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Sustainable Prosthodontics Through Eco-Dentistry: A Scoping Review of Current Practices and Future Challenges

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Abstract

Background: Green dentistry, also known as eco-dentistry, mainly focuses on ecologically friendly clinical procedures that minimize waste, which use less energy, and on uplifting the use of biocompatible materials. Due to its considerable use of impression materials, resins, metals, ceramics, and energy-intensive laboratory procedures, prosthodontics is a dental specialty that significantly increases the environmental burden. The main goal of eco-dentistry is to decrease the environmental effect without affecting patient safety and to have the best possible outcomes. Therefore, it is important to introduce the sustainable methods into prosthodontic treatment to equalize conventional dental care with global sustainability objectives. This contributes to standardizing life cycle assessment (LCA), developing sustainable materials, implementing circular economy models, adopting digital workflows with life-cycle thinking, and educating the dental workforce, which are some of the top priorities.

Aim: This paper aims to provide an overview of contemporary green-dentistry practices in prosthodontics, focusing on developments in digital technology, sustainable materials, and clinical approaches that reduce environmental impact while maintaining high standards of patient care.

Methods: A scoping review was carried out by searching PubMed, Scopus, and Google Scholar for articles published between 2010 and 2025. "Eco-dentistry," "green dentistry," "prosthodontics," "sustainable dental materials," "digital prosthodontics," "3D printing dentistry sustainability," were among the keywords. Included were studies on digital processes, innovative materials, and ecologically conscious clinical and laboratory procedures.

Results: The outcomes show that material waste and reliance on traditional impression processes which are greatly reduced by using CAD/CAM systems, intraoral scanners, and 3D printing. Because of their properties like durability, recyclability, and biocompatibility, zirconia and glass ceramics have become famous sustainable restorative materials. When compared to traditional processing methods, digital dentures and hybrid procedures showed less of an ecological impact. Alloy recycling, decrease in single-use plastics, energy-efficient equipment, and increased professional awareness which are other sustainable tactics.

Conclusion: Eco-dentistry or green dentistry, in prosthodontics is a vital step for long-term oral health care. Digital technology, biocompatible materials, and green therapeutic practices can all majorly reduce the impact on the environment without touching the outcomes of treatment. Eco-friendly materials, thorough life-cycle assessments, and uniform eco-certification of dental goods should be the main objectives of future study.

Keywords: Eco-dentistry, Prosthodontics, Sustainability, CAD/CAM, Digital dentures, Green dentistry, Dental materials, Green Prosthodontics.

Introduction

The increasing global concern regarding climate change, environmental degradation, and decline of natural resources has motivated all professional disciplines, including healthcare, to critically check their environmental impact. Dentistry is a resource-intensive healthcare field that contributes significantly to environmental burden through high energy consumption, wide use of single-use materials, and generation of biomedical waste. Within dentistry, prosthodontics is the specialty that works on the replacement and rehabilitation of missing teeth and oral structures that excels as one of the disciplines with the largest ecological footprint.

Eco-dentistry represents an environmentally responsible step to oral healthcare that focuses on the reduction of waste, conservation of energy and water, minimization of pollution, and the use of sustainable materials, without affecting the clinical efficacy or patient safety [1]. The Eco-Dentistry Association and subsequent academic literature define eco-dentistry through the execution of the "4Rs"—Reduce, Reuse, Recycle, and Rethink—across dental practice and education. These principles resemble closely the United Nations Sustainable Development Goals (SDGs), particularly those that are responsible for consumption and production, climate action, and health and well-being [2, 3].

Dentistry leads to environmental degradation through its reliance on disposable plastics, chemical disinfectants, energy-intensive equipment, and improper waste segregation. The increasing demand for advanced dental treatments has further intensified this impact and helped in making the change toward sustainable practices both timely and imperative [4].

Within this context, prosthodontics occupies an uncommon position. As a material and technology intensive specialty, prosthodontic practice includes frequent use of impression materials, gypsum products, resins, metals, ceramics, and laboratory consumables, all of which contribute substantially to solid and chemical waste. Additionally, high-temperature furnaces, milling machines, curing units, and casting devices majorly increase energy consumption in both clinical and laboratory settings [5, 6]. Improper disposal of residual materials and unused inventory retained by manufacturers, laboratories, and clinics further takes part in environmental risk and socioeconomic burden [7]. Moreover, conventional workflows involving the transportation of physical impressions, casts, and prostheses between clinics and laboratories substantially increase the carbon footprint of prosthodontic care [8].

