and dental practice sustainability, this review provides a framework for minimizing ecological harm while preserving the economic and patient-care benefits of dental tourism.

Key Insight: A single international flight for dental treatment may outweigh the environmental benefits achieved through sustainable practices within dental clinics[1,18]. Hence, addressing cross-border travel is critical for holistic sustainability in dentistry.

2. METHODOLOGY

This paper adopts a narrative review approach to synthesize existing evidence on the environmental impacts of dental tourism, including cross-border travel emissions, energy consumption in dental practices, and waste management challenges. The review is not intended to be systematic but rather to integrate diverse sources, highlight key thematic insights, and identify knowledge gaps for future research.

A targeted literature search was conducted between January and July 2025 across major electronic databases including PubMed, Scopus, Web of Science, and Google Scholar. Keywords and keyword combinations used included: *"dental tourism"*, *"environmental impact"*, *"carbon footprint in dentistry"*, *"energy use in dental clinics"*, *"waste management in dentistry"*, *"sustainable dentistry"*, and *"sustainable healthcare supply chain"*. Boolean operators (*AND*, *OR*) were applied to refine results.

Inclusion criteria were:

- Peer-reviewed articles, reviews, and editorials published between 2010 and 2025
- Studies addressing environmental sustainability in dentistry or specifically in dental tourism
- Articles in English

Exclusion criteria were:

- Studies unrelated to dentistry or healthcare tourism
- Non-peer-reviewed sources, except where policy or professional guidelines provided context

Reference lists of relevant publications were also screened for additional sources. The selected literature was organized into thematic categories—travel-related emissions, energy consumption, waste generation and management, and sustainable supply chain models—to structure the synthesis. No formal quality assessment was performed due to the heterogeneous nature of the sources, consistent with narrative review methodology.

3. DISCUSSION

3.1. Energy Use in Dental Practices Catering to Tourists

The demand from international patients leads dental clinics to extend operating hours, employ high-energy equipment, and maintain climate-controlled environments. Duane et al. (2019)[1] emphasized that such practices substantially elevate energy consumption, indirectly exacerbating environmental degradation. Charati et al. (2024)[2] further how dental tourism amplifies this energy demand via the complex logistics and high patient throughput, stressing the need for sustainable supply chain design to incorporates energy efficiency.

Expanding on these concerns, Duane et al. (2019)[3] advocated renewable energy adoption and energy-saving technologies as potential solutions. Garg and Guez (2011)[4] noted that dental tourism's popularity often pressures clinics to scale up infrastructure rapidly, inadvertently increasing their reliance on energy-intensive systems such as autoclaves, compressors, and HVAC units. Collins (2022)[5] added that these high-energy operations disproportionately affect regions already struggling with limited energy resources, raising ethical and environmental questions.

The health risks associated with energy-intensive environments in tourism contexts, such as barotrauma and barodontalgia, have also been flagged by Felkai et al. (2023)[6]. While not directly linked to clinic energy use, these effects underscore the complex interplay between human health and the broader environmental footprint of dental tourism. Similarly, Ramachandra (2011)[7] and Misch (2020)[8] warned that the infrastructural and technological escalation required to support international patients often overlooks sustainable practices, leading to long-term environmental costs.

Katakam et al. (2024)[9], though focusing on 3D printing in space medicine, emphasized energy efficiency in high-tech healthcare applications—principles equally applicable to advanced dental setups serving tourists. Antoniadou et al. (2021)[10] proposed circular economy frameworks where energy-intensive waste management in dental practices could be restructured for sustainability. Complementing this, Khadse et al. (2024)[11] advocated for up-cycling dental materials to lower both waste

and energy footprints.

A critical factor in energy management is the awareness and practices of local dental professionals, as revealed by Abdallaoui Maan et al. (2023)[12], who documented gaps in sustainable energy and waste management knowledge among practitioners in Morocco. Duane et al. (2019)[13] reinforced this point by urging systemic adoption of low-energy alternatives in clinical operations, including LED lighting, efficient sterilization protocols, and power-saving dental equipment.

