

**Awareness, Knowledge, Attitude and Practice Towards Sustainable
Dentistry Among Dental Practitioners in Alexandria:
A Cross-Sectional Study**

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Abstract

The study aims to assess awareness, knowledge, attitude and practices (AKAP) regarding sustainable dentistry among dental practitioners, and to investigate challenges, as well as enablers for establishing an eco-friendly dental practice. A cross-sectional study was conducted in 2024, among dental practitioners in Alexandria, Egypt. The sample size was 216 practitioners. A pre-designed, structured, closed-ended online questionnaire was used that consisted of six sections. The majority of dental participants (72.7%) demonstrated a low level of awareness, and 75.9% either had never encountered the term "sustainable dentistry" or possessed minimal knowledge of the overall concept. About half (53.3%) exhibited a moderate level of knowledge, and 67.6% showed poor sustainable practices. However, they expressed a positive attitude, with 63.4% agreeing to embrace sustainability and (21.3%) were neutral. No significant difference was found between groups across all the domains.

The main challenge to establishing an eco-friendly practice was 'lack of knowledge' followed by 'financial constraints', while the reported enablers were the 'presence of recycling programs', 'modern digital technologies', and 'renewable energy'. The study identified low awareness and insufficient levels of knowledge and practice regarding sustainable dentistry. It is recommended to incorporate sustainability into the dental undergraduate curriculum, as well as into

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extracurricular activities, to enhance the competencies of future generations. Additionally, interventional studies should be conducted to improve sustainable dentistry practices.

Keywords: Sustainable oral health care; Eco-dentistry; Green dentistry; KAP dental sustainability; Sustainable development.

Introduction

Nearly half of the world (3.5 billion people) suffers from oral diseases, which causes pain and considerable health burdens, and it is well known that the burden of oral diseases exerts a substantial negative impact on public health, even though most oral diseases are preventable and treatable in the early stages. Hence, this can be mitigated through oral health care, and so dentistry occupies a critical position within the healthcare field, serving as the cornerstone of oral healthcare for communities. (WHO, 2023)

Climate change is the greatest challenge facing humanity today. All human activities cause a rise in greenhouse gas within the atmosphere, which results in global warming, creates a challenging world problem, and threatens the health of both present and future generations (Bakar Majidi & Fennell-Wells, 2023; Shellard et al., 2022). This concern is echoed in the UN's 2030 Agenda for Sustainable Development, which issues a strong call for action across all segments of society (UN, 2015).

Oral health care (OHC) is a resource-intensive sector, placing considerable demands on supplies, energy, water, and fuel for daily operations. This, in turn, increases its financial costs and environmental impacts. Additionally, the disposal of dental hazardous waste and the release of pollutants exacerbate environmental challenges, as they negatively affect air, water, and food quality, thereby impacting

public health (Duane, 2022; Mulligan et al., 2021). It was found that the carbon footprint of OHC practices worsens global climate conditions by contributing to 5% of global greenhouse gas emissions from healthcare systems (Pichler et al., 2019).

Sustainable OHC is an emerging topic that offers a solution to these undesirable effects of the profession. It not only impacts dentistry but also the broader healthcare industry and society as a whole. According to the World Dental Federation (FDI), sustainable OHC involves delivering equitable, ethical, and high-quality care while using resources efficiently. It emphasizes reducing environmental impacts, enhancing social responsibility, and ensuring economic viability, guiding dental professionals to consider these factors in service delivery. A sustainable OHC could potentially result in significant CO₂ reduction while enhancing patient care, staff satisfaction, cost savings and improved quality of life. (Shellard et al., 2022). Minimizing the carbon footprint of OHC starts with prioritizing oral health promotion and disease prevention, providing durable interventions and implementing effective, practical maintenance plans (Duane et al., 2021).

Clinical guidelines for environmental sustainability in dentistry have been recently released by a collaborative body, in the UK. These guidelines aim to equip all dental staff with a deeper understanding of how to make OHC services more environmentally sustainable, raise awareness and promote best practices for a greener approach in dentistry (Bakar Majidi & Fennell-Wells, 2023).

Common dental practices and materials that can harm the environment:

The literature revealed that commuting to and from dental practices (by patients, staff, and for procurement) was the primary source of emissions and the leading contributor to the carbon footprint associated with dental services (Duane et al., 2017; Steinbach et al., 2018). Additionally, carbon modeling within dentistry

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showed that 'dental examinations' contribute the largest portion of dentistry's carbon footprint. (Borglin et al., 2021; Duane et al., 2017).