Given these objectives, the integration of eco-dentistry principles into prosthodontics is not solely important but essential. The rising adoption of digital technologies, including intraoral scanning, CAD/CAM systems, and additive manufacturing, has demonstrated significant potential to reduce material consumption, minimize laboratory waste, and reduce treatment timelines [9]. Simultaneous progress in sustainable prosthodontic materials, such as biocompatible ceramics, bio-based resins, and green polymer synthesis methods, along with emerging recycling technologies, offers viable alternatives to conventional materials with reduced environmental impact [10].

The addition of digital workflows, regenerative materials, and smart technologies, which encourages prosthodontics into a new era, exceeds the limitations of traditional static prostheses and supports a model of care that is both technologically advanced and environmentally responsible [11]. Despite these advancements, the existing studies on eco-dentistry have majorly focused on general dental practice, with relatively limited emphasis on prosthodontics as a distinct specialty [12].This represents a significant research gap, given the considerable sustainability gains achievable through material selection, digital workflows, and laboratory optimization in prosthodontic practice.

Aim of the Review

The present review focuses on exploring current eco-friendly practices within prosthodontics, with particular focus on digital innovations, sustainable materials, and environmentally conscious clinical and laboratory strategies. Additionally, the review aims to identify existing problems and outline future directions to increase the addition of eco-dentistry principles into prosthodontic care.

Materials And Methods

Study Design

This review was organized as a narrative review, with an extensive perspective, to form available evidence on eco-dentistry practices that connect to prosthodontics. The review work focuses on identifying sustainable materials, technologies, clinical workflows, laboratory practices, and policy perspectives, as well as identifying the challenges and future directions associated with environmentally responsible prosthodontic care.

Databases Searched

A digital literature search was performed across PubMed, Scopus, Web of Science, and Google Scholar databases to retrieve relevant publications [2].

Timeframe

The search included studies published between January 2010 and March 2025, ensuring the addition of both foundational literature and newer advancements in sustainable prosthodontics [3].

Search Strategy and Keywords

The search strategy is to make use of a combination of keywords and Boolean operators, including "eco-dentistry" OR "green dentistry" AND "prosthodontics" OR "sustainable dental materials" OR "CAD/CAM dentistry" OR "digital dentures" OR "3D printing." Manual searches of reference lists from included articles were also conducted to identify additional relevant studies not captured during the initial search [4].

Inclusion Criteria

Studies were included if they:

- Addressed eco-friendly or sustainable practices relevant to prosthodontics
- Discussed environmental impact, sustainability, or green dentistry in prosthodontics or related dental specialties
- Work on sustainable materials such as zirconia, glass ceramics, or bio-based resins
- Measure digital workflows (CAD/CAM, intraoral scanners, 3D printing, digital dentures)
- Addressed waste management, recycling, energy efficiency, or water conservation in prosthodontic clinics or laboratories
- Explored educational, institutional, or policy perspectives on eco-dentistry
- Included original research, narrative reviews, systematic reviews, or institutional reports published in English
- Had full-text availability through institutional or open-access sources

Exclusion Criteria

Articles were excluded if they:

- Focused exclusively on general dentistry without prosthodontic relevance
- Without discussion of sustainability or environmental impact
- Provided less methodological detail or sustainability-related outcomes
- Represented the same publications of the same dataset
- Were conference abstracts, editorials, commentaries, or non–peer-reviewed sources [5]

Selection Process

The initial search yielded 721 records (to modify the following final screening). Titles and abstracts were separately screened by two reviewers for relevance. Full-text articles of potentially eligible studies were taken and checked against inclusion and exclusion criteria. Any differences were resolved through discussion and consensus[6].