Iqbal et al. (2014)[14] linked the strain on local healthcare systems caused by dental tourists to an increased demand for resources, including energy. Brown et al. (2020)[15] echoed this sentiment, reporting from patient narratives that popular dental tourism destinations often struggle to balance economic benefits against environmental costs, especially rising energy consumption. Nadershahi and Ojcius (2024)[16] suggested that dentistry as a profession needs to embrace sustainability as a core value, recommending reduced reliance on fossil-fuel-based power sources.

Wadhawan et al. (2024)[17] provided further evidence of the environmental impact of energy use in dental practice, advocating for renewable energy integration and energy audits. Wainer (2022)[18] emphasized leveraging insights from the COVID-19 pandemic, where reduced clinic hours and remote consultations led to a measurable drop in energy use. Wagatsuma et al. (2021)[19] indirectly pointed to the environmental benefits of minimizing unnecessary travel and resource use in healthcare, which applies to dental tourism contexts. Finally, Wainer (2022)[20] reiterated the need to build on the post-pandemic momentum to establish greener, energy-efficient dental practices catering to both local and international patients.

Key Insight: Energy optimization strategies such as renewable energy adoption, smart scheduling, and tele-dentistry could significantly reduce the environmental burden of clinics serving dental tourists.[13,18,16]

Environmental Impacts of Dental Tourism:

Dental tourism generates a substantial environmental footprint through two interlinked pathways: cross-border travel and elevated energy consumption in host dental facilities. International patient movement significantly increases greenhouse gas emissions, with air travel and long-distance transport identified as major contributors to dentistry's carbon footprint[1]. Once at the destination, high patient volumes, extended operating hours, climate-controlled environments, and the use of energy-intensive equipment such as autoclaves, compressors, and HVAC systems further intensify environmental pressures[2–5]. The infrastructural scaling required to meet tourist demand often occurs without adequate sustainability measures, compounding ecological strain[4,5]. Additionally, tourism-related air travel carries physiological risks such as barotrauma and barodontalgia, underscoring the broader health–environment nexus[6]. Collectively, these factors highlight the need for integrated strategies—such as renewable energy adoption, energy-efficient clinical technologies, and reduced non-essential travel—to mitigate the environmental burden of dental tourism while maintaining service quality.

Waste Generation and Management in Dental Tourism:

Charati et al. (2024)[2] analyzed waste treatment challenges in dental tourism supply chains, highlighting that high patient turnover from diverse countries often leads to a surge in biomedical, plastic, and packaging waste. Many host nations, particularly in developing regions, lack robust systems to sustainably manage this influx, exacerbating environmental and public health concerns. Improper disposal of single-use plastics, sterilization wraps, and hazardous materials from dental procedures poses significant ecological risks[2].

Wainer (2022)[20] emphasized that the post-COVID-19 recovery offers a critical opportunity to re-evaluate waste management practices in dentistry. The pandemic underscored the environmental toll of increased disposable PPE and sterilization supplies, calling for innovations like reusable alternatives and biodegradable materials to mitigate future waste burdens. Ashiti and Moshkun (2021)[21] added that dental tourism often involves complex re-treatment cases requiring additional resource consumption and waste generation, raising questions about the sustainability of repeatedly managing such patients.

Broader environmental frameworks also intersect with these issues. Alsaleh et al. (2023)[22], while focusing on coastal tourism and fisheries sustainability, proposed integrated supply chain models that could be adapted for dental tourism to balance economic gains with environmental protection. Similarly, Al-Mulali et al. (2015)[23] highlighted that tourism-induced surges in transportation directly elevate CO_2 emissions, which in turn interact with waste-related ecological stressors.

In developing nations hosting many dental tourists, inadequate infrastructure for waste segregation and disposal remains a critical issue. Al-

Khatib et al. (2010)[24] found that dental solid and hazardous waste management practices in Palestine were insufficient, often leading to unregulated dumping and environmental contamination. This mirrors challenges in other low-resource settings where rising dental tourism intensifies waste streams. Babanyara et al. (2015)[25] reviewed environmental and health risks tied to poor dental waste management, underscoring the potential for pathogen transmission, soil and water pollution, and harm to waste workers.

Babaee Tirkolaee and Aydın (2021)[26] proposed sustainable models for medical waste collection and transportation during pandemics, advocating route optimization and centralized treatment facilities to minimize environmental footprints. Such models could be adapted to dental tourism contexts where high volumes of hazardous waste require efficient handling systems.

