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Readiness and Capacity of Dental Hospitals for Implementing Green Dentistry and Sustainable Supply Chain Practices: A Qualitative Study in Makassar, Indonesia

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Abstract

Background: Climate change and the increasing volume of healthcare waste underscore the need for sustainable practices in dentistry. While green dentistry promotes efficiency, waste reduction, and eco-friendly technologies, its adoption in Indonesian dental hospitals remains limited.

Objective: This study aimed to assess the readiness of dental hospitals in Indonesia to adopt green dentistry practices and identify the factors that enable or inhibit their implementation.

Methods: A qualitative approach was employed through semi-structured interviews with dental healthcare professionals from selected hospitals. The interviews explored current sustainability practices, perceived challenges, institutional readiness, and stakeholder expectations regarding the implementation of green dentistry.

Results: While some initiatives, such as partial digitalisation and general awareness of waste management, exist, significant barriers hinder broader adoption. These include dependence on single-use materials, lack of structured recycling programmes, absence of formal policy support, limited training and awareness among staff, and financial constraints. Respondents expressed a strong willingness to transition toward greener practices if given appropriate institutional and policy support.

Conclusion: Indonesian dental hospitals show early signs of readiness but face structural and systemic challenges in implementing green dentistry. A coordinated approach involving institutional reform, government regulation, and stakeholder collaboration is necessary to facilitate a sustainable transition.

Unique Contribution: This study presents one of the first qualitative examinations of green dentistry readiness in Indonesia, illuminating systemic gaps and opportunities for environmental integration within dental healthcare. It bridges the knowledge gap between sustainability theory and practice in resource-constrained settings.

Key Recommendation: Stakeholders should prioritise the development of national guidelines for green dentistry, invest in staff training, promote cross-sector partnerships with suppliers of eco-friendly technologies, and implement financial incentives to support sustainability initiatives within dental healthcare facilities.

Keywords: Green dentistry, sustainable healthcare, environmental sustainability, waste reduction, medical waste management

Introduction

Global climate change and the rapid increase in medical waste have become critical environmental challenges, urging the health sector worldwide to adopt more sustainable practices, including those in dentistry (Batsford et al., 2022; Deshmukh et al., 2023). Green dentistry focuses on reducing energy consumption, minimising waste generation, and integrating digital and environmentally friendly technologies in dental care services (Brown, 2009; Duane et al., 2019a). Despite its potential benefits, the implementation of sustainable dental practices remains limited, particularly in developing countries like Indonesia (de Leon, 2020; Mulimani, 2017).

Healthcare services contribute significantly to environmental degradation through high energy use, large volumes of clinical waste, and extensive reliance on non-biodegradable materials. Dental

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facilities are notable contributors, producing substantial clinical waste such as single-use plastics, chemical residues, and consuming excessive amounts of water and electricity (Talli et al., 2025; Duane et al., 2019a). In light of escalating environmental concerns, it is imperative for healthcare institutions, including dental hospitals, to adopt sustainable operational models to reduce their ecological footprint.

The concept of green dentistry, or eco-friendly dental practice, involves environmentally responsible dental care by emphasising resource efficiency, waste reduction, and the use of biocompatible and recyclable materials while maintaining high standards of patient care (Alsawaf & Albadry, 2022; Brown, 2009). Core strategies include the digitalisation of medical records to reduce paper consumption, the adoption of energy-efficient equipment, systematic waste management, and re-engineering clinical workflows aligned with ecological sustainability (de Leon, 2020; Mulimani, 2017).

While developed countries have integrated green dentistry into health policies and institutional operations, adoption in Indonesia and similar developing contexts remains nascent. Major obstacles include a lack of regulatory frameworks, limited financial and technical resources, and insufficient training of dental healthcare professionals (Batsford et al., 2022). Additionally, most Indonesian research on green dentistry is conceptual, lacking empirical evidence on institutional readiness for implementing sustainable practices.

Assessing the readiness of dental hospitals to implement green dentistry is vital for designing effective interventions. Readiness encompasses infrastructure, technological capacity, as well as the awareness, attitudes, and behaviours of healthcare providers, which collectively influence the successful adoption of innovation (Deshmukh et al., 2023). Qualitative methods, particularly semi-structured interviews with dental practitioners, offer critical insights into the contextual challenges and practical experiences that influence the transition toward sustainable dental care.