Results

3.1 Digital Dentistry and Waste Reduction

The transition toward digital workflows in prosthodontics has been consistently associated with reduced material consumption and waste generation. Intraoral scanners are increasingly replacing conventional impression techniques, thereby minimizing the use of impression trays, alginate, and elastomeric materials [1]. Similarly, CAD/CAM systems have reduced reliance on gypsum casts, physical storage, and transportation of impressions, leading to a measurable reduction in packaging waste and carbon emissions [2].

Additive manufacturing technologies, particularly 3D printing, enable on-demand fabrication of crowns, bridges, and dentures. This approach optimizes material usage and reduces excess waste commonly associated with subtractive manufacturing processes [3]. Collectively, digital workflows enhance precision, cost-efficiency, and patient comfort while simultaneously supporting sustainability goals, positioning them as a cornerstone of eco-friendly prosthodontic practice [4].

3.2 Sustainable Prosthodontic Materials

Material selection plays a pivotal role in determining the environmental footprint of prosthodontic care. Zirconia and glass ceramics are increasingly reported as environmentally favorable materials due to their durability, biocompatibility, and potential for recycling [5]. Advances in bio-based resins and polymers have further contributed to sustainability by providing alternatives to conventional petroleum-derived acrylics commonly used in denture fabrication [6].

Efforts to reduce dependence on single-use plastics and non-biodegradable impression materials are also gaining momentum, underscoring the need for continued innovation in sustainable prosthodontic materials [7].

3.3 Energy Efficiency and Resource Management

Modern prosthodontic laboratories are increasingly adopting energy-efficient equipment, including low-energy milling units, optimized sintering furnaces, and induction casting devices, to reduce overall power consumption [8]. Recycling programs for dental alloys and prosthetic frameworks are becoming more widespread, supporting circular economy principles within dental laboratories [9].

Additionally, the implementation of water-saving devices, dust-filtration systems, and improved ventilation has been shown to reduce resource consumption while enhancing occupational safety [10].

3.4 Eco-friendly Clinical and Laboratory Practices

Digitally fabricated dentures, produced using CAD/CAM or 3D printing technologies, eliminate multiple steps involved in conventional flasking, packing, and curing procedures, thereby reducing resin waste and chemical exposure [11]. Although single-use plastics remain a major contributor to biomedical waste in dentistry, innovative strategies such as reusable or redesigned 3D-printed impression mixing tips have been introduced to mitigate plastic consumption [12].

Minimally invasive prosthodontic techniques, including adhesive restorations and conservative tooth preparation designs, align closely with eco-dentistry principles by preserving natural tooth structure and minimizing material usage [13]. Furthermore, widespread adoption of digital patient records has significantly reduced the environmental burden associated with paper-based documentation systems [14].

3.5 Patient and Professional Awareness

Awareness of sustainable dental practices is steadily increasing among both patients and dental professionals. Patients increasingly favor clinics that demonstrate environmental responsibility, with eco-dentistry influencing healthcare decision-making processes [15]. Academic institutions are progressively integrating eco-dentistry concepts into prosthodontic curricula, preparing future clinicians for sustainable practice models [16]. Additionally, eco-friendly branding has emerged as a strategic advantage for dental practices, enhancing patient trust and institutional reputation [17].

Discussion

This review highlights the contrast between conventional prosthodontic workflows and eco-dentistry-oriented approaches. Traditional prosthodontic practices rely heavily on physical impressions, gypsum casts, multiple laboratory procedures, and non-recyclable plastics, contributing substantially to material waste and environmental burden [18-20]. In contrast, eco-dentistry incorporates digital impressions, CAD/CAM workflows, and 3D printing technologies to streamline processes, reduce waste, and lower environmental impact [21-25].

Benefits of Eco-dentistry in Prosthodontics

The transition toward sustainable practices offers several advantages. Eco-friendly prosthodontic workflows significantly reduce waste by minimizing the use of conventional impressions and casts while employing efficient digital fabrication techniques [3]. These approaches also provide long-term economic benefits by reducing material waste, transportation requirements, and energy consumption [26]. Patient acceptance of digital and environmentally responsible treatments is generally favorable, reflecting a growing awareness of sustainability in healthcare [27]. Moreover, eco-dentistry in prosthodontics aligns closely with the United Nations Sustainable Development Goals (SDGs), reinforcing its relevance in broader global sustainability initiatives [28-30].