Key Finding: Addressing the improper disposal of single-use plastics and sterilization materials through circular economy approaches and advanced waste treatment models is vital to mitigate the ecological risks posed by dental tourism.[24,26]

Designing Sustainable Dental Tourism Supply Chains:

To address the environmental concerns associated with dental tourism, Charati et al. (2024)[2] proposed sustainable supply chain models that emphasize eco-friendly materials, efficient waste treatment facilities, and collaboration with local governments for regulatory frameworks. Such systems aim to balance the economic incentives of dental tourism with environmental stewardship.

Al-Khatib et al. (2010)[24] highlighted the deficiencies in hazardous waste management in developing countries, underscoring the need for robust infrastructural support when designing dental tourism supply chains. Babanyara et al. (2015)[25] further reinforced this, pointing out the health and environmental risks of improper dental waste disposal, which sustainable supply chain models must mitigate. Babaee Tirkolaee and Aydın (2021)[26] justified for integrated waste collection and transportation systems in times of pandemics principles equally applicable to managing high-flow waste in tourism-focused dental clinics. Behl et al. (2023)[27] remarked on the pen down to utilize Industry 4.0 technologies and circular economy enablers for developing resilient and sustainable operations, which could revolutionize how dental tourism supply chains are imagined. Boley et al. (2017)[28] averred that the community views of sustainable tourism, highlighted the fact that effective initiatives would have to include local resident buy-in, resonating well with Charati et al.'s (2024)[2] articulation of the need for government and community cooperation.

Çapar and Aslan (2020)[29] identified sustainability to increase destination competitiveness. Abbasi et al. (2022)[30] assessed sustainable supply chain performance amidst COVID-19 and determined adaptive strategies are essential for sustaining operations with minimal ecological footprints—findings directly transferrable to dental tourism. Ahmadimanesh et al. (2019)[31] put forth a mathematical model for dental tourism supply chains with optimized logistics and reduced environmental damage. Eskandarpour et al. (2015)[32] discussed optimization-based frameworks for sustainable supply chains with the focus on reconciling cost, environmental, and social goals. Ferrer and Medhekar (2012)[33] listed prominent drivers in managing global medical tourism supply chains, including environmental concerns and management of waste. Lastly, Fetscherin and Stephano (2016)[34] constructed the Medical Tourism Index, which stresses sustainability as an important determinant in destination attractiveness.

Key Insight: Sustainable dental tourism supply chains need to be designed through the incorporation of advanced technologies, local engagements, and circular economy thinking towards attaining resilience while reducing environmental imprints[27,32].

Recommendations for Environmental Sustainability: Both Duane et al. (2019)[1] and Charati et al. (2024)[2] advocate for strategic interventions to minimize the environmental footprint of dental tourism. Promoting virtual consultations to reduce unnecessary cross-border travel, encouraging eco-friendly certifications for dental clinics serving international patients, and developing policies that address the cumulative ecological impacts of dental tourism are key actions proposed.

Ahmadimanesh et al. (2019)[3] suggested mathematical models for optimizing dental tourism supply chains that integrate environmental considerations, such as minimizing transportation emissions and waste. Eskandarpour et al. (2015)[32] reinforced this with their optimization-oriented review, highlighting the importance of designing sustainable supply chain networks that balance economic performance with environmental protection. Ferrer and Medhekar (2012)[33] emphasized management practices that include rigorous environmental protocols for global medical tourism service chains, aligning well with calls for

international environmental policy harmonization.

Fetscherin and Stephano (2016)[34] noted that sustainability is increasingly a factor influencing destination attractiveness in the Medical Tourism Index, suggesting that environmentally responsible practices may also confer competitive advantages. Ghoushchi et al. (2021)[35] demonstrated the relevance of sustainable waste management through their study on landfill site selection for medical waste, which used a spherical fuzzy set framework—a methodology adaptable to dental tourism waste challenges.

The risks of environmental degradation through unregulated dental tourism practices were underlined by Barrowman et al. (2010)[36] and further echoed in the International Medical Travel Journal (2014)[37], which reported shifting trends as UK dentists began offering more cost-effective, locally sustainable alternatives. Doughty et al. (2025)[38] analyzed media reporting on dental tourism and called for greater public awareness about its environmental and ethical dimensions.