This study aims to evaluate the readiness of Indonesian dental hospitals to implement green dentistry principles through qualitative interviews with dental health professionals. The research focuses on current sustainable practices, barriers encountered, institutional support systems, and future perspectives on eco-friendly dental services. Findings will inform policymakers, educational institutions, and healthcare administrators on how to accelerate the adoption of green dentistry, thereby contributing to the broader goals of environmental engineering and ecological sustainability in healthcare. Key research areas include reducing single-use materials, adopting digital technologies, improving energy efficiency, implementing waste management programmes, and identifying challenges in green dentistry applications within the Indonesian context.

Methods

Study Design

This study employed a qualitative research design using a phenomenological approach, targeting hospital directors in Makassar City as the population. The phenomenological method was chosen

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to explore in depth the lived experiences and perspectives of hospital directors regarding missed opportunities, referred to as gap chances in implementing Environmentally Friendly Dentistry (EFD). A qualitative approach was considered appropriate for capturing rich, contextualised insights, especially within the hospital systems of Makassar City, where institutional dynamics and experiences vary among informants.

Study Setting

This study was conducted in four dental and oral health institutions located in Makassar City, Indonesia. These included the Dental and Oral Hospital of Hasanuddin University (RSGM Unhas), the Dental and Oral Hospital of the Muslim University of Indonesia (RSIGM UMI), the Yos Sudarso Naval Dental and Oral Hospital (RSGM TNI AL Yos Sudarso), and the South Sulawesi Provincial Dental and Oral Hospital (RSKDGM South Sulawesi). These institutions were selected due to their relevance in providing specialised dental services and their strategic role in advancing environmentally sustainable practices within the healthcare sector.

Participants and Recruitment

The study involved four participants, each serving as a hospital director and manager in the selected institutions. Participants were selected through purposive sampling based on specific inclusion criteria. Informants were required to hold the position of hospital director or an equivalent strategic managerial role with decision-making authority over hospital operations. They were also required to have a minimum of three to five years of experience in hospital management, particularly in the context of dental or oral health services. Additional inclusion criteria included a willingness to participate voluntarily in the interview and the ability to provide informed consent. Informants were also required to reside in or near Makassar City to facilitate either face-to-face or remote interviews, depending on availability. Recruitment involved direct contact with each potential participant, during which the researcher explained the study's objectives and procedures. Once verbal and written consent were obtained, the interviews were scheduled at mutually convenient times.

Data Collection

Data collection was conducted through semi-structured interviews. An interview guide was developed in advance to direct the conversation, ensuring consistency while allowing for flexibility in follow-up questions. The guide contained open-ended questions designed to explore issues related to the implementation of environmentally friendly practices in dental health services, perceptions of current challenges, and potential future opportunities. Interviews were conducted either in person or via online platforms, depending on participant availability. All interviews were audio-recorded with the participants' permission. Field notes were also taken to document contextual details and any relevant observations made during the interviews.

Data Analysis

Interview data were transcribed verbatim and analysed using a thematic analysis method based on the framework outlined by Feng and Behar-Horenstein (2019). The process involved open coding to identify initial codes, grouping related codes into broader categories, and synthesising these into

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overarching themes. NVivo software was used to organise and manage the data systematically. Themes were interpreted in relation to the study objectives to provide a nuanced understanding of the gaps in implementing environmentally sustainable practices in dental hospitals.

Ethical Considerations

This study received ethical approval from the Health Research Ethics Committee, Faculty of Public Health, Hasanuddin University. The approval number is 2880/UN4.14.1/TP.01.02/2024. Prior to participation, all informants were provided with detailed information about the study's objectives, procedures, and confidentiality measures. Written informed consent was obtained from all participants. The study adhered to the principles of the Declaration of Helsinki regarding ethical standards in research involving human participants.

Results

Informant Characteristics

Table 1. *Informant characteristics*

Code	Sex	Age	Position	Hospital
1.1	Female	37	Hospital Director	RSIGM UMI
1.2	Female	53	Hospital Director	RSGM TNI AL Yos Sudarso
1.3	Female	48	Hospital Manager	RSKDGM South Sulawesi
1.4	Male	50	Hospital Director	RSGM Unhas

This study involved four informants, consisting of one male and three females, aged between 37 and 53 years. Informants were professionals serving as hospital directors or managers in dental and oral hospitals in Makassar. Their length of work experience ranged from 3 to 15 years, offering a diverse yet relevant perspective on the topic of sustainable dental practice implementation.