OHC involves the use of various materials and procedures that could eventually harm the environment. Given the social responsibility to manage waste properly and reduce its negative environmental and health impacts, dental staff should be trained in proper methods of handling and separating different types of waste at the point of generation. Additionally, a waste minimization strategy should be implemented to reduce, reuse, and recycle (Dhar & Sridharan, 2018). This circular economy model shapes the future of dentistry, as it decreases the industry's reliance on limited natural resources and minimizes waste generation. Designing products that can be transformed into raw materials for other sectors after their dental use creates a closed-loop system (Duane, 2022). According to the World Health Organization, most healthcare waste (85%) is regular trash and not hazardous, while the remaining 15% is hazardous, of which 10% infectious and 5% non-infectious (Chartier, 2014).

Mercury makes up 50% of dental amalgam by weight, a restorative material used in tooth fillings, and is identified as a toxic heavy metal. The placement and removal of amalgam result in the generation of mercury waste, raising concerns about the improper disposal of this hazardous substance. Whether disposed of through landfill, wastewater, or incineration, it poses a serious environmental risk (Dhar & Sridharan, 2018; Smith et al., 2023). Once in the environment, factors such as pH, temperature, oxygen, bacteria contribute to its conversion from inorganic mercury into the more toxic organic form "methylmercury", which is bioavailable and can accumulate in the food chain (Basu, 2023). The Minamata Convention in 2013 targeted mercury reduction in various products, including dental amalgam (Saito, 2019). Unfortunately, it is still used in many countries, and dentistry is

considered a major source of mercury pollution, consuming roughly 20% globally (Tibau & Grube, 2019).

Lead and silver in X-ray films are other major hazardous dental wastes, making them unsuitable for disposal in regular trash or incineration. Lead is known to have harmful health effects on both children and adults, even at low doses. Recycling the lead foil used in X-ray film packets is easy and considered the best practice to prevent environmental contamination from this toxic material. Moreover, the x-ray fixer solution has a high content of silver, which is highly toxic and should not be flushed or poured down the drain. Instead, it should be collected in special containers and sent to the manufacturer for use in local recycling programs or for safe discarding. On the other hand, digital radiography is considered a better alternative to traditional film-based x-rays, because it uses sensors instead of lead containing films and does not require developer or fixer solutions, in addition to its lower radiation dose (Dhar & Sridharan, 2018; Hiltz, 2007).

Gypsum is also a hazardous waste; it is used in dental laboratories and some OHC practices for the manufacturing of prosthodontic devices. When disposed of, it can form hydrogen sulfide gas (H_2S) which is highly toxic to the respiratory tract and nervous system with a characteristic rotten egg smell. Recycling gypsum will reduce its health burden and allow its use in different manufactures (Duane, 2022; Tawade et al., 2024).

Infection Control regulations in dentistry are necessary to protect patients and avoid preventable harm. Unfortunately, dentists often prioritize single-use products, considering them the safest option for infection control. While some are mandatory, others are a matter of convenience. Single-use plastics (SUPs) and other disposable clinical items that are used daily in the dental clinics in very high quantities and are disposed of as medical waste, end up in landfill or incinerator. Single use items used

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in dentistry pose a serious problem since they generate a large volume of waste. In the UK it was estimated that dental SUPs exceed 720 million items/year which end up as waste. Fortunately, a significant portion of these single-use items could be replaced with reusable alternatives that can be sterilized and reused several times. If regulations were set by environmentally aware and responsible authorities or stakeholders, significant progress could be made in reducing SUP reliance and transitioning to a more sustainable healthcare system (Duane, 2022; Hashemizadeh et al., 2024; Mulligan et al., 2021; Shellard et al., 2022; Wilson et al., 2020)

Nitrous Oxide (N₂O) and volatile halogenated agents are anesthetic gases that have been used to comfort patients during dental surgical treatment for decades, nevertheless, they remain for a long time in the atmosphere and are considered as greenhouse gases that affect the ozone layer and contribute to global warming. In hospitals, N₂O is commonly captured and neutralized during use to reduce its emission into the atmosphere, however, this proven technology is not adopted yet in dentistry (Duane, 2022; Yasny & White, 2012).

The road to achieving the UN's sustainable development goals (SDGs) requires dentists to become active participants in eco-friendly practices, from minimizing waste to conserving resources like water and energy. They have the power to significantly reduce their environmental footprint while still delivering top quality care. But without the awareness and commitment, progress will be limited (Shellard et al., 2022).

The AKAP model is used to examine awareness, knowledge, attitudes, and practices which are critical components of behavioral change models. They are connected and mutually reinforcing, and they influence individual behavior and societal outcomes. Awareness is the state of being conscious or informed of something. It involves perceiving and recognizing a particular phenomenon,

concept, or situation, and it is the initial stage of cognitive processing (Wessman, 2007). While Knowledge is the information or facts acquired through education and experience. It involves understanding and comprehension of a particular subject matter (Schrader & Lawless, 2004). Attitude refers to a positive or negative or even neutral evaluation of a matter, it is shaped by beliefs, values, and emotions and it influences behavior (Ajzen & Fishbein, 2000). Practice represents the regular activities; it involves applying knowledge and skills in a real-world context (Bourdieu, 1990).

A significant gap in the knowledge and skill persists among dental professionals towards sustainable OHC practices, despite increasing public awareness and governmental commitments to address the climate and ecological crisis globally (Antoniadou et al., 2023; Prathima et al., 2017; Verma et al., 2020). Therefore, the first step to achieve progress in sustainable dentistry should be through investigating the current situation. This study aims to assess dentists' awareness, knowledge, attitude, and practice (AKAP) regarding sustainable dentistry, in Alexandria Egypt, and gather information about the challenges and enablers that they reflect for establishing an eco-friendly dental practice.

Materials and Methods

A cross-sectional observational study design was chosen to estimate the prevalence of AKAP regarding sustainable dentistry among dental practitioners in Alexandria Egypt. The study was conducted over a period of 2 months (March–May 2024). The sample size was calculated using Epi Info 7 software to be 216, based on the percentage of dentists (82.9%) who chose to reduce the impact of dental activity on the environment, which represents sustainability in today's dental practice (Didilescu et al., 2023). With a confidence limit of 5%, the minimum required sample size at a 95% confidence level was determined.

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A snowball sampling technique was used to recruit participants. To minimize sampling bias, a network recruiting approach was employed. Dentists from diverse settings, including academic institutions, government and non-government centers, and private clinics in Alexandria, were initially contacted. These dentists were then asked to share the online questionnaire with their colleagues or other known dentists via a provided hyperlink. Additionally, formal and informal dental groups on social media were utilized to disseminate the questionnaire. This process allowed for the expansion of the sample beyond the initial contacts.

Inclusion criteria required participants to be dentists, working in Alexandria Governorate and willing to complete the questionnaire. The questionnaire was created on an online Google form and distributed through various online channels. To facilitate data collection, the researcher visited academic institutions and dental centers in Alexandria, providing participants with a mobile barcode that enabled direct online access to the questionnaire.

To ensure confidentiality, no personal identifying information was collected from respondents. Participation was entirely voluntary, and a welcoming message at the beginning of the questionnaire emphasized the study's purpose, the estimated completion time of 10-15 minutes, and the importance of reading the questionnaire carefully before proceeding were all mentioned at the beginning of the questionnaire.

To assess the baseline levels of awareness, knowledge, attitude, and practices (AKAP) regarding sustainable dentistry, a well-structured questionnaire with closed-ended questions was developed. This approach aligns with the established use of AKAP surveys for quantitative data collection on these topics. The questionnaire consisted of six sections comprising 38 questions. The first section collected socio-demographic data. The second section assessed dentists' awareness of sustainability, including their sources of information. The third section evaluated

participants' knowledge of sustainable dentistry. The fourth section measured dentists' attitudes toward sustainability using 3-point Likert scale. The fifth section examined dentists' common practices, such as transportation methods, material usage, waste management, and energy and water conservation. The final section explored dentists' perceived barriers and enablers to establishing eco-friendly dental clinics, these 2 questions specified several items where the respondent could choose multiple responses from, and one open-ended question at the end to add other possible options.

As the questionnaire was self-designed, its content validity was initially established by a panel of dental public health professionals from the Faculties of Dentistry at Pharos and Alexandria Universities, as well as the High Institute of Public Health in Alexandria. The panel consisted of experienced professors and lecturers specializing in various fields of dental public health, including epidemiology, dental health education, and community dentistry. Their expertise in research ensured the questionnaire's relevance and comprehensiveness. To determine the reliability of the questionnaire after confirmation of its validity, a pilot study involving 20 dental practitioners was conducted. It assessed the questionnaire's clarity, relevance, and feasibility. Participants completed the questionnaire online and were asked to provide feedback on any unclear questions or confusing sections. The pilot data revealed that while the questionnaire was comprehensive, it was perceived as somewhat lengthy. Based on this feedback, several sections were restructured to reduce its length. Also, the addition of visual aids, such as images, to certain questions was recommended to enhance understanding and several questions were rephrased for better clarity. Then Cronbach's alpha was calculated to be 79.0. please check the number

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The participants' levels of awareness and knowledge were evaluated according to the participants' mean percentage of correct answers scores with cutoffs Low: 0% - 35%, Moderate: 36% - 65%, and High: 66% - 100%. The attitude was categorized as "agree", "neutral" and "disagree" mean percentages. The practice was evaluated as good and poor, according to the mean percentages of the participants with good or poor practices.

