applied sciences

Systematic Review

Dental Solid Waste Analysis: A Scoping Review and Research Model Proposal

Ioanna Mitsika [1,2], Maria Chanioti [1] and Maria Antoniadou [1,*]

[1] Department of Dentistry, School of Health Sciences, National and Kapodistrian University of Athens, 11527 Athens, Greece; ioannamhtsika@gmail.com (I.M.); mariachanioti1@gmail.com (M.C.)
[2] Postgraduate Program in Epidemiology—Research Methodology in Biomedical Sciences, Clinical Practice and Public Health, Department of Medicine, School of Health Sciences, National and Kapodistrian University of Athens, 11527 Athens, Greece
* Correspondence: mantonia@dent.uoa.gr; Tel.: +30-6944-342-546

Featured Application: This scoping review emphasizes the environmental responsibility of dental healthcare concerning dental solid waste. It calls for a collective effort to ensure that the practices aimed at preserving health do not compromise the well-being of our planet and future generations, avoiding the improper disposal and accumulation of dental waste.

Abstract: In the face of 21st-century environmental challenges, including climate change, migration pressures, and waste disposal issues, certain healthcare sectors, notably dentistry, pose a significant global environmental footprint with concerns about carbon emissions and waste production. This scoping review searches the paradox that healthcare, while dedicated to safeguarding health, inadvertently contributes to environmental degradation through waste accumulation and disposal. The analysis of the relevant literature emphasizes the imperative for an environmentally sustainable approach to dental waste measurement, disposal methods, and comprehensive education for stakeholders. Aligned with the World Conference on Sustainable Development and the United Nations' 2030 Agenda, the study adhered to PRISMA-ScR systematic review guidelines and the Institute of Medicine's recommendations. The study utilized Medline/PubMed and international organization websites for data retrieval, employing Boolean operator queries in Medline. The systematic literature analysis identified six cross-sectional studies (2004–2023) highlighting variations in dental waste composition due to the lack of standardized identification methods. This heterogeneity underscores the need for a proposed research model, emphasizing comprehensive methodologies and healthcare staff training in waste management, thus transforming the analysis into a scoping review. The study advocates for environmentally conscious dental practices, contributing to broader sustainable healthcare goals through sharing of a research protocol for dental solid waste management.

Keywords: environmental impact; waste production; dental waste; carbon footprint; dental services; sustainability; dental practice; research model

Citation: Mitsika, I.; Chanioti, M.; Antoniadou, M. Dental Solid Waste Analysis: A Scoping Review and Research Model Proposal. *Appl. Sci.* **2024**, *14*, 2026. https://doi.org/10.3390/app14052026

Academic Editors: Nuno Lapa and Elena Surra

Received: 25 January 2024
Revised: 22 February 2024
Accepted: 24 February 2024
Published: 29 February 2024

1. Introduction

Humanity confronts profound environmental challenges in the 21st century [1]. Climate change manifests in rising ocean temperatures, land degradation, altered precipitation, sea level rise, ocean acidification, extreme weather events, and biodiversity loss. Climate change, coupled with migration pressures, waste accumulation, and threats to food and health security, poses the most urgent challenges to sustaining the planet [2]. Epidemiological studies estimate that climate change currently may have an impact on more than 150,000 deaths worldwide per year and, between 2030 and 2050, this number will rise to 250,000 additional deaths per year [3]. Moreover, examining the global healthcare system reveals that its environmental, social, and economic sustainability is questionable due to significant carbon dioxide and waste production and disposal issues [4]. Specifically, as mentioned by WHO, the total amount of waste generated by healthcare activities is approximately 85% general, nonhazardous waste [5]. The remaining 15% is considered hazardous material that may be infectious, toxic, or radioactive. It is further estimated that 16 billion injections are administered worldwide annually, but not all needles and syringes are disposed of properly. To add more, a healthcare waste that is incinerated or burned in open space may release dioxins, furans, and particulates [5].

Sustainability, on the other edge, entails human activities meeting present needs without compromising the needs of future generations, achieving a balance between economic growth, environmental care, and social well-being [6]. In dental clinical practice, sustainability involves providing ethical, high-quality care using efficient materials, emitting low carbon dioxide, and producing less waste [7]. For example, adopting a digital working protocol with the use of a digital scanner and a digital X-ray machine can contribute to this goal by applying new technology [8].

The three pillars of sustainability, social equity, economic sustainability, and environmental preservation, emerged from the 2005 World Conference on Sustainable Development [9]. The 2030 Agenda for Sustainable Development, adopted in 2015, outlines 17 goals across social, economic, and environmental categories specifically identifying the problem of waste accumulation and disposal [8–10]. Additionally, the FDI World Dental Federation published a statement in 2017 highlighting sustainability in dentistry [7]. In particular, the paper states that, by promoting good oral health habits and facilitating access to health services for all people, we contribute substantially to the health and well-being of populations worldwide. We may also help achieve environmental goals as well as foster inclusive, productive, and healthy living environments. According to the statement, whenever possible, dentistry should then limit energy, water, and paper consumption, emissions to the air and discharges to the water, as well as the improper disposal of environmentally harmful materials.

Dental waste poses significant environmental challenges, with dental mercury, primarily from dental amalgam waste, being a major contributor [8]. Regulations enforcing proper collection of mercury-contaminated waste, especially from extracted teeth with amalgam fillings, are crucial to prevent the release of harmful mercury vapor during combustion [9]. However, adherence to hazardous dental waste collection rules varies worldwide [10,11]. Additionally, the systematic classification of solid waste in dental practices reveals alarming figures, with infectious waste constituting more than 90% [8]. The absence of waste management plans in surveyed clinics, coupled with dentists' lapses in handling mercury-containing waste, and recycling in the dental office raise concerns about effective healthcare waste disposal [11]. Public safety concerns heighten as dentists must control the critical issue of dental waste, recognizing it as a pressing environmental concern, especially with the protocols that arose during and after the COVID-19 pandemic [10,11]. As is derived from the relevant literature, urgent measures and comprehensive waste management strategies are imperative to address these challenges effectively [12]. In this sense, the World Dental Federation published a statement entitled "Sustainability in Dentistry" in 2017 [13]. This document is based on the Sustainable Development Goals of the United Nations 2030 Agenda for Sustainable Development mentioned before. The goal is to lay the groundwork for defining a greener and more sustainable dental clinical practice, emphasizing the use of new equipment technology to reduce waste production and disposal among other issues.

Despite the legislative effort worldwide, a systematic review on dental solid waste (DSW) is missing from the relevant literature. Thus, this systematic review aims to comprehensively address the multifaceted challenges surrounding DSW production and management of the last 24 years. Objectives include quantitatively assessing DSW scale, investigating disposal challenges, and examining the environmental impact. This study further evaluates global adherence to hazardous waste collection rules in dental facilities, analyzes the systematic classification of solid waste in dental practices, and explores any lapses in handling mercury-containing waste. Additionally, it examines the post-pandemic impact on dental waste management and critically evaluates research methodologies in the existing literature. The overarching goal is to provide insights and recommendations for advancing sustainable practices through waste management within dental clinical settings by systematically evaluating existing data and proposing a future research model on the issue.

2. Materials and Methods

For this study, we addressed the design and implementation of a systematic review. All publications from 2000 to November 2023 reporting on waste management in dental practices and dental laboratories, as well as the ecological footprint of dentistry, were included in this study. Figure 1 shows a brief classification of dental waste categories used to describe the issue in this study.

Further, to be considered for inclusion in the study sample, publications could not be narrative reviews, systematic reviews, letters to the editor, or editorials. Any study that did not explain the process for collecting, separating, and analyzing dental waste, lacked an abstract, or used a language other than English was further excluded. In Tables S1 and S2, the papers that were excluded can be found, along with the reasons for exclusion.

The Preferred Reporting Items for PRISMA-ScR scoping review statement [14] and the Institute of Medicine's guidelines [15] were followed in this study. Additionally, the electronic database of Medline/PubMed was used. Also included were the websites of international organizations such as the Health and Social Care Information Centre, the United Nations Framework Convention on Climate Change, the American Society for Testing and Materials, the World Dental Federation, the World Economic Forum, and Public Health England accessed by 18 November 2023.

Using queries with Boolean operators as keywords for titles and abstracts, an electronic search was performed in Medline (via PubMed). Specifically, we used the following search query: ("dental laboratoires") OR ("dental practice") OR ("dentistry") AND ("sustainab*") OR ("green dentistry") AND ("waste management") OR ("carbon footprint") OR ("green dentistry") OR ("dental solid waste") OR ("carbon emissions"). The references of each paper were reviewed and conference abstracts were searched as well. The last search date was 1 November 2023. Furthermore, papers that had already been published at the time of the search were only included in the analysis.

Overall, 13 cross-sectional studies published through November 2023 were assessed for eligibility but only 6 full-text articles were included in the final analysis. In 7 of the excluded studies, dental waste was measured and separated by weight/day or grams/day, rather than by the $w/w\%$ ratio. Due to the variability of sampling days, dental structures involved, and lack of raw data in each study, it was not feasible to group and compare the data on $w/w\%$ ratios. Also, taking into consideration the heterogeneous nature of the $w/w\%$ ratio in these studies, exclusion was decided due to the number of samples, the different units of measurement, and the classification of waste. Based on the search strategy, PRISMA-ScR Flow Chart [14] demonstrates the results (Figure 2).

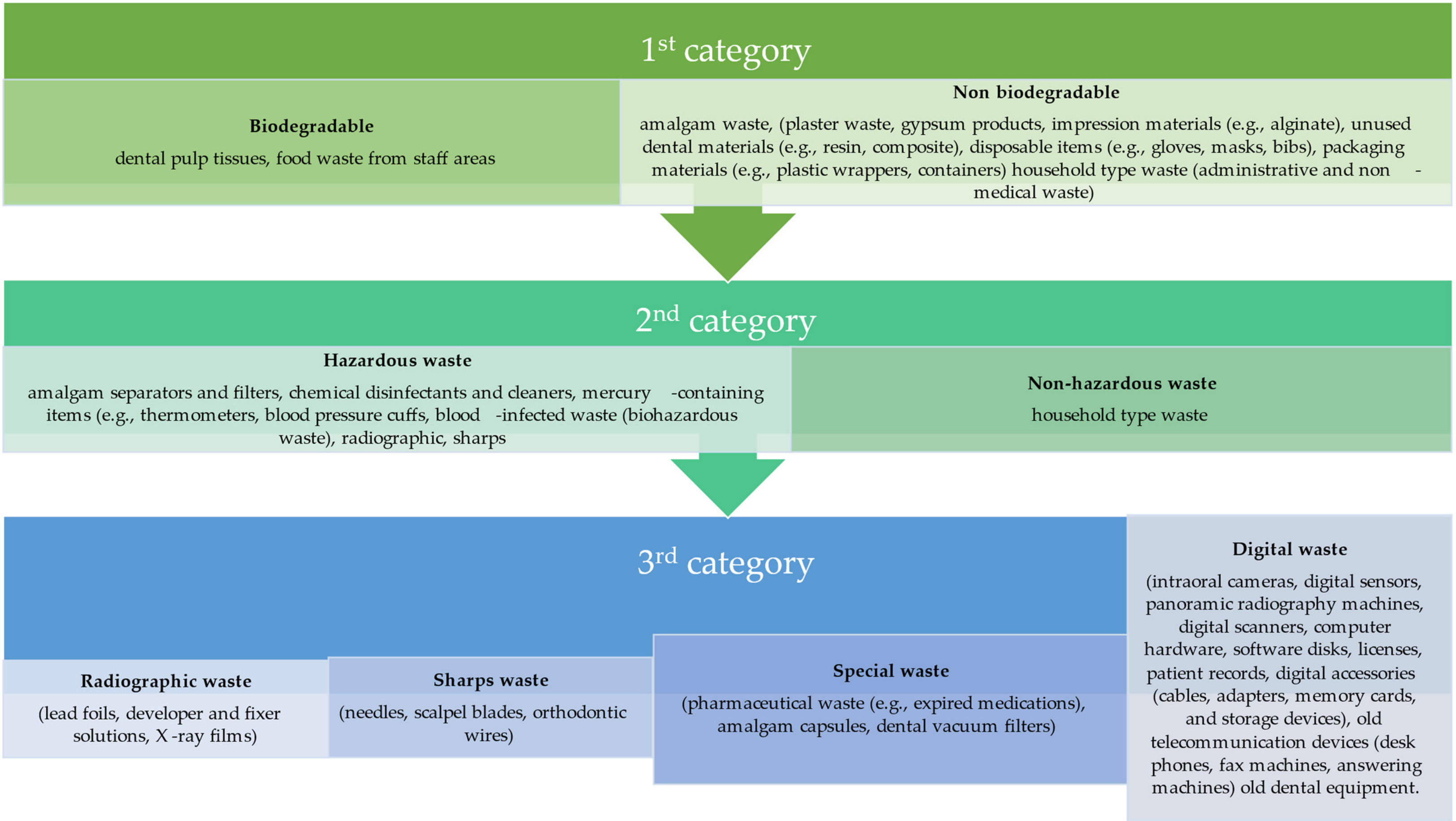

Figure 1. Classification diagram of dental waste categories.

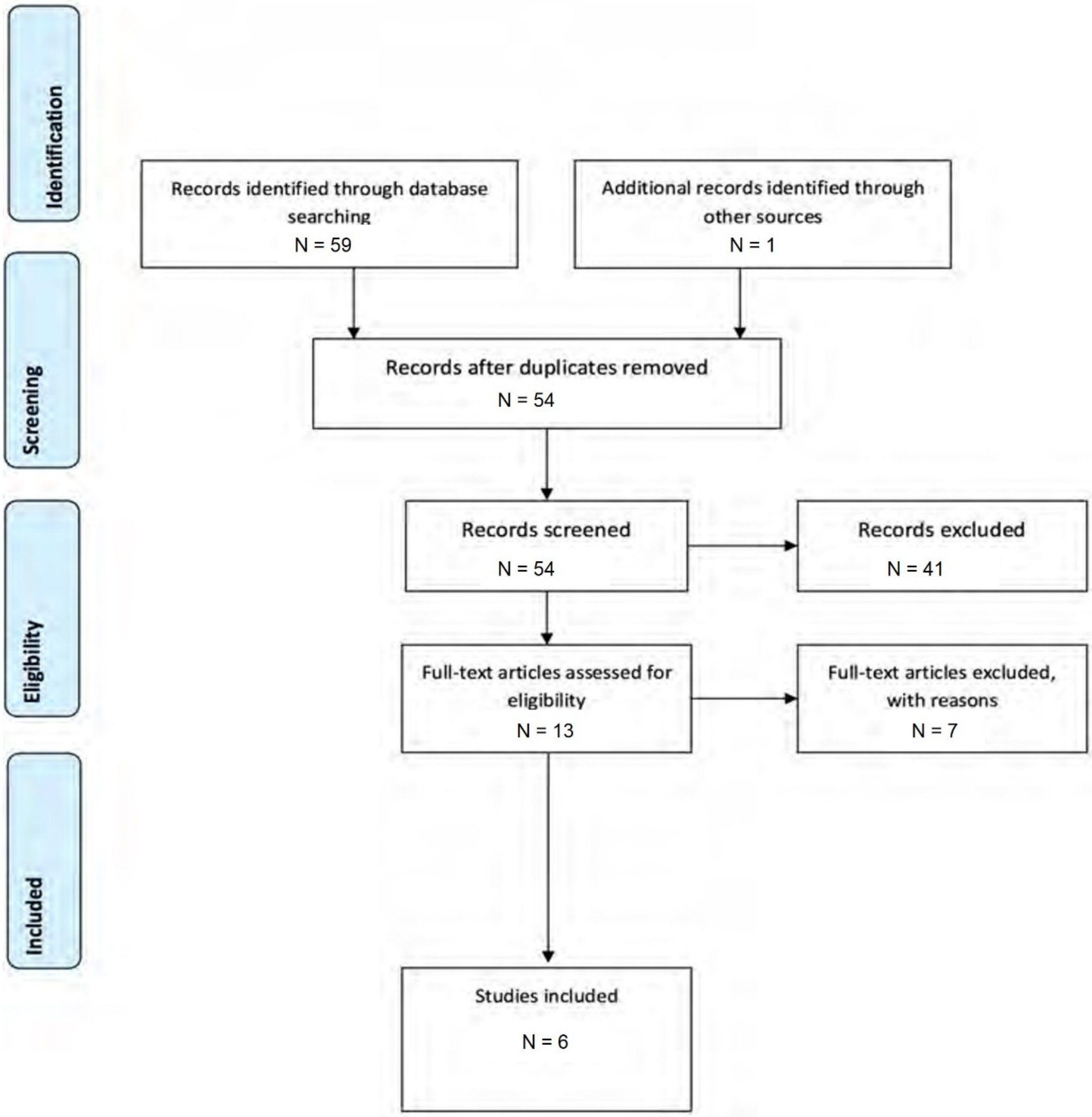

Figure 2. Flow chart PRISMA of the study.

3. Results

3.1. Data Charting Process

Data collection protocols were designed based on forms with 12 variables for each study. Data were obtained from the studies for the following variables: sampling year, study location, number of overall samples, the sector of the healthcare facility (public or private), number of general dental practices, number of dental clinics with specialties, number of laboratories, amount of infectious and potentially infectious waste, amount of toxic/chemicals/pharmaceuticals waste, amount of household-type waste, total dental hazardous waste, and total dental solid waste. The selected studies were examined independently. A rising trend in articles addressing dental waste can be observed in Figure 3, indicating a consistent increase in the number of publications each year.

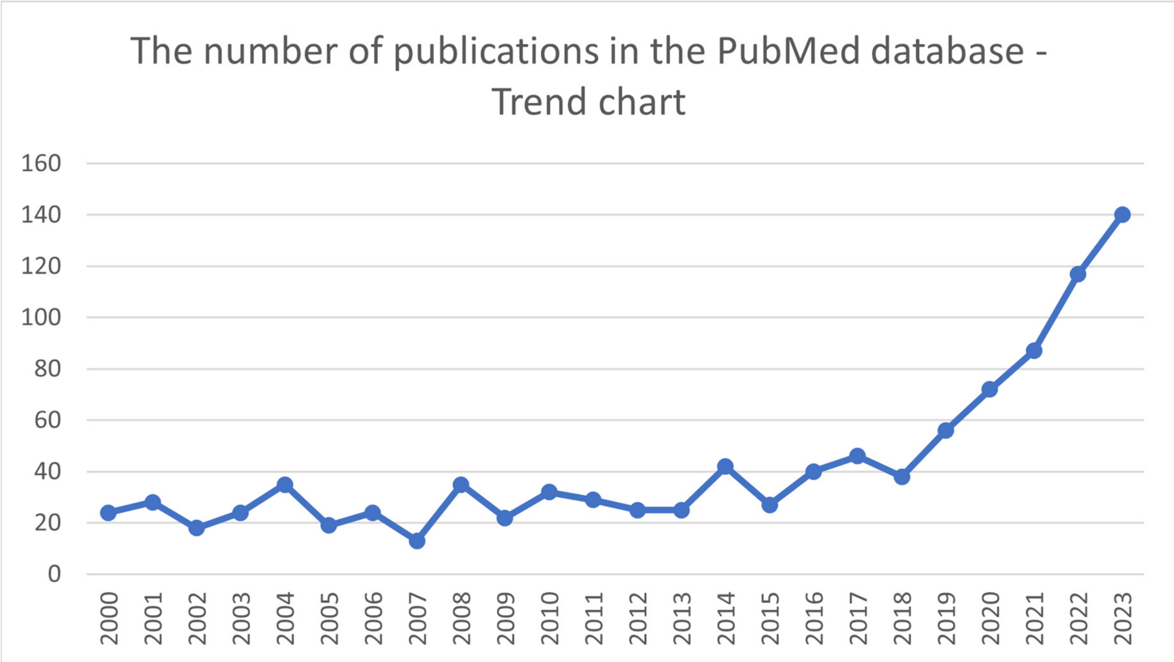

Figure 3. Trend chart showing the articles published in the database PubMed during the period 2000–2013 with the keyword "dental waste" in the title and/or abstract.

3.2. Data Items and Synthesis of the Results

Data were collected for each trial as follows: (1) main author, year of publication, and study location, (2) period of study, (3) objective/aim, (4) details of methodology, (5) details of primary and secondary outcome, (6) funding sources, (7) critical appraisal of individual sources of evidence, and (8) included cross-sectional studies using Critical Appraisal Tool (CAT) were assessed for the current scoping review [16,17]. Several studies have investigated the composition, production rates, and management practices of dental solid waste (DSW) in different regions, namely in Greece and Iran. More specifically, Komilis et al. (2009), [18] in Greece, analyzed solid waste from dental laboratories in Xanthi, finding a daily production rate of 0.059 g per capita, primarily household-type and infectious waste. Also, Koolivand et al. (2012) [19] examined healthcare waste in Bandar Abbas, Iran, identifying shortcomings in waste management practices, particularly in handling sharps and infectious waste. Nabizadeh et al. (2012) [20] analyzed DSW in Hamadan, Iran, reporting substantial annual waste generation with recommendations for improved management. Further, Bazrafshan et al. (2014) [21] evaluated DSW in Sistan and Baluchestan Province, also in Iran, emphasizing the need for source reduction and recycling programs. Additionally, Majlesi et al. (2016) [22] assessed DSW in Qaem Shar, Iran, underlining the urgency of implementing waste reduction and recycling initiatives too. Finally, Mandalidis et al. (2018) [23] studied DSW in Xanthi, Greece, noting a predominance of hazardous waste and also emphasizing the need for improved waste management practices. As seen by their reports, all previous studies collectively highlight the importance of addressing DSW management to minimize environmental and public health risks. Data from the included cross-sectional studies are presented in a narrative format in Table 1.

Table 1. Main characteristics of the studies included in the review.

Main Author (Year) Study Location	Period of Study	Sector	Objective	Methodology	Results	Funding
Komilis et al., 2009 Greece [18]	2002	Private	Analysis of solid waste composition and production rates in dental laboratories.	In Xanthi, Greece, solid waste composition and production rates from four dental laboratories were studied over a two-month period.	During the study, dental laboratories (DLSW) generated 0.059 g of solid waste per capita daily (22 g per capita annually). The waste composition was 74% household-type, 26% infectious, and less than 0.5% toxic. DLSW constituted around 0.007% of Xanthi's municipal solid waste.	No reporting
Koolivand et al., 2012 Iran [19]	2010	Private	Study on healthcare waste composition, production rate, and management practices in Bandar Abbas, southern Iran.	Two random samples were selected from 90 centers, with one sample each in summer and winter.	Average daily waste production rates were 2125.3 grams for clinics, 498.3 grams for dental offices, and 374.9 grams for physician's offices. Domestic and highly infectious waste had the highest percentages, while chemical, pharmaceutical, and sharps waste had the lowest. The survey revealed shortcomings in waste minimization, separation, reuse, and recycling practices in healthcare centers, particularly in managing sharps, potentially infectious, and other hazardous waste.	No funding
Nabizadeh et al., 2012 Iran [20]	-	Private and Public	Analysis of dental solid waste composition and production rates in Hamadan, Iran.	Twenty-eight dental clinics were randomly selected, including ten general dentists, eight specialists, five practical dentists, and five denture makers.	Dental offices generate 41,947.43 kg of annual waste, comprising 71.15 tons of domestic waste, 21.40 tons of potentially infectious waste, and 7.26 tons of chemical and pharmaceutical waste, with toxic waste at 0.18%. The majority (80%) includes gypsum, latex gloves, nylon, dental impression material, used medicine ampoules, saliva-contaminated paper towels, and saliva ejectors.	Department of Environmental Health Engineering

Table 1. *Cont.*

Main Author (Year) Study Location	Period of Study	Sector	Objective	Methodology	Results	Funding
Bazrafshan et al., 2014 Iran [21]	April 2011–2012	Private and Public	Evaluation of the hazardous and infectious status of dental solid waste.	Measured the composition and generation rate of dental solid waste in 123 private and 36 public dental clinics in the Sistan and Baluchestan Province.	The dental solid waste was categorized into domestic-type (11.7%), potentially infectious (80.3%), chemical and pharmaceutical (6.3%), and toxic (1.7%). Daily generation rates per patient for total, domestic-type, potentially infectious, chemical and pharmaceutical, and toxic wastes were 169.9, 8.6, 153.3, 11.2, and 3.3 g/patient, respectively. The daily generation rates for total, domestic-type, potentially infectious, chemical and pharmaceutical, and toxic wastes were 194.5, 22.6, 156.1, 12.3, and 3.4 kilograms. The study recommends implementing source reduction, separation, reuse, and recycling programs for effective dental waste management, emphasizing separate collection and disposal for each type in accordance with relevant criteria.	Health Research Deputy of Zahedan University of Medical Sciences
Majlesi et al., 2016 Iran [22]	June to September 2016	Public	Assessment of the composition and production rate of solid waste generated by dental offices.	From June to September 2016, 21 dental offices in Qaem Shar were randomly chosen as sampling sites. These offices were sampled three times each week (on Sunday, Monday, and Tuesday) at the end of the day.	Dental clinics are the main sources of biohazardous and potentially infectious wastes. Critical need for proper management and safe disposal of biohazard wastes to protect public health and the environment. Absence of initiatives in these clinics for waste reduction, segregation, and recycling. Urgency of implementing practices for reducing waste, promoting recycling, and enhancing overall management of dental solid waste.	Shahid Bheshti University of Medical Sciences
Mandalidis et al., 2018 Greece [23]	22 April to 5 July 2013	Private and Public	Evaluation of the composition and production rate of solid waste generated by dental facilities in Greece.	Over a four-week period, dental practices in Xanthi, Greece, collected, manually separated, and weighed dental solid waste (DSW).	Dental solid waste (DSW) consisted of 92% hazardous waste and 8% domestic waste. The hazardous waste unit production rate averaged 48.7 ± 1.3 g/patient/day. DSW production rates were 53.3 ± 1.4 g/patient/day and 381 ± 15 g/practice/day. Multiple measurements, including bulk density, calorific value, moisture, ash, and volatile solids, were recorded.	No reporting

As described previously the analysis of qualitative data was conducted on only 6 cross-sectional studies out of 13 potentially eligible studies. Of the six included studies, four were conducted in Iran and two in Greece, while two of them were conducted in private sectors, one in public, and three studies used data from both (private and public) sectors. Funding for such research was applied in half of them. More specifically, Iran was the country with the largest number of included studies (n = 4, 66%), followed by Greece (n = 2, 33%).

Most research groups included in their studies (n = 3, 50%) dental facilities in both the private and public sectors, whereas two studies (n = 2, 33%) collected data only from private dental facilities. Specifically, a study (n = 1, 16%) focused on dental practices in the public sector; in four studies (n = 4, 66%), data were collected from dental practices providing general dentistry; two studies (n = 2, 33%) collected data from dental laboratories; and one study (n = 1, 16%) collected data from dental practices providing specialty dentistry. The sample size of one study (n = 1, 16%) included general dentistry, dental laboratories, and specialty dentistry. Furthermore, in terms of study funding, one (n = 1, 16%) study reported no funding, while two (n = 2, 33%) studies did not provide information. It has been reported, finally, that three (n = 3, 50%) studies received funding, with all three cases involving university resources. The descriptive tables of the results of cross-sectional studies were created using StataCorp software, Stata: Release 13.1 (Table 2).

Table 2. Descriptive tables of the results of cross-sectional studies.

Location	Freq.	Percent	Cum.
Iran	4	66.67	66.67
Greece	2	33.33	100.00
Total	6	100.00	-
Sector	**Freq.**	**Percent**	**Cum.**
Private sector	2	33.33	33.33
Public sector	1	16.67	50.00
Both	3	50.00	100.00
Total	6	100.00	-
Funding	**Freq.**	**Percent**	**Cum.**
NO	1	16.67	16.67
YES	3	50.00	66.67
NO REPORTING	2	33.33	100.00
Total	6	100.00	-

To gain deeper insights from the collected data, it is noteworthy that all the studies employed longitudinal designs, utilizing continuous or repeated measures to track the generation rate of dental waste over extended periods. Moreover, sampling days range from 3 to 26. Specifically, in three studies, samples were collected between 31 May and 5 July 2002, 22 April and 5 July 2013, and June and September 2016, respectively. Another two studies collected samples for 1 year (April 2011–2012) twice monthly and four samples in each season of 2010, respectively. According to one study, samples were taken at a time interval that was not specified. It was calculated that 63, 84, 104, 120, 400, and 3816 samples were taken in total, respectively, in each study. Additionally, the number of dental-care-related structures participating in each survey was 38, 4, 21, 30, 20, and 159, respectively. Nabizadeh et al. (2012) [20] collected their data from 28 dental practices in the public sector and 10 dental laboratories. It is important to note that 10 of the 28 dental clinics were involved in general dentistry and 8 were involved in dental specialties. In another study that was conducted by Komilis et al. (2009), [18] they utilized samples from four dental laboratories to compose their study. Another example is the study of Koolivand et al. (2012), [19] who analyzed waste generation in 30 general and private dental practices. Moreover, Mandalidis et al. (2019) [23] conducted their investigation into 19 private and 1 public general dentistry practices, while Bazrafshan et al. (2014) [21] included 123 private and 36 public dental practices in their study. Finally, Majlesi et al. [22] collected data from 21 general dentistry practices in the public sector. Overall, the aim of all included research studies was to analyze the production rate and composition of DSW. To accomplish this, they collected the waste of the dental care centers under study within the time frame determined by each survey. Following this, qualified personnel followed safety and avoidance measures to divide the collected waste into fractions. For each fraction, its composition was categorized into infectious and toxic, toxic/chemicals/pharmaceuticals, and domestic.

3.3. Critical Appraisal within Sources of Evidence

Table 3 presents data on the critical appraisal of the sources of evidence included. More specifically, the sampling period of each survey as well as the number of total samples are listed. Each survey was conducted in the regions of either West Asia or Southeast Europe. Participating dental practices were classified into private, public, and combined sectors using the codes 0, 1, and 2, correspondingly. Additionally, the number of dental practices that practiced general dentistry or included dental specialties was assessed. In studies that included dental laboratories in their sample, the number of laboratories was also recorded, as they were part of the study and could not be excluded. Lastly, data on the composition of DSW collected in the sample of each survey were recorded in percentage terms, with categories such as infectious and potentially infectious wastes, toxic/chemicals/pharmaceuticals, domestic waste, total dental hazardous waste, and total DSW.

Additional methodological information on the data derived from each study is presented in Table 4. As derived from our results, studies included in the review described the inclusion criteria without providing descriptive information about the study population. For example, in the study of Nabizadeh et al. [20], there were no specific inclusion criteria. On the other hand, a detailed description of the research purpose and scope was provided in all studies. Also, dental clinics measured exposure in a reliable manner by estimating patient flow, workload, etc. However, confounding factors were not controlled in all studies and no strategy was adopted to minimize their impact. Precision scales were additionally used in all studies to measure the weight of DSW, as well as qualified personnel evaluating the composition of the measured waste volume in a valid manner. An issue is that, due to the lack of a standardized method for identifying and categorizing dental waste in all included studies, the composition of dental waste could not be considered objective. To present the results of the statistical analysis, appropriate descriptive methods were further used in all studies.

Generally, the mean number of days of sampling is 13. Studies (n = 3, 50%) collected their samples daily for a continuous period, whereas other studies (n = 2, 33%) collected their samples twice a month during the study year or one sample during each season. However, in one study (n = 1, 16%), there was no information about the specific period of sampling. Lastly, a longitudinal cross-sectional design was chosen by all researchers (n = 6, 100%). Each study's sample size varied, with the calculated mean being 764.5 for the number of overall samples. Overall, the variation in the values of the samples of dental solid waste is included in the range of 764.5 ± 3000 and is substantial, as the minimum value of 63 and maximum value of 3816 are outliers.

Table 3. Data on the critical appraisal of the source of evidence included.

Main Author (Year)	Sampling Year	Study Location	N. Overall Sample	Private Sector, 0; Public, 1; Both, 2	Private Sector	Public Sector	N. General Dental Practice	N. Dental Clinics Special	N. Labora-tories	Infectious and Potentially Infectious Waste	Toxic/ Chemicals/ Pharmaceuticals	Domestic Type	Total Dental Hazardous Waste	Total DSW
Komilis, 2009 [18]	31 May to 5 July 2002	Greece	104	0	4				4	26	0.47	74	26.47	100
Koolivand, 2012 [19]	2 samples in summer and 2 samples in winter 2010	Iran	120	0	30		30			48.5	10.7	40.9	59.2	100
Nabizadeh, 2012 [20]		Iran	84	2		28	10	8	10	21.40	7.44	71.15	28.84	100
Bazrafshan, 2014 [21]	For 1 year (April 2011–2012) twice monthly	Iran	3816	2	123	36				80	8	11.7	88	100
Majlesi, 2016 [22]	June to September 2016	Iran	63	1		21	21			64.09	2.7	33.2	66.79	100
Mandalidis, 2018 [23]	From 22 April to 5 July 2013	Greece	400	2	19	1	20			88.5	3.5	8.0	92	100

Table 4. Individual sources of evidence from studies included.

Main Author (Year)	Inclusion Criteria	Study Subjects and the Setting Described in Detail	Exposure Measured in a Valid and Reliable Way	Objective, Standard Criteria Used for Measurement of the Condition	Confounding Factors Identified	Strategies to Deal with Confounding Factors Stated	Outcomes Measured in a Valid and Reliable Way	Appropriate Statistical Analysis
Komilis DP., 2009 [18]	YES	YES	YES	UNCLEAR	NO	NOT APPLICABLE	YES	YES
Koolivand, 2012 [19]	YES	YES	YES	UNCLEAR	NO	NOT APPLICABLE	YES	YES
Nabizadeh, 2012 [20]	UNCLEAR	YES	YES	UNCLEAR	NO	NOT APPLICABLE	YES	YES
Bazrafshan, 2014 [21]	YES	YES	YES	UNCLEAR	NO	NOT APPLICABLE	YES	YES
Majlesi 2016, [22]	YES	YES	YES	UNCLEAR	NO	NOT APPLICABLE	YES	YES
Mandalidis, 2018 [23]	YES	YES	YES	UNCLEAR	NO	NOT APPLICABLE	YES	YES

The composition of DSW was measured in weight/weight percent in all included studies ($n = 6$). Primarily, two studies ($n = 2$, 33%) calculated 21,4% and 26% in the infectious and potentially infectious waste category based on their sample, while two studies ($n = 2$, 33%) calculated 80% and 88.5% in the same category. In addition, two studies ($n = 2$, 33%) figured intermediate values of 48.5% and 64%. A mean of 60.2 w/w% is found in the infectious and toxic categories of dental waste, though there are several outliers. However, the results from studies in the category toxic/chemicals/pharmaceuticals were not as widely varied. Particularly, toxic/chemicals/pharmaceutical category has a mean of 5.4%, while the variable distribution is 5.4 ± 3.8%. As a result of the outliers, the distribution of the domestic type of dental waste is wide. According to the data, domestic dental waste has a mean of 39.8 w/w%. Finally, domestic waste and waste with a high potential for infection had the highest percentages in all included studies, while toxic, chemical, and pharmaceutical waste had the lowest (Table 5).

Table 5. Dental solid waste measurements in the studies included.

Variable	Obs	Mean	SD	Min	Max
N. overall samples	6	764.5	1500.089	63	3816
N. of general dental practices	4	20.25	8.180261	10	30
Infectious type of waste	6	54.74833	27.71898	21.4	88.5
Toxic type of waste	6	5.468333	3.851973	0.47	10.7
Domestic type of waste	6	39.825	28.27748	8	74
Days of sampling	6	13.33333	11.12954	3	26

4. Limitations of the Studies Included

Due to the lack of a representative sample in the design of the descriptive studies included in this systematic review, the results cannot be generalized and there is no external validity of their findings. Aside from Nabizadeh et al. (2012) [20] and Bazrafshan et al. (2014) [21], none of the other studies mentions the criteria for selecting dental structures or the method for calculating samples. Nabizadeh et al. (2012) [20], however, do not indicate when the survey was conducted. Also, it is unclear from Bazrafshan et al. (2014) [21] and Mandalidis et al. (2018) [23] whether the dental clinics selected deal with general dentistry or specializations. It is then worth mentioning that all the included studies do not provide any information on the general characteristics of the participating dentists, such as their gender, age, and educational background. Further, the number of dental patients visiting the dental units included in the studies daily as well as the types and/or frequency of dental work performed are not provided in the studies. Moreover, no study provides information on the number of dental units in each dental facility. It has further not been investigated whether the characteristics of the study population have a confounding effect on the composition of dental solid waste collected from the sample in any of the studies. Finally, the samples in studies of Komilis (2009) [18], Majlesi et al. (2016) [22], and Mandalidis et al. (2018) [23] were collected consecutively over a specific period. It may, however, affect patients' natural flow of dental work, the frequency of their dental visits, and the workflow of dental unit employees during certain times of the year. But, again, neither of the above-mentioned studies discussed the criteria for selecting the sampling interval.

Overall, the most significant limitation of the studies included in our study lies in the lack of a representative sample, limiting the generalizability of the findings to the broader population. In addition, the criteria for selecting dental structures, the method for calculating samples, and essential information about participating dentists' characteristics were often undisclosed or inadequately addressed [18–23]. This limitation turns the systematic review process into a scoping one and necessitates the inclusion of a more diverse and representative sample in future studies to enhance external validity [24].

5. Proposed Research Model

Considering the difficulties of conducting a DSW collection study, as our data revealed, this review is described as a scoping one (instead of systematic) and proposes a cross-sectional future study design [24]. First, when selecting dental practices to monitor for such a purpose, it is necessary that they reflect the characteristics of each dental community in the city in which the study will take place. The relevant dental association should be consulted before selecting the settings that will participate in the study to determine the percentage of general and specialized dentists, the number of working dentists, the level of university education, and general characteristics, such as gender and age. Based on these findings, a determination should be made further as to how many dentists with specialties and generalists are required for the study to have external validity. Then, it would be preferable if the sampling intervals were established throughout the dental clinic's opening hours and days with normal patient flow. Subsequently, the classification of the waste samples should then be well defined and waste samples should be separated into categories. It is imperative that trained staff should segregate waste and that there should be a discrepancy check among the staff members. In general, there should also be detailed descriptions of the separation method as well as a standardized approach for all participants. Further, precision should be maintained in the use of equipment, such as scales. Finally, to analyze and evaluate the results, it is necessary to consider confounding factors, such as the dentist's age or university education level. Lastly, we suggest stratifying the findings based on race, age, dental specialty, and level of university education. Key aspects of the proposed research model are presented in Table 6.

Table 6. Key aspects and recommendations for future studies.

Aspect	Recommendation
Study design and sampling	A cross-sectional study with a sampling strategy reflecting the characteristics of each dental community. Collaboration with dental associations for representative samples.
Waste categorization and identification	Establishment of clear definitions and classification criteria for infectious waste, toxic/chemicals/pharmaceuticals, and domestic waste. Implementation of a meticulous waste categorization system.
Methodological standardization	Use of a standardized approach to waste separation and measurement. Clear definition of methodological details, including equipment calibration and measurement precision
Consideration of confounding factors	Stratification of findings based on potential confounding factors such as age, gender, and educational background of dentists for a detailed analysis
Training and awareness programs	Inclusion of training and awareness programs for dental practitioners focusing on waste minimization, separation, reuse, and recycling practices.
Environmental impact assessment	Integration of a comprehensive environmental impact assessment, including the evaluation of the carbon footprint of dental services in conjunction with waste production and exploration of sustainable practices
Patient education initiatives	Exploration of the effectiveness of patient education initiatives to engage patients in understanding the environmental impact of dental practices and waste production and encourage sustainable behaviors.
Longitudinal studies for temporal trends	Conduction of longitudinal studies extending over several years to capture temporal trends and variations in waste generation.

6. Discussion

The exploration of dental solid waste (DSW) has gathered considerable attention in recent years, reflecting the growing significance of sustainability in healthcare practices. In our scoping review, we examine six pertinent studies to comprehensively understand the methodology and findings associated with DSW [18–23].

Notably, data on DSW composition exhibited considerable variability among the studies, particularly in categories such as toxics/chemicals/pharmaceuticals, infectious waste, and domestic waste. The observed heterogeneity in data could be attributed to the absence of a standardized method for identifying and categorizing DSW among researchers and participating dentists; thus, although we used a systematic review approach, the present review is considered as a scoping one. This lack of consistency is also described in the relevant literature in other healthcare domains. Considering the methodological deficiencies of published studies as well as the heterogeneity of the literature regarding other healthcare domains, such as medical waste and pharmaceutical waste, it is imperative that guidelines and regulations be developed for the management of medical waste, as well as technologies, knowledge, and financing to upgrade medical waste management in the world today [25].

Despite differences in the methodology, a similar *w*/*w*% composition below 10% was found across the six included studies in the category of toxics/chemicals/pharmaceuticals. The results of the studies in the categories of infectious waste and potentially infectious waste as well as domestic-type waste appeared to be unevenly distributed at the extremes of the range, i.e., 20% and 80%. According to the study conducted by Kizlary et al. (2005) [26], which was excluded due to non-measurement of waste composition in *w*/*w*% scale, a total of 11.168 kilograms of infectious and potentially infectious waste was produced each day, whereas only 387 kilograms was produced by domestic waste. Conversely, Vieira et al. (2009) [27], which was excluded from our analysis too due to using a different classification of medical waste, reported that 24.3%, 48.1%, and 27.6% of waste was non-infectious, infectious, and domestic waste, respectively. Moreover, data of Mandalidis et al. (2019) [23] indicate that, in terms of hazardous waste, unit production rate was 48.7 × 1.3 g/patient/day (mean and standard error). Thus, according to their evaluation, the DSW production rates were 53.3 × 1.4 g/patient/d and 381 × 15 g/practice/d [24], which is a considerable amount of waste to discuss when addressing sustainability issues in dentistry.

This heterogeneity of the extracted data from relevant studies discussing the issue is due to the absence of a repeatable method of identifying dental solid waste among researchers or dentists participating in each study. The difficulty of properly managing wastes is primarily related to separate infectious and potentially infectious waste types. The study by Koolivand et al. (2012) [19] concluded that healthcare centers lack effective practices on waste minimization, separation, reuse, and recycling as well as inadequate practices on disposing of sharps, potentially infectious waste, and other hazardous waste. Consequently, it seems necessary to evolve educational strategies concerning waste separation issues. As healthcare workers, dentists and dental auxiliary staff should learn to assess the hazardous and infectious status of dental solid waste by understanding its possible role in cross-infection and follow specific protocols for waste accumulation and disposal [7].

According to WHO standards, waste types cover a wide range of materials, including infectious wastes, pathological wastes, sharps wastes, chemical wastes, pharmaceutical wastes, cytotoxic wastes, radioactive wastes, and nonhazardous/general wastes. In accordance with WHO and CE regulations, all healthcare facilities are required to dispose of waste appropriately [5,28–30] to diminish the carbon footprint. Studying the carbon footprint in the NHS, 17 dental procedures were identified, emitting 1798.9 tonnes of CO_2 equivalent annually. Travel was the largest contributor (45.1%), followed by procurement (35.9%) and building energy (18.3%). Moreover, waste disposal accounted for 0.22% of NHS dental services' overall carbon footprint, with 90.3% of emissions derived from domestic waste [31]. To achieve the goal of reduced carbon footprint, dental care facilities should currently develop a formal waste management plan. As part of this plan, everyone involved in the generation, handling, and treatment of waste should have access to combined knowledge and decision making. Aside from training and familiarizing dentists and dental staff with the proper disposal of dental waste, raising patient awareness is also an essential step in this direction. By educating patients about the green dental economy and reducing the environmental footprint, dentistry will be able to achieve the fulfillment of sustainability criteria in healthcare [11,32].

In addition some ideas for sustainable waste management from other areas of the industry, like the food industry, could be incorporated in the management of dental solid waste [33]. For example, the dental industry and research should explore methods for converting dental waste into energy sources, similar to the biofuel production discussed elsewhere [34]. This could involve techniques such as anaerobic digestion or pyrolysis to convert organic dental waste into biogas or bio-oil. We could also investigate opportunities to recover materials from dental waste for reuse or recycling. For example, metals from dental amalgam waste could be reclaimed and repurposed, similar to the recovery of materials from food waste for the production of materials [33]. Moreover, we can implement composting techniques for organic dental waste materials such as dental pulp or food waste from staff areas. Composting can facilitate the decomposition of organic matter and produce nutrient-rich compost that can be used for landscaping or gardening purposes. Furthermore, we can establish partnerships with waste management organizations, dental associations, and research institutions to develop innovative waste management solutions for the dental industry. This collaboration can lead to the sharing of best practices, research findings, and resources to address common challenges in dental waste management. It is also suggested that the approach of Life Cycle Assessment (LCA) in dentistry can evaluate the environmental impacts of different waste management strategies in the dental sector as conducted in the food industry [35]. This approach could be extremely helpful since, by analyzing the environmental footprint of various waste management options, dental practices can make informed decisions to minimize their ecological footprint and promote sustainability. It is the way to ensure that all stakeholders contribute to minimizing the environmental impact of dental services through less waste and appropriate disposal of it.

7. Conclusions

Dental solid waste composition and generation rate cannot be determined from the available extracted data due to a lack of evidence and heterogeneity; thus, a new research protocol should be followed in future studies. For valid conclusions to be drawn, descriptive studies involving enough general or specialist dental care dentists should be conducted. This scoping review revealed, however, that healthcare staff and dentistry practitioners could benefit from training on the effective handling of dental waste. The future scope of dental association representatives should be to raise awareness among dental professionals and patients concerning the importance of sustainable waste management practices in dentistry and educate stakeholders about the environmental implications of dental waste, encouraging them to adopt eco-friendly alternatives and practices. Also, compliance with regulatory requirements and certifications related to waste management in the dental industry is currently imperative. Dentistry should implement proper segregation, handling, and disposal procedures for different types of dental waste to meet environmental standards and minimize environmental pollution. Altogether, the dental profession could benefit from other areas' waste management tools and procedures so that agile techniques should be incorporated to guarantee that dental care is delivered while prioritizing environmental considerations.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app14052026/s1, Table S1: Studies excluded from the review and reasons for their exclusion. S2: Checklist for analytical cross-sectional studies included. References [36–70] are cited in the Supplementary Materials.

Author Contributions: Conceptualization, I.M. and M.A.; methodology, I.M. and M.A.; software, I.M.; validation, I.M., M.C. and M.A.; formal analysis, I.M.; investigation, I.M., M.C. and M.A.; resources, I.M., M.C. and M.A.; data curation, I.M. and M.A.; writing—original draft preparation, I.M., M.C. and M.A.; writing—review and editing, I.M., M.C. and M.A.; visualization, I.M. and M.A.; supervision, M.A.; project administration, M.A.; funding acquisition, M.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Forzieri, G.; Cescatti, A.; Silva, F.B.; Feyen, L. Increasing risk over time of weather-related hazards to the European population: A data-driven prognostic study. *Lancet Planet. Health* **2017**, *1*, 200–208. [CrossRef] [PubMed]
2. World Economic Forum. The Global Risks Report 2020, Geneva, 2020. Available online: http://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf (accessed on 18 November 2023).
3. Martin, N.; Sheppard, M.; Gorasia, G.; Arora, P.; Cooper, M.; Mulligan, S. Awareness and barriers to sustainability in dentistry: A scoping review. *J. Dent.* **2021**, *112*, 103735. [CrossRef]
4. Duane, B.; Stancliffe, R.; Miller, F.A.; Sherman, J.; Pasdeki-Clewer, E. Sustainability in Dentistry: A Multifaceted Approach Needed. *J. Dent. Res.* **2020**, *99*, 998–1003. [CrossRef] [PubMed]
5. WHO. Healthcare Waste. February 2018. Available online: https://www.who.int/news-room/fact-sheets/detail/health-care-waste (accessed on 13 February 2024).
6. Martin, N.; Mulligan, S.; Shellard, I.J.; Hatton, P.V. *Consensus on Environmentally Sustainable Oral Healthcare: A Joint Stakeholder Statement*; White Rose University Press: Leeds, UK, 2022; pp. 11–36. [CrossRef]

7. FDI World Dental Federation. *Sustainability in Dentistry Statement*; FDI: Madrid, Spain, 2017. Available online: https://www.fdiworlddental.org/sustainability-dentistry-statement (accessed on 18 November 2023).
8. *ASTM E3014–15*; Standard Practice for Managing Sustainability in Dentistry. ASTM International: West Conshohocken, PA, USA, 2015; ICS 11.060.01. Available online: https://standards.globalspec.com/std/3857932/astm-e3014-15 (accessed on 18 November 2023).
9. *ASTM E3014–21*; Standard Practice for Managing Sustainability in Dentistry. ASTM International: West Conshohocken, PA, USA, 2021; ICS 11.060.01. Available online: https://standards.globalspec.com/std/14477041/astm-e3014-21 (accessed on 18 November 2023).
10. Oviedo-Allison, B.; Shockley, M. *The Sustainable Dentist—The New Normal*; Dental Medicine Books; 3L Publishing: York, UK, 2022; ISBN 978-1-7361051-5-3.
11. Antoniadou, M.; Chrysochoou, G.; Tzanetopoulos, R.; Riza, E. Green Dental Environmentalism among Students and Dentists in Greece. *Sustainability* **2023**, *15*, 9508. [CrossRef]
12. Mazur, M.; Ndokaj, A.; Jedliński, M.; Maruotti, A.; Stamegna, C.; Corridore, D.; Capocci, M.; Ottolenghi, L.; Guerra, F. How Dentistry is impacting the environment. *Senses Sci.* **2019**, *6*, 922–928. [CrossRef]
13. UNFCCC. Paris Agreement. 2015. Available online: https://unfccc.int/sites/default/files/english_paris_agreement.pdf (accessed on 18 November 2023).
14. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.; Horsley, T.; Weeks, L.; et al. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Ann. Intern. Med.* **2018**, *169*, 467–473. [CrossRef]
15. Institute of Medicine. Standards for Systematic Reviews. National Academy of Sciences. 2015. Available online: http://www.iom.edu/Reports/2011/Finding-What-Works-in-Health-Care-Standards-for-Systematic-Reviews/Standards.aspx (accessed on 18 November 2023).
16. Higgins, J.P.T.; Thomas, J.; Chandler, J.; Cumpston, M.; Li, T.; Page, M.J.; Welch, V.A. Cochrane Handbook for Systematic Reviews of Interventions Version 6.4 Cochrane. 2023. Available online: www.training.cochrane.org/handbook (accessed on 18 November 2023).
17. Moola, S.; Munn, Z.; Tufanaru, C.; Aromataris, E.; Sears, K.; Sfetcu, R.; Currie, M.; Qureshi, R.; Mattis, P.; Lisy, K.; et al. Chapter 7: Systematic reviews of etiology and risk. In *JBI Manual for Evidence Synthesis*; Aromataris, E., Munn, Z., Eds.; JBI: North Adelaide, SA, Australia, 2020; Available online: https://synthesismanual.jbi.global (accessed on 18 November 2023).
18. Komilis, D.P.; Voudrias, E.A.; Anthoulakis, S.; Iosifidis, N. Composition and production rate of solid waste from dental laboratories in Xanthi, Greece. *Waste Manag.* **2009**, *3*, 1208–1212. [CrossRef]
19. Koolivand, A.; Mahvi, A.H.; Alipoor, V.; Azizi, K.; Binavapour, M. Investigating composition and production rate of healthcare waste and associated management practices in Bandar Abbass, Iran. *Waste Manag. Res.* **2012**, *6*, 601–606. [CrossRef]
20. Nabizadeh, R.; Koolivand, A.; Jonidi Jafari, A.; Yunesian, M.; Omrani, G. Composition and production rate of dental solid waste and associated management practices in Hamedan, Iran. *Waste Manag. Res.* **2012**, *30*, 619–624. [CrossRef]
21. Bazrafshan, E.; Mohammadi, L.; Mostafapour, F.K.; Moghaddam, A.A. Dental solid waste characterization and management in Iran: A case study of Sistan and Baluchestan Province. *Waste Manag. Res.* **2014**, *2*, 157–164. [CrossRef]
22. Majlesi, M.; Alavi, N.A.; Mohammadi, A.A.; Valipor, S. Data on composition and production rate of dental solid waste and associated management practices in Qaem Shahr, Iran 2016. *Data Brief* **2018**, *19*, 1291–1296. [CrossRef]
23. Mandalidis, A.; Topalidis, A.; Voudrias, E.A.; Iosifidis, N. Composition, production rate and characterization of Greek dental solid waste. *Waste Manag.* **2018**, *75*, 124–130. [CrossRef]
24. Munn, Z.; Peters, M.D.; Stern, C.; Tufanaru, C.; McArthur, A.; Aromataris, E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med. Res. Methodol.* **2018**, *18*, 143. [CrossRef]
25. Ashtari, A.; Tabrizi, J.S.; Rezapour, R.; Rashidian Maleki, M.; Azami-Aghdash, S. Health Care Waste Management Improvement Interventions Specifications and Results: A Systematic Review and Meta-Analysis. *Iran. J. Public Health* **2020**, *49*, 1611–1621. [CrossRef]
26. Kizlary, E.; Iosifidis, N.; Voudrias, E.; Panagiotakopoulos, D. Composition and production rate of dental solid waste in Xanthi, Greece: Variability among dentist groups. *Waste Manag.* **2005**, *25*, 582–591. [CrossRef]
27. Vieira, C.D.; Carvalho, M.A.; Menezes Cussiol, N.A.; Alvarez-Leite, M.E.; Dos Santos, S.G.; da Fonseca Gomes, R.M.; Silva, M.X.; de Macêdo Farias, L. Composition analysis of dental solid waste in Brazil. *Waste Manag.* **2009**, *4*, 1388–1391. [CrossRef]
28. Chartier, Y.; Emmanuel, J.; Pieper, U.; Prüss, A.; Rushbrook, P.; Stringer, R.; Townend, W.; Wilburn, S.; Zghondi, X.; Raki, X. *Safe Management of Waste from Healthcare Activities*, 2nd ed.; WHO: Geneva, Switzerland, 2014; ISBN 978-92-4-154856-4.
29. Benítez-Rico, A.; Pérez-Martínez, A.; Muñóz-López, B.I.; Martino-Roaro, L.; Alegría-Baños, J.A.; Vergara-Castañeda, A.; Islas-García, A. Medical Household Waste as a Potential Environmental Hazard: An Ecological and Epidemiological Approach. *Int. J. Env. Res. Public Health* **2023**, *20*, 5366. [CrossRef]
30. World Health Organization (WHO). Medical Waste. 2013. Available online: http://www.who.int/topics/medical_waste/en/ (accessed on 18 November 2023).
31. Duane, B.; Hyland, J.; Rowan, J.S.; Archibald, B. Taking a bite out of Scotland's dental carbon emissions in the transition to a low carbon future. *Public Health* **2012**, *126*, 770–777. [CrossRef]

32. Antoniadou, M.; Varzakas, T.; Tzoutzas, I. Circular Economy in Conjunction with Treatment Methodologies in the Biomedical and Dental Waste Sectors. *Circ. Econ. Sust.* **2021**, *1*, 563–592. [CrossRef]
33. Aparajita, L.; Santhanaraj, D.; Rajakumar, K.; Ramkumar, V.; Adinaveen, T.; Leema, S.P. A critical review on food waste management for the production of materials and biofuel. *J. Hazard. Mater. Adv.* **2023**, *10*, 100266. [CrossRef]
34. Lam, C.-M.; Yu, I.K.M.; Hsu, S.-C.; Tsang, D.C.W. Chapter 18—Life-Cycle Assessment of Food Waste Recycling. In *Waste Biorefinery*; Bhaskar, T., Pandey, A., Rene, E.R., Tsang, D.C.W., Eds.; Elsevier: Amsterdam, The Netherlands, 2020; pp. 481–513. [CrossRef]
35. Antoniadou, M.; Tsarouhas, P.; Varzakas, T. Life cycle assessment and circular economy in conjunction with treatment methodologies: Presentation and critical comparison between different food industry waste. *GSC Adv. Res. Rev.* **2020**, *3*, 29–50. [CrossRef]
36. Chin, G.; Chong, J.; Kluczewska, A.; Lau, A.; Gorjy, S.; Tennant, M. The environmental effects of dental amalgam. *Aust. Dent. J.* **2000**, *45*, 246–249. [CrossRef] [PubMed]
37. Ozbek, M.; Sanin, F.D. A study of the dental solid waste produced in a school of dentistry in Turkey. *Waste Manag.* **2004**, *24*, 339–345. [CrossRef] [PubMed]
38. Tzoutzas, J.; Panis, V.; Kozirakis, K. The disposal of solid dental waste in the Dental School of the University of Athens. *Paedodontia* **2004**, *18*, 23–29.
39. Nazar, M.W.; Pordeus, I.A.; Werneck, M.A. Dental waste management in municipal health clinics in Belo Horizonte, Brazil. *Rev. Panam. Salud Publica* **2005**, *17*, 237–242. [CrossRef] [PubMed]
40. Kontogianni, S.; Xirogiannopoulou, A.; Karagiannidis, A. Investigating solid waste production and associated management practices in private dental units. *Waste Manag.* **2008**, *28*, 1441–1448. [CrossRef]
41. Sudhakar, V.; Chandrashekar, J. Dental health care waste disposal among private dental practices in Bangalore City, India. *Int. Dent. J.* **2008**, *58*, 51–54. [CrossRef]
42. Birpinar, M.E.; Bilgili, M.S.; Erdoğan, T. Medical waste management in Turkey: A case study of Istanbul. *Waste Manag.* **2009**, *29*, 445–448. [CrossRef]
43. Muhamedagic, B.; Muhamedagic, L.; Masic, I. Dental office waste—public health and ecological risk. *Mater. Sociomed.* **2009**, *21*, 35–38. [CrossRef]
44. Al-Widyan, M.I.; Oweis, R.J.; Abu-Qdais, H.; Al-Muhtaseb, M. Composition and energy content of dental solid waste. *Resour. Conserv. Recycl.* **2010**, *55*, 155–160. [CrossRef]
45. Sunil Kumar, V.C.; Manjunatha, M.; Badami, V.; Pradeep, P.R. Biomedical waste management: A review. *J. Oral. Health Comm. Dent.* **2012**, *6*, 141–144.
46. Avinash, B.; Avinash, B.S.; Shivalinga, B.M.; Jyothikiran, S.; Padmini, M.N. Going green with eco-friendly dentistry. *J. Contemp. Dent. Pract.* **2013**, *1*, 766–769. [CrossRef]
47. Rastogi, V.; Sharma, R.; Yadav, L.; Satpute, P.; Sharma, V. Green dentistry, a metamorphosis towards an eco-friendly dentistry: A short communication. *J. Clin. Diagn. Res.* **2014**, *8*, 1–2. [CrossRef] [PubMed]
48. Al-Qarni, M.A.; Shakeela, N.V.; Alamri, M.A.; Alshaikh, Y.A. Awareness of Eco-Friendly Dentistry among Dental Faculty and Students of King Khalid University, Saudi Arabia. *J. Clin. Diagn. Res.* **2016**, *10*, 75–78. [CrossRef]
49. Richardson, J.; Grose, J.; Manzi, S.; Mills, I.; Moles, D.R.; Mukonoweshuro, R.; Nasser, M.; Nichols, A. What's in a bin: A case study of dental clinical waste composition and potential greenhouse gas emission savings. *Br. Dent. J.* **2016**, *22*, 61–66. [CrossRef] [PubMed]
50. Mulimani, P. Green dentistry: The art and science of sustainable practice. *Br. Dent. J.* **2017**, *222*, 954–961. [CrossRef]
51. Rathakrishnan, M.; Priyadarhin, I.A. Green dentistry: The future. *J. Int. Clin. Dent. Res. Org.* **2017**, *9*, 59–61. [CrossRef]
52. Harford, S.; Duane, B. Sustainable Dentistry: How-to Guide for Dental Practices Sustainable Dentistry. *Cent. Sustain. Healthc.* **2018**. Available online: https://sustainablehealthcare.org.uk/dental-guide (accessed on 18 November 2023).
53. Phillipson, J. Carbon modelling within dentistry: Towards a sustainable future. The need for sustainable dentistry. Public Health England. *BDJ Pract.* **2018**, *31*, 17–18.
54. Duane, B.; Ramasubbu, D.; Harford, S.; Steinbach, I.; Swan, J.; Croasdale, K.; Stancliffe, R. Environmental sustainability and waste within dental practice. *Br. Dent. J.* **2019**, *226*, 611–618. [CrossRef]
55. Hsu, L.H.; Hsiao, Y.H. Facilitating Green Supply Chain in Dental Care through Kansei Healthscape of Positive Emotions. *Int. J. Env. Res. Public Health* **2019**, *16*, 3507. [CrossRef]
56. De Leon, M.L. Barriers to environmentally sustainable initiatives in oral health care clinical settings. *Can. J. Dent. Hyg.* **2020**, *54*, 156–160. [PubMed]
57. Duane, B.; Ashley, P.; Saget, S.; Richards, D.; Pasdeki-Clewer, E.; Lyne, A. Incorporating sustainability into assessment of oral health interventions. *Br. Dent. J.* **2020**, *229*, 310–314. [CrossRef]
58. Subramanian, A.K.; Nivethigaa, B.; Srirengalakshmi, M.; Varghese, R.M.; Navaneethan, R.; Babu, H. Biomedical waste management practice in dentistry. *Bioinformation* **2020**, *16*, 958–964. [CrossRef]
59. Borglin, L.; Pekarski, S.; Saget, S.; Duane, B. The life cycle analysis of a dental examination: Quantifying the environmental burden of an examination in a hypothetical dental practice. *Community Dent. Oral. Epidemiol.* **2021**, *49*, 581–593. [CrossRef] [PubMed]
60. Martin, N.; Sheppard, M.; Gorasia, G.; Arora, P.; Cooper, M.; Mulligan, S. Drivers, opportunities and best practice for sustainability in dentistry: A scoping review. *J. Dent.* **2021**, *112*, 103737. [CrossRef] [PubMed]

61. Ndokaj, A.; Iacono, R.; Pasqualotto, D.; Stamegna, C.; Capocci, M.; Guerra, F. Trends in Sustainable Dentistry. *Clin. Ter.* **2021**, *172*, 523–524. [CrossRef] [PubMed]
62. Wolf, T.G.; Campus, G. Changing Dental Profession-Modern Forms and Challenges in Dental Practice. *Int. J. Env. Res. Public Health* **2021**, *18*, 1945. [CrossRef]
63. Byrne, D.; Saget, S.; Davidson, A.; Haneef, H.; Abdeldaim, T.; Almudahkah, A.; Basquille, N.; Bergin, A.M.; Prida, J.; Lyne, A.; et al. Comparing the environmental impact of reusable and disposable dental examination kits: A life cycle assessment approach. *Br. Dent. J.* **2022**, *233*, 317–325. [CrossRef]
64. Martin, N.; Mulligan, S.; Fuzesi, P.; Hatton, P.V. Quantification of single use plastics waste generated in clinical dental practice and hospital settings. *J. Dent.* **2022**, *118*, 103948. [CrossRef]
65. Mazur, M.; Ndokaj, A.; Bietolini, S.; Nisii, V.; Duś-Ilnicka, I.; Ottolenghi, L. Green dentistry: Organic toothpaste formulations: A literature review. *Dent. Med. Probl.* **2022**, *59*, 461–474. [CrossRef]
66. Abed, R.; Ashley, P.; Duane, B.; Crotty, J.; Lyne, A. An environmental impact study of inter-dental cleaning aids. *J. Clin. Periodontol.* **2023**, *50*, 2–10. [CrossRef] [PubMed]
67. Khanna, R.; Konyukhov, Y.; Maslennikov, N.; Kolesnikov, E.; Burmistrov, I. An Overview of Dental Solid Waste Management and Associated Environmental Impacts: A Materials Perspective. *Sustainability* **2023**, *15*, 15953. [CrossRef]
68. Shinkai, R.S.A.; Biazevic, M.G.H.; Michel-Crosato, E.; de Campos, T.T. Environmental sustainability related to dental materials and procedures in prosthodontics: A critical review. *J. Prosthet. Dent.* **2023**, in press. [CrossRef] [PubMed]
69. Spaveras, A.; Antoniadou, M. Awareness of Students and Dentists on Sustainability Issues, Safety of Use and Disposal of Dental Amalgam. *Dent. J.* **2023**, *11*, 21. [CrossRef]
70. Thakar, S.; Kinariwala, N.; Pandya, D.; Parekh, N.H.; Patel, N.K.; Patel, A. Awareness and Constraints towards the Implementation of Green Dentistry amongst Dental Students and Private Practitioners of West India. *J. Pharm. Bioallied Sci.* **2023**, *116*, 1287–1290. [CrossRef]