Emerging Theme

Use of single-use products

The RSGM Unhas minimises the use of single-use products to improve cost efficiency and reduce waste, but continues to use disposable items for specific instruments, such as syringes and headscopes, to maintain safety standards. Conversely, RSIGM UMI still relies heavily on single-use products like personal protective equipment and masks. This was confirmed during interviews where one participant stated, "*Some products must be single-use, such as syringes and headscopes, but we try to use sterilisable tools whenever possible.*" Another interviewee noted, "*We consider cost efficiency by choosing reusable tools without compromising hygiene.*" Despite the necessity for certain disposable items, efforts to reduce single-use products through reuse and sterilisation balance cost, safety, and environmental concerns.

Adoption of digital technology

All hospitals have adopted electronic medical records (EMR), with the South Sulawesi Provincial Dental and Oral Hospital in the process of transitioning to a fully paperless system. Interview data supported this, with one respondent saying, "*We have implemented EMR to reduce paper use in*

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hospital administration." Another stated, "*Patient registration and scheduling are now online, reducing physical queues.*" These digital initiatives have effectively reduced paper waste and improved operational efficiency, representing significant progress toward sustainable healthcare delivery.

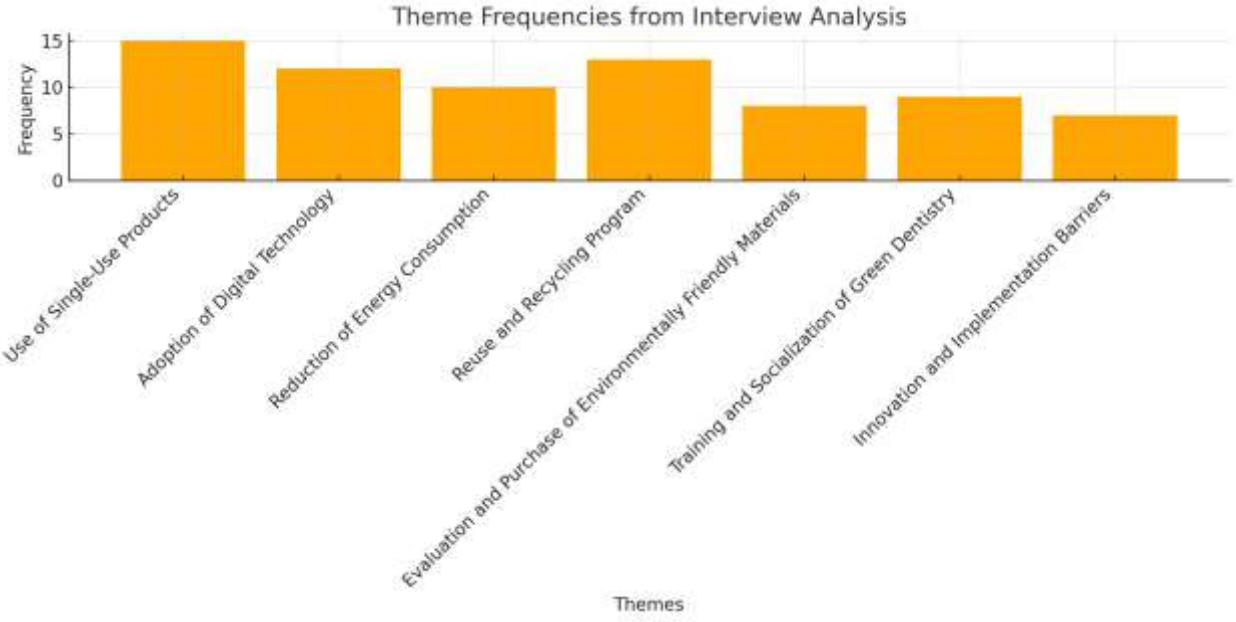

Figure 1. Distribution of theme frequencies

Energy consumption reduction

Energy-saving policies are implemented in all hospitals, including turning off unused electronic devices and replacing traditional lighting with energy-efficient light-emitting diode (LED) bulbs. Natural ventilation is also utilised to decrease air conditioning use. Interviewees shared, "*We switched to LED lights as part of our efforts to cut electricity use,*" and "*Some rooms use natural ventilation to reduce air conditioning.*" Such practical measures contribute to sustainability goals by lowering electricity consumption and operational costs.

Reuse and recycling programmes

All hospitals reuse stainless steel instruments after sterilisation and segregate non-medical waste for recycling through third-party partnerships. Interview comments included, "*Medical waste is carefully separated to meet standards for further processing,*" and "*We collaborate with external parties to recycle plastics and paper from hospital operations.*" The combination of stringent waste segregation and recycling partnerships demonstrates a strong commitment to minimising environmental impact.

Evaluation and procurement of eco-friendly materials

Some hospitals are beginning to assess and replace chemical materials with more environmentally friendly options. Interviewees said, "*We regularly evaluate chemicals to choose the most*

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environmentally safe," and "*When possible, we switch to biodegradable alternatives.*" Although still emerging, this focus on eco-friendly materials indicates growing environmental awareness influencing procurement decisions.

Training and socialization on green dentistry

Periodic training for staff and patient education on sustainable dentistry exist but remain limited. Interview feedback included, "*We hold regular training on eco-friendly dental practices,*" and "*We educate patients on the importance of sustainability in oral health.*" These training efforts play an important role in fostering a culture of environmental responsibility within hospitals and encouraging wider adoption of green dentistry.

Innovation and implementation barriers

Key barriers include high initial investment costs, lack of staff awareness, and limited regulatory support. One interviewee noted, "*We want to adopt more green innovations, but high startup costs hold us back,*" while another commented, "*Supportive regulations would greatly aid green practice implementation.*" Addressing these financial, regulatory, and behavioural challenges will be crucial to enabling broader adoption of sustainable dental care practices.

Key findings summary of the emerging themes

The study revealed that efforts to reduce single-use products are actively implemented, particularly through sterilisation and reuse, balancing cost efficiency and safety. The adoption of digital technology, including electronic medical records and online patient services, effectively reduces paper waste and enhances hospital operations. Energy conservation measures such as switching to LED lighting and utilising natural ventilation contribute to lowering electricity consumption. Reuse and recycling programmes, supported by strict waste segregation and collaboration with third parties, play a vital role in managing hospital waste. Although eco-friendly material procurement is still emerging, some hospitals are beginning to prioritise biodegradable and less harmful substances. Training programmes on green dentistry exist but are limited in scope, highlighting the need for expanded education and awareness. Key barriers to sustainability include high initial costs, limited regulatory support, and a staff mindset that hinders the broader implementation of environmentally friendly practices. Overall, the focus remains on reducing disposables, embracing digital tools, and improving waste management. Overcoming financial and institutional challenges is essential for future progress.

Word Cloud of Key Themes

The word cloud above illustrates the key themes that emerged from the interview analysis on environmentally friendly dental practices. Larger words represent themes that appeared more frequently in the interviews, while smaller words indicate less frequent mentions. The main themes can be interpreted as follows:

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The prominence of terms like "Usage," "Products," and "Single-Use" highlights that the topic of disposable product use is the most frequently discussed. This reflects a strong concern among dental professionals about the waste generated from single-use tools in dental practice.
Terms such as "Adoption," "Technology," and "Digital" emphasize the critical role of digital transformation in supporting green dentistry. Digital technologies, including electronic medical records and online appointment systems, are recognized as important steps toward reducing paper use and enhancing operational efficiency.

Figure 2. Word cloud of key themes

Words like "Reduction," "Energy," "Recycling," and "Reuse" underscore efforts to lower energy consumption and implement recycling and reuse programmes. These themes indicate that resource efficiency is a core component of sustainability strategies within dental settings. The appearance of "Evaluation," "Purchasing," "Materials," and "Environmentally Friendly" points to an increasing focus on selecting greener materials in hospital and clinic operations. Evaluating medical supplies and collaborating with suppliers to source sustainable products are key considerations in the interviews.

Finally, the presence of "Training," "Socialisation," "Implementation," and "Barriers" suggests that educating staff and promoting awareness about green dentistry remain challenges. Obstacles such as limited regulatory support and high initial costs hinder the broader adoption of environmentally sustainable practices. Overall, the word cloud reveals that the primary areas of focus are reducing single-use products, adopting digital technology, minimising energy consumption, and evaluating eco-friendly materials. Despite ongoing efforts, challenges in training and outreach persist and must be addressed to ensure the successful and sustainable implementation of green dentistry practices.

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Coding Occurrences Across Hospitals

The chart in Figure 3 displays the frequency of various themes mentioned during interviews conducted across several hospitals. The patterns observed can be interpreted as follows:

High-frequency themes (4 occurrences)

"Use of Single-Use Products" and "Adoption of Digital Technology" are the most frequently mentioned themes, each appearing four times. This indicates that concerns about disposable product waste and the shift towards digital solutions are top priorities in nearly all hospitals interviewed. It suggests that hospitals are actively seeking ways to reduce medical waste while improving efficiency through digitalisation.

Medium-frequency themes (3 occurrences)

Themes such as "Energy Consumption Reduction," "Reuse and Recycling Programs," and "Evaluation and Procurement of Environmentally Friendly Materials" appeared three times each. This reflects that energy efficiency and recycling initiatives are recognised as important but may not yet be fully implemented across all hospitals. Similarly, the evaluation of medical materials is gaining attention but has yet to become a primary focus.

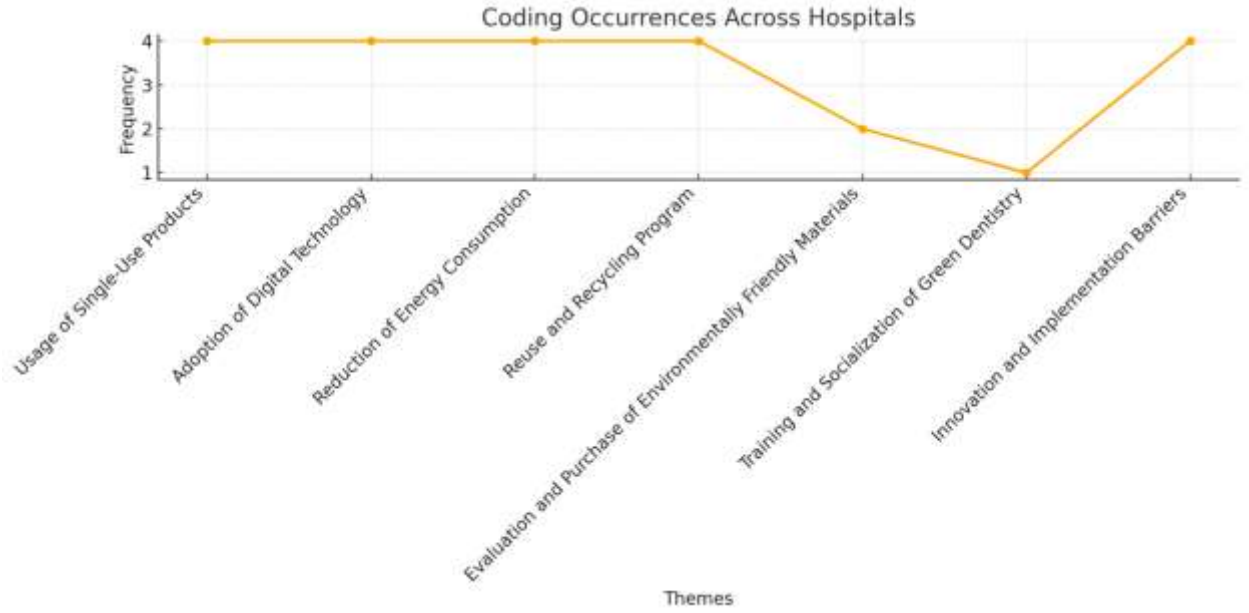

Figure 3. Coding occurrences across hospitals

Low-frequency themes (1–2 occurrences)

"Training and Socialisation of Green Dentistry" appeared only twice, indicating that education and awareness about environmentally friendly practices are still limited. "Innovation and Implementation Barriers" were mentioned just once, suggesting that while innovations exist, challenges in implementation have received little emphasis or discussion during the interviews.

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Overall, the chart reveals that managing single-use products and advancing digitalisation are the primary issues hospitals face. Efforts toward energy efficiency and recycling are somewhat recognised but lack widespread implementation. Meanwhile, challenges in staff training and green dentistry innovation remain areas that need improvement to support the more effective adoption of sustainable practices in hospitals.

Coding Matrix Query

Table 2 presents the coding matrix query, which shows the distribution of Green Dentistry themes across four hospitals. Five themes are applied consistently in all hospitals, as indicated by checkmarks in every column. These include the usage of single-use products, adoption of digital technology, reduction of energy consumption, reuse and recycling programmes, and innovation, along with implementation barriers. This pattern demonstrates that all hospitals have a strong awareness and commitment to reducing medical waste, improving energy efficiency, and embracing digital transformation while pursuing innovation in Green Dentistry practices. The continued use of single-use products is likely due to safety and sterilisation requirements inherent in dental procedures. The universal adoption of digital technology reflects a collective effort to move towards efficient, paperless healthcare systems. Furthermore, efforts to reduce energy consumption and implement recycling programmes indicate proactive steps to lessen environmental impacts. However, even though innovation is pursued across all hospitals, challenges persist in its implementation.

Table 2. *Coding matrix query*

Theme	RSGM Unhas	RSIGM UMI	RSKDGM South Sulawesi	RSGM TNI AL Yos Sudsarso
Usage of Single-Use Products	✓	✓	✓	✓
Adoption of Digital Technology	✓	✓	✓	✓
Reduction of Energy Consumption	✓	✓	✓	✓
Reuse and Recycling Programme	✓	✓	✓	✓
Evaluation and Purchase of Environmentally Friendly Material	✓	✕	✓	✕
Training and Socialization of Green Dentistry	✕	✕	✓	✕
Innovation and Implementation Barriers	✓	✓	✓	✓

In contrast, some themes are inconsistently applied. For example, the evaluation and purchase of environmentally friendly materials are practised only by RSGM Unhas and RSKDGM South Sulawesi, but not by RSIGM UMI and RSGM TNI AL Yos Sudarso. This inconsistency suggests that not all hospitals have established standards or policies for selecting eco-friendly materials. Possible barriers include financial limitations or regulatory gaps that hinder wider adoption. Similarly, training and socialisation of green dentistry are conducted only at RSKDGM South Sulawesi, while the other three hospitals lack formal education or training programmes related to sustainable dental practices. This gap highlights a major barrier because, without proper training, healthcare workers may not fully understand or effectively implement environmentally friendly practices.

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Overall, most hospitals have embraced the fundamental principles of green dentistry, particularly in digitalisation, energy conservation, and recycling efforts. However, the evaluation and procurement of environmentally friendly materials remain inconsistent, likely due to cost and accessibility issues. The scarcity of training and awareness programmes indicates the need to enhance education and strengthen regulations to better prepare medical personnel for implementing green practices.

To address these issues, it is recommended that education and training initiatives for healthcare staff be increased, which will enhance the effective adoption of green dentistry. Additionally, encouraging regulations and offering incentives for hospitals to use eco-friendly materials will help promote sustainable practices. Establishing partnerships with suppliers of environmentally friendly medical products can also facilitate better access and more competitive pricing for these materials.

Discussion

This study found that although most dental hospitals have made efforts to reduce the use of single-use products, some still rely heavily on them, especially for instruments that cannot be re-sterilised. The continued use of disposable products is closely linked to hygiene standards and patient safety concerns, which remain significant barriers to reducing waste in dental practice. This aligns with the findings of Batsford et al. (2022), who identified reducing single-use products as a major challenge, despite the potential for considerable cost savings and environmental benefits. However, some studies also suggest that healthcare professionals often resist reducing the use of single-use products due to perceived health risks. Duane et al. (2019b) noted that although reusable and sterilisable instruments provide ecological advantages, transitioning away from disposables requires time and intensive training for medical staff.

All dental hospitals surveyed have adopted EMR, and some are moving towards entirely paperless systems. The application of digital technology in dentistry has proven effective in lowering paper consumption and enhancing operational efficiency. Khanna and Dhaimade (2019) demonstrate that EMR can significantly reduce the environmental impact of dental hospitals by minimising the use of physical resources, such as paper and ink. Nonetheless, in developing countries such as Indonesia, the adoption of digital technologies is often limited by financial constraints and infrastructural challenges. Debrah et al. (2022) highlight that while digital solutions offer potential savings and improved efficiency, their implementation is frequently hindered by inadequate access and insufficient training.

Energy-saving measures, such as the use of energy-efficient LED lighting and natural ventilation, have been implemented across all hospitals studied, reflecting an increased awareness of energy efficiency within Green Dentistry practices. Saxena et al. (2023) support these findings by emphasising that reducing energy consumption is a vital element of sustainability in healthcare facilities. Despite the adoption of these measures, research indicates that energy-saving efforts

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often remain confined to basic infrastructure improvements, with less focus on upgrading to more energy-efficient medical devices. According to Mulimani (2017), achieving substantial energy savings in dentistry requires investment in advanced, energy-efficient equipment, which can be costly.

Recycling programmes for non-medical waste have also been established in collaboration with third-party vendors, consistent with Fotovatfard and Heravi's (2021) assertion that managing non-medical waste through recycling is essential to reducing the environmental footprint of hospitals. Some hospitals also prioritise recycling of medical waste, although this requires strict segregation protocols to ensure safety. A significant challenge remains the lack of clear regulatory frameworks governing medical waste management, resulting in inconsistent recycling practices. Debrah et al. (2022) also noted that in developing countries, weak regulations hinder the successful implementation of sustainable waste management initiatives.

Training related to Green Dentistry is still limited, with only one hospital regularly conducting education programmes for staff. Rupa et al. (2015) emphasize that continuous training is critical to ensuring effective adoption of environmentally friendly practices. Without adequate training, healthcare professionals may not fully understand the importance of waste reduction and energy efficiency, which could hinder the adoption of green practices in dental care settings.

Several barriers to implementing Green Dentistry have been identified, including high initial costs associated with adopting eco-friendly technologies and products, as well as resistance among healthcare workers to change long-standing conventional practices (Wadhawan et al., 2024). Deshmukh et al. (2023) confirm that upfront implementation costs pose one of the most significant challenges for introducing green technologies in healthcare, particularly in developing countries.

In summary, while dental hospitals in Makassar have made notable strides towards implementing Green Dentistry practices and sustainable supply chain management, significant challenges remain. Efforts to reduce single-use products, adopt digital technologies, conserve energy, and promote recycling demonstrate a growing awareness of environmental responsibility. However, barriers such as financial constraints, infrastructural limitations, insufficient training, regulatory gaps, and resistance to change continue to impede full-scale implementation. Addressing these challenges will require coordinated efforts involving policy support, capacity building, investment in green technologies, and ongoing education for healthcare professionals.

Equally important is the role of committed leadership at both institutional and policy levels. Strong leadership can drive organisational change, allocate resources effectively, foster a culture of environmental responsibility, and ensure that green dentistry principles are embedded in hospital operations. Without sustained commitment from leaders, efforts toward sustainable practices risk losing momentum and failing to achieve a meaningful, long-term impact (Badanta et al., 2025). Only through such comprehensive strategies, supported by visionary leadership, can sustainable

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practices be effectively integrated into dental healthcare, ultimately reducing environmental impact while maintaining patient safety and quality of care.

This study offers important strengths, including being among the first in Indonesia to explore the readiness and capacity of dental hospitals in implementing green dentistry and sustainable supply chain practices. The use of a phenomenological approach captured rich, in-depth insights from hospital directors across diverse institutional settings, providing a nuanced understanding of institutional perspectives. However, the small number of participants and the focus on Makassar City may limit the breadth and generalisability of the findings. Additionally, as the data relied on self-reported information, the potential for social desirability bias should be considered when interpreting the results.

Conclusion

The findings indicate that although several elements of sustainable dentistry have been implemented, significant challenges remain in reducing single-use products, advancing recycling programmes, and enhancing awareness among healthcare professionals. To address these issues effectively, it is essential to strengthen regulations and policies that support environmentally friendly practices in dental hospitals. Additionally, providing incentives to encourage dental facilities to adopt greener technologies and materials will help accelerate progress. Implementing comprehensive training and educational programmes is necessary to raise awareness among dental healthcare workers about the importance of sustainable dentistry. It is also crucial to establish partnerships with suppliers to ensure the consistent availability of eco-friendly dental equipment and materials. Overall, collaboration among government bodies, academic institutions, and industry stakeholders is crucial to support and speed up the adoption of sustainable dental practices throughout Indonesia.

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