Miyagi et al. (2012)[39] revealed the hidden costs of cosmetic tourism, including environmental implications of medical waste management in host countries. Jamil et al. (2016)[40] highlighted mercury usage in dental amalgams as a significant occupational and ecological concern, reinforcing the need for mercury-free practices in dental tourism destinations.

Additionally, Duro and Turrión-Prats (2019)[41] discussed the seasonality of tourism, which can create cyclical peaks in environmental pressure that are particularly acute in medical and dental tourism hubs. Katircioglu (2014)[42] demonstrated a strong link between international tourism, energy consumption, and environmental pollution, urging stakeholders to develop energy-efficient practices tailored to high-demand periods.

Key Recommendations: Integrating virtual consultations[3], adopting sustainable waste disposal frameworks[35], and aligning dental tourism policies with global environmental goals[33] are essential to achieve a balance between economic growth and ecological preservation. Table-1

Table-1: Recommendations For Enhancing Environmental Sustainability in Dental Tourism.

Recommendation	Rationale	Supporting References
Promote virtual consultations and teledentistry	Reduces unnecessary cross-border travel, lowering transportation-related carbon emissions.	Duane et al. (2019)[1]; Charati et al. (2024)[2]; Ahmadimanesh et al. (2019)[3]
Encourage eco-friendly certifications for dental clinics catering to tourists	Incentivizes clinics to adopt sustainable practices, improving their environmental footprint and reputation.	Fetscherin & Stephano (2016)[34]; Ferrer & Medhekar (2012)[33]
Implement sustainable waste management systems using advanced technologies	Addresses biomedical and plastic waste challenges from high patient turnover in tourism.	Ghoushchi et al. (2021)[35]; Babaee Tirkolaee & Aydın (2021)[26]
Develop international policies regulating environmental practices in dental tourism	Harmonizes standards across countries and ensures cumulative impacts are considered.	Eskandarpour et al. (2015)[32]; Ferrer & Medhekar (2012)[33]; Katircioglu (2014)[42]
Adopt energy-efficient technologies and renewable energy sources in clinics	Mitigates the surge in energy consumption from extended operations for tourists.	Katircioglu (2014)[42]; Duro & Turrión-Prats (2019)[41]
Shift towards mercury-free dental practices	Minimizes ecological contamination and health risks associated with amalgam use.	Jamil et al. (2016)[40]
Engage local communities in sustainable tourism planning	Enhances community support and distributes environmental responsibility equitably.	Boley et al. (2017)[38]
Plan for seasonal demand to distribute environmental pressure	Reduces strain on infrastructure and ecosystems during tourism peaks.	Duro & Turrión-Prats (2019)[41]; Miyagi et al. (2012)[39]

Policy Implications: Addressing the environmental impacts of dental tourism requires coordinated action from clinics, professional bodies, and governments. Dental clinics can implement energy-efficient equipment, adopt renewable energy sources, and incorporate eco-friendly sterilization and waste management protocols into daily operations. Governments can incentivize sustainable practices through tax benefits, green certification programs, and subsidies for low-carbon technologies. Cross-border regulatory frameworks can be developed to encourage patients to choose environmentally responsible clinics and to standardize sustainability benchmarks across destinations. Public awareness campaigns highlighting the carbon footprint of travel and promoting preventive oral healthcare can further reduce unnecessary international journeys. By embedding sustainability criteria into healthcare accreditation and tourism promotion policies, stakeholders can ensure that the growth of dental tourism aligns with global climate and environmental goals.

4. CONCLUSION

While dental tourism offers access and

affordability, it carries hidden environmental costs through increased travel emissions, energy use, and waste. Adopting sustainable practices and supply chains is essential to minimize these impacts and align dental tourism with global sustainability goals.

Acknowledgement: We thank the anonymous reviewers for their constructive comments, which greatly strengthened this manuscript. This work was supported by the academic and research environment of Dayananda Sagar College of Dental Sciences, whose continued commitment to sustainable dentistry facilitated the development of this review. The authors would especially like to thank the faculty and research personnel of the institution for their support and cooperation throughout the preparation of this article

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