Statistical Analysis

Data was tabulated and analyzed using SPSS software version 25. The data was presented as frequency and percentage. The mean percentage was calculated by dividing the sum of the percentages of each question by the sum of the total number of questions. Chi-square test was used to compare different categorical groups.

Results

It was found as shown in Table 1 that among 216 participants more than half of them (68.5%) were females, while (31.5%) were males. According to participants' age, (38.0%) were between 20 to <30 years, (38.9%) between 30 to <40 years, (15.7%) between 40 to <50 years and (7.4%) were 50 years or older. Upon viewing their marital status, more than half of the participants (55.1%) were married, (38.4%) were single, and (6.5%) were either divorced or widowed. Regarding the participant's last earned degree (41.7%) held a bachelor's degree, (28.2%) earned a Master's degree, (22.2%) earned a PhD, (5.1%) earned a Fellowship and (2.9%) of them earned a Diploma. About the participants' specialty and main field of practice, it was found that the highest percentage of participants were general practitioners (26.4%), followed by dentists practicing pedodontics (13.0%), oral surgery and implantology (12.5%), prosthodontics (11.1%), restorative dentistry (8.4%), dental public health and preventive dentistry (7.9%) oral medicine periodontics and oral

pathology (6.5%), endodontics (6%) orthodontics (4.2%) and other specialties (4.2%). Concerning the main working place of the participants, it was found that (43.5%) were working in the academic sector, (30.1%) were working in the governmental sector and (26.4%) were working in private hospitals or clinics. More than half of the participants (54.2%) had been in dental practice for more than 10 years, (31.9%) for 3-10 years, and (13.9%) for less than 3 years.

Table 1: Distribution of the participants according to their sociodemographic data

Sociodemographic data	Total No.=216 No. (%)
Gender	
Female	148 (68.5)
Male	68 (31.5)
Age	
20-	82 (38.0)
30-	84 (38.9)
40-	34 (15.7)
50 and more	16 (7.4)
Marital status	
Married	119 (55.1)
Single	83 (38.4)
Divorced/Widow	14 (6.5)
Last earned degree	
Bachelor	90 (41.7)
Masters	61 (28.2)
PhD	48 (22.2)
Fellowship	11 (5.1)
Diploma	6 (2.9)
Specialty	

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General practitioner	57 (26.4)
Pedodontics	28 (13.0)
Oral surgery/Implantology	27 (12.5)
Prosthodontics	24 (11.1)
Restorative	18 (8.4)
Dental Public health and preventive Dentistry	17 (7.9)
Oral medicine &Periodontics/ Oral Pathology	14 (6.5)
Endodontics	13 (6.0)
Orthodontics	9 (4.2)
Others	9 (4.2)
Main working place	
Academic Sector	94 (43.5)
Governmental	65 (30.1)
Private	57 (26.4)
Number of years practicing dentistry	
Less than 3 years	30 (13.9)
3-10 years	69 (31.9)
More than 10 years	117 (54.2)

The distribution of participants according to their awareness of sustainable development through activities and institution involvement is illustrated in Figure 1.

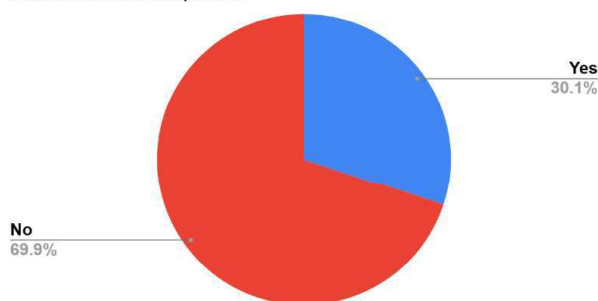
When the participants were asked if they have attended seminars or conducted any studies about sustainable development, nearly two thirds of them (69.9%) said they never did, while around one third (30.1%) said they did. When they were asked if they have participated in any events or activities about sustainable development nearly three quarters of them (75.5%) said they never did, and only one quarter of the participants (24.5%) reported that they did. It was found that (27.3%) of

participants' institutions adopted and implemented the sustainability approach, while (23.1%) did not, and about half of the participants (49.5%) didn't know if their institution officially adopted a sustainability approach or not.

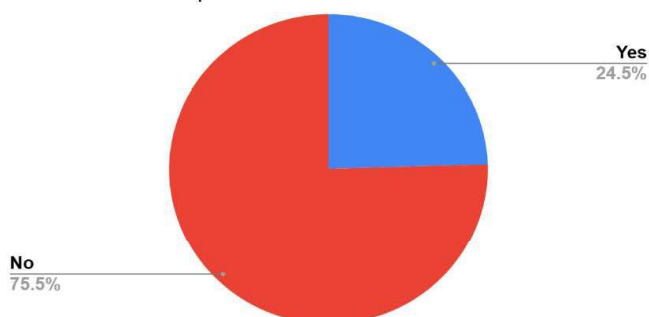
The distribution of the participants according to their awareness of the concept of sustainability in dentistry and their source of information is illustrated in Table 2.

When the participants were asked to assess their information about the concept of sustainability in dentistry (37.5%) of them said they never heard about the concept of sustainability before this survey, (38.4%) heard about the concept of sustainability but had little information about it, (16.7%) had some knowledge about the basic concept of the sustainability approach (6%) received some training/or had some experience with the sustainability approach and only (1.4%) had enough experience with the sustainability approach that they can teach it to others. Regarding the participants' sources of information about sustainability in dentistry, multiple responses were accepted; the highest reported source was 'from this questionnaire' (55.65%), followed by 'social media' (46.8%), 'trainings/workshops & awareness campaigns' (37.5%), 'websites' (34.3%) 'colleagues/relatives' (32.4%), 'workplace' (31.5%), 'university or postgraduate studies' (22.7%), and finally 'TV/Radio' (15.7%).

Did you attend any seminars or made any studies in sustainable development?



Did you participate in any events or activities related to sustainable development?



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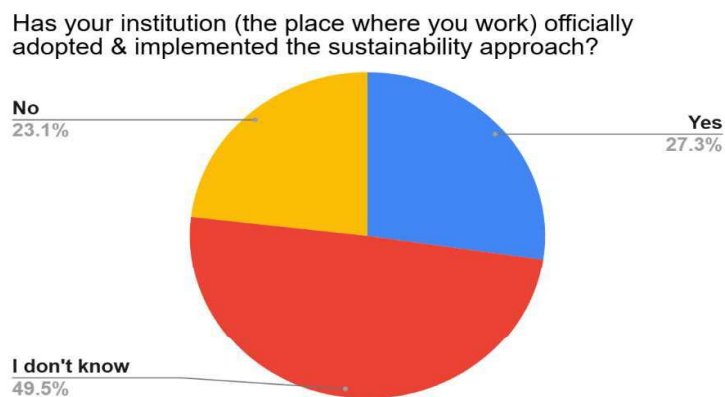


Figure (1): Distribution of the participants according to their awareness of sustainable development through activities and institution involvement.

Table (2): Distribution of the participants according to their awareness of the concept of sustainability in dentistry and their source of information

Total	Total No=216 No. (%)
What do you know about the concept of sustainability in the field of dentistry?	
I never heard about the concept of sustainability before this survey	81 (37.5)
I heard about the concept of sustainability, but I have little information about it	83 (38.4)
I have some knowledge about the basic concept of the sustainability approach	36 (16.7)
I received some training/ or I have some experience with the sustainability approach	13 (6.0)
I have enough experience with the sustainability approach that I can teach it to others	3 (1.4)
Your source of information regarding the sustainability approach in the field of dentistry is	
<i>From this questionnaire</i>	
Yes	120 (55.6)
No	96 (44.4)
<i>Social media</i>	
Yes	101 (46.8)
No	115 (53.2)

<i>Awareness campaigns/ Training courses and workshops</i>	
Yes	81 (37.5)
No	135 (62.5)
<i>Websites</i>	
Yes	74 (34.3)
No	142 (65.7)
<i>Colleagues and relatives</i>	
Yes	70 (32.4)
No	146 (67.6)
<i>My workplace</i>	
Yes	68 (31.5)
No	148 (68.5)
<i>University/Postgraduate studies</i>	
Yes	49 (22.7)
No	167 (77.3)
<i>TV/Radio</i>	
Yes	34 (15.7)
No	182 (84.3)

The results found that the **total mean percentage of participants who were aware** of the concept of sustainable dentistry, its adoption in their workplaces and have participated in any related activity were only **(28.0%)**. While the **total mean percentage of participants who correctly answered knowledge questions** about sustainable dentistry like: definitions, waste management strategies, proper management of some hazardous materials, and materials that could be recycled in the dental office...etc., were **(47.2%)**. According to the pre-identified score, this means that the study participants showed **low level of awareness** about sustainability and **moderate level of knowledge** regarding sustainable dentistry, (Figure 2).

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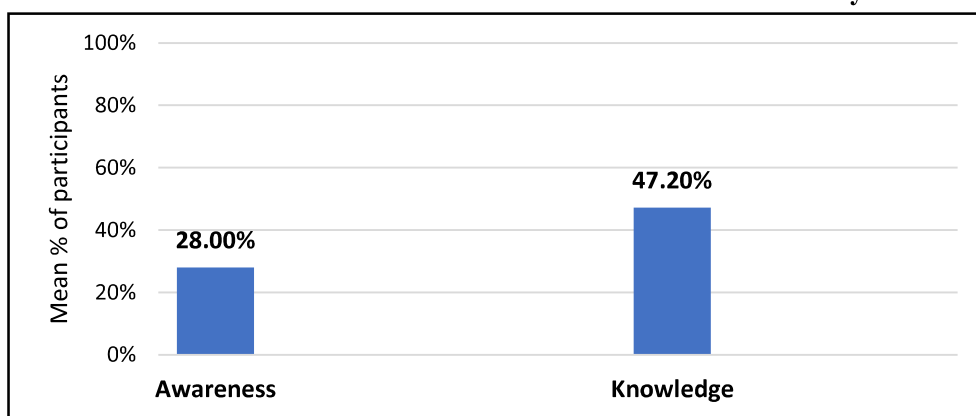


Figure (2): Mean Percentage of the participants who were aware of sustainability and those who correctly answered knowledge questions about sustainable dentistry.

After age adjustment for participants' awareness of sustainability (Table 3), it was found that there was no significant difference between different age groups by mean percentages of 26.8%, 27.4%, 26.5% and 31.3% respectively ($p = 0.98$).

Table(3): Age-adjusted for participants' awareness of sustainability

Age	Aware Mean number (%)	Unaware Mean number (%)	P value
20-	22 (26.8)	60 (73.2)	0.98
30-	23 (27.4)	61 (72.6)	
40-	9 (26.5)	25 (73.5)	
> 50	5 (31.3)	11(68.8)	
Total	59 (27.3)	157 (72.7)	

Significance at $p \text{ value} \leq 0.05$

Regarding knowledge, after age adjustment, it was found in Table 4 that there was no significant difference between different age groups regarding their mean percentage of correct answers to knowledge questions with mean percentages of 52.4%, 45.2%, 41.2% and 50.0% respectively ($p = 0.67$).

Significance at p value ≤ 0.05

Table (4): Age-adjusted for participants' knowledge of sustainability

Age	Correct answer Mean number (%)	Incorrect answer Mean number (%)	P value
20-	43 (52.4)	39 (47.6)	0.67
30-	38 (45.2)	46 (54.8)	
40-	14 (41.2)	20 (58.8)	
> 50	8 (50.0)	8 (50.0)	
Total	103 (47.7)	113 (52.3)	

Looking at the participants' self-reported attitudes towards sustainability, it was found that a mean percentage of (63.4%) had a positive attitude toward sustainability, (21.3%) had a neutral attitude and only (15.3%) had a negative attitude, as shown in figure 3.

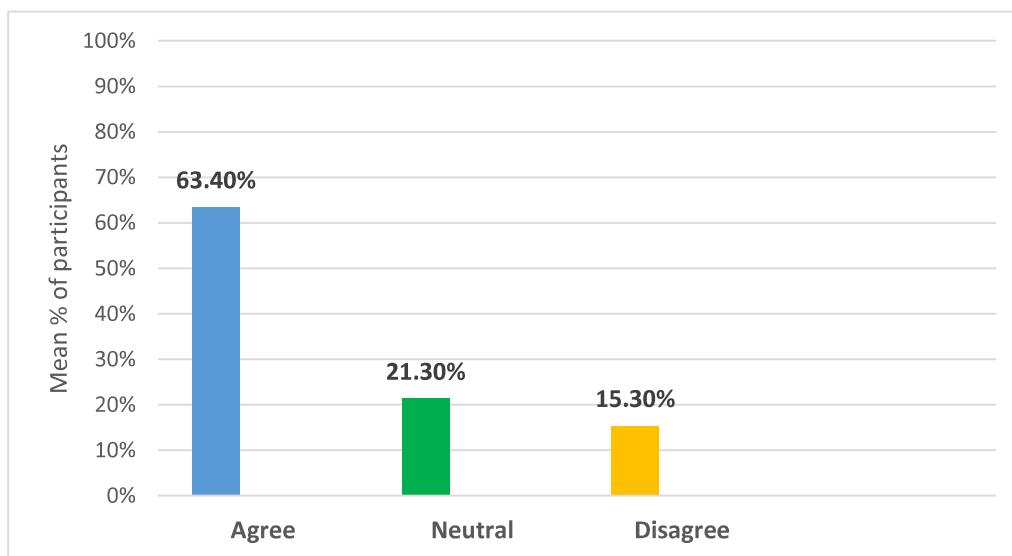


Figure (3): Mean percentage of the participant's attitudes toward sustainability

Table 5 shows participants' attitudes toward sustainability after the age adjustment. It was found that 60.9%, 60.7%, 61.8% and 68.7% are the mean percentages of participants who agreed with sustainable attitude, 20.7%, 20.2%, 26.5% and 18.8%

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reported neutral attitude, 18.4%, 19.0%, 11.7% and 12.5% disagreed with sustainable attitude for different age groups respectively. The difference between age groups was not statistically significant ($p = 0.95$).

Table (5): Age-adjusted for participants' attitudes toward sustainability

Age	Agree Mean number (%)	Neutral Mean number (%)	Disagree Mean number (%)	P value
20-	50 (60.9)	17 (20.7)	15 (18.4)	0.95
30-	51 (60.7)	17 (20.2)	16 (19.0)	
40-	21 (61.8)	9 (26.5)	4 (11.7)	
> 50	11 (68.7)	3 (18.8)	2 (12.5)	
Total	133 (61.6)	46 (21.3)	37 (17.1)	

Significance at p value ≤ 0.05

Regarding the practice of sustainable dentistry, it was found that the mean percentage of the participants with poor sustainable dental practice was (67.6%) and the mean percentage of participants with good sustainable dental practice was (32.4%) (Figure 4).

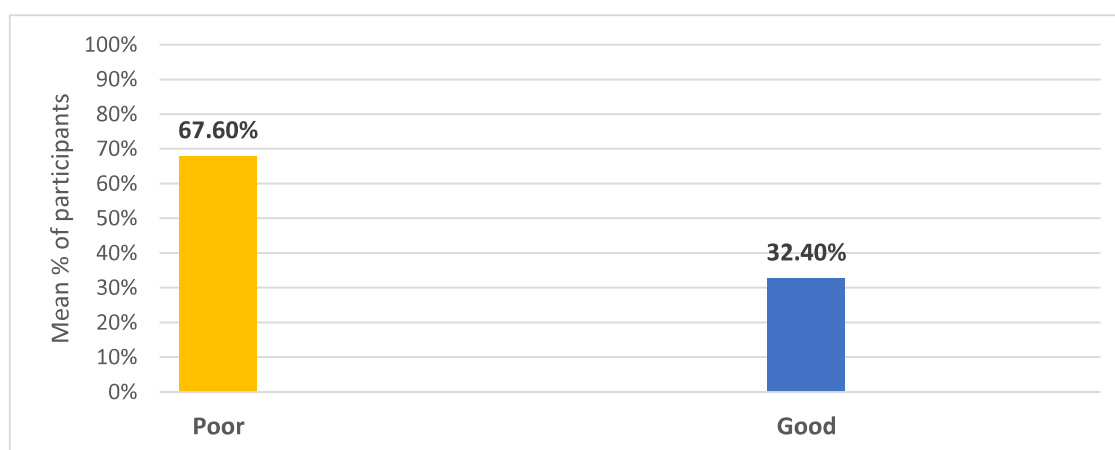


Figure (4): Mean percentage of the participant's practice toward sustainable dentistry

Table 6 shows practices of participants toward sustainable dentistry after age adjustment. It was found that 39.0%, 35.7, 29.4%, and 25.0% of the participants performed good practices toward sustainable dentistry in different age groups, while 61.0%, 64.3%, 70.6%, and 75.0% of participants performed poor practices in different age groups, without statistically significant differences (p= 0.62).

Table (6): Age-adjusted for participants' practices toward sustainable dental practice

Age	Good Mean number (%)	Poor Mean number (%)	P value
20-	32 (39.0)	50 (61.0)	0.62
30-	30 (35.7)	54 (64.3)	
40-	10 (29.4)	24 (70.6)	
> 50	4 (25.0)	12 (75.0)	
Total	76 (35.2)	140 (64.8)	

Significance at p value ≤0.05

When the participants were distributed according to the number of challenges and barriers that they faced in establishing an eco-friendly dental clinic, it was found that (17.6%) of them faced one challenge, (20.4%) of them faced two challenges and about two-thirds (62%) faced three challenges or more.

As shown in (Figure 5) ‘Lack of information’ followed by ‘financial constraints’ were considered the main challenges faced in establishing an eco-friendly dental clinic by (59.7%, 59.3%) of the participants, respectively. Then ‘lack of sustainable options from manufacturers or suppliers’ was considered a challenge by (52.8%) of the participants. Whereas ‘shortage in skilled workers’, ‘time constraints’, ‘fear of compromising the quality of practice’, ‘fear of negatively impacting patient’s outcome’, ‘fear of negative response from staff’ were seen as challenges/barriers, by (44.4%, 26.9%, 21.3%, 18.1% and 17.6%) of the participants, respectively.

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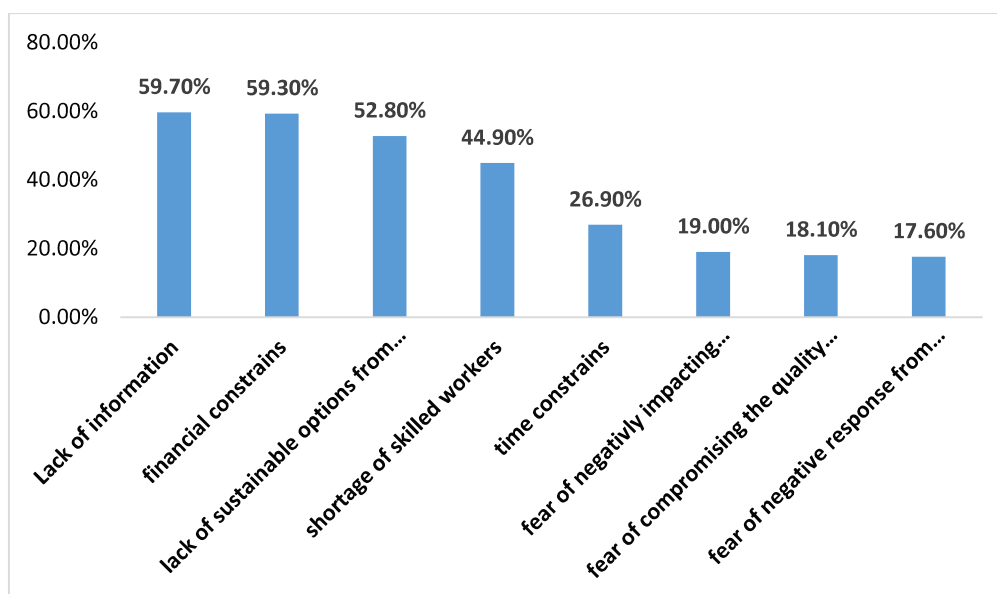


Figure (5): Distribution of participants based on the challenges and barriers faced in establishing an eco-friendly dental clinic

Regarding the number of enablers that help the participants in establishing an eco-friendly dental clinic, it was found that (37.5%) of the participants stated one enabler, (19.4%) stated two enablers and less than half (43.1%) of them stated three or more enablers.

Regarding the distribution of the participants according to the concerned enablers that help in establishing an eco-friendly dental clinic, as shown in fig 6, it was found that ‘the presence of recycling programs’ and ‘the presence of modern digital and technological devices’ were seen as enablers by around two-thirds of the participants (62% and 59.7%), respectively. Also, ‘the availability of renewable energy sources’ was considered as a helpful enabler by more than half of the participants (53.2%). While ‘Government incentives and regulations’, followed by ‘the availability of furniture made from environmentally friendly materials’ were considered enablers by (38% and 25.5%) of participants respectively.

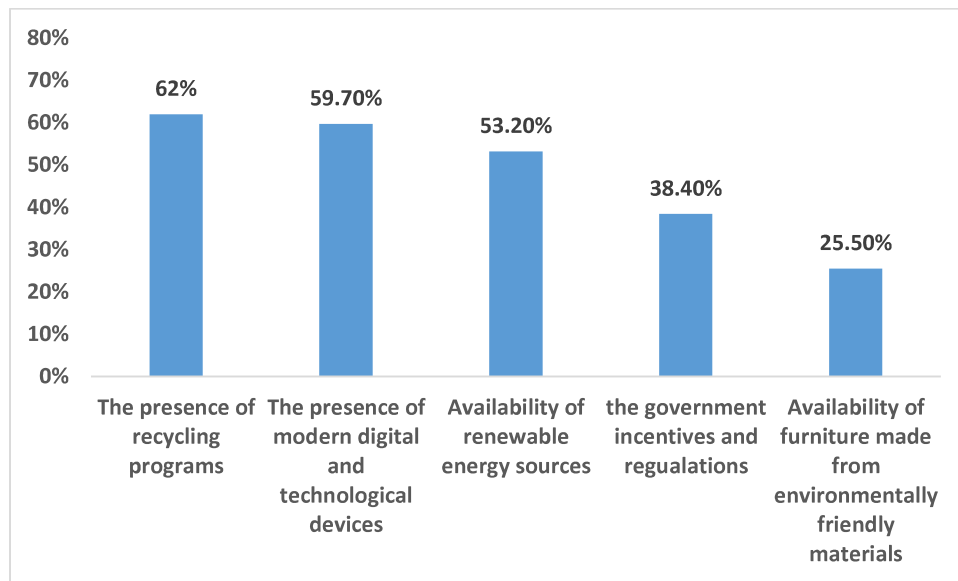


Figure 6: Distribution of participants based on the enablers that help in establishing an eco-friendly dental clinic

Discussion

Oral health professionals are increasingly recognized