Challenges in Implementation

Despite these advantages, several challenges hinder widespread adoption. High initial investment costs associated with digital systems limit their accessibility, particularly for smaller practices [7], [31-33]. Limited availability of certified sustainable materials, along with concerns regarding their long-term performance, durability, and biocompatibility,

further constrain progress [8]. Additionally, the absence of standardized sustainability guidelines and the need for structured clinician training impede the consistent implementation of eco-dentistry practices [9].

Future Trends and Directions

Future developments are expected to focus on the advancement of recyclable and bio-based materials to further reduce environmental impact [10]. Comprehensive life-cycle assessment (LCA) studies will play a crucial role in evaluating the environmental footprint of dental materials and technologies, guiding evidence-based decision-making [11],[34-36]. The integration of artificial intelligence and cloud-based technologies is anticipated to optimize workflows, reduce waste, and enhance remote collaboration [12]. Finally, the establishment of eco-certification systems for prosthodontic laboratories may provide standardized sustainability benchmarks and encourage environmentally responsible practices across the profession [13].

Table-1: Comparison of Environmental Impact Between Traditional and Digital/Sustainable Prosthodontic Practices.

Key Aspect	Traditional Prosthodontic Practices	Digital / Sustainable Prosthodontic Practices	Environmental Impact Advantage
Impression Materials	Use of alginate, elastomers, trays, and disinfectants; largely single-use and non-recyclable	Intraoral scanners eliminate physical impression materials	Significant reduction in material waste
Model Fabrication	Gypsum casts requiring repeated pouring, trimming, and storage	Virtual models; limited or no physical casts	Reduced solid waste and storage demand
Material Waste	High waste from excess impression material, stone, wax, and casting sprues	Optimized material use via CAD/CAM and additive manufacturing	Lower overall waste generation
Manufacturing Method	Predominantly subtractive (milling, casting) with excess material loss	Additive manufacturing (3D printing) with on-demand fabrication	Improved material efficiency
Energy Consumption	Multiple laboratory steps, repeated remakes, prolonged equipment usage	Streamlined workflows with fewer steps and remakes	Lower cumulative energy use
Equipment Efficiency	Conventional furnaces and casting units with higher energy demand	Energy-efficient milling units and optimized sintering furnaces	Reduced power consumption
Transportation & Logistics	Physical transport of impressions, casts, and prostheses between clinic and laboratory	Digital data transfer; centralized or in-house fabrication	Reduced fuel use and emissions
Packaging Waste	Significant use of plastic and protective packaging	Minimal packaging due to digital file transfer	Lower plastic waste
Chemical Usage	Disinfectants, acrylic monomers, investment materials, and solvents	Reduced chemical exposure with digital workflows	Decreased chemical pollution
Paper Consumption	Paper-based records, prescriptions, and lab communication	Digital patient records and electronic communication	Reduced paper waste
Occupational Safety	Higher exposure to dust, monomers, and chemicals	Improved safety through enclosed digital systems	Health and environmental co-benefit
Overall Carbon Footprint	Higher due to materials, energy use, and transportation	Lower due to digitalization and resource efficiency	Improved sustainability performance

Conclusion

Eco-dentistry serves as a great transformation in prosthodontics, consolidating environmental stewardship with clinical excellence. The adoption of digital workflows, sustainable materials, and eco-friendly clinical and laboratory protocols has the ability to significantly decrease the specialty's ecological footprint while maintaining high standards of patient care [1, 2], [37].

Eco-certified materials have limitations. High initial investment costs are a barrier. The absence of sustainability metrics also continues [3, 4] [38].

To tackle these backlogs, coordinated efforts among clinicians, manufacturers, academic institutions, and policymakers are required.

Future research should prioritize the development of eco-friendly biomaterials, life-cycle assessments of prosthodontic products, and standardized sustainability guidelines [5]. Policy support and formal eco-certification systems may further increase the transition toward greener prosthodontic practice [6],[39-40].

In conclusion, eco-dentistry is not only an option but also an essential pathway for aligning prosthodontics with global sustainability goals, ensuring that advancements in dental care do not come at the expense of environmental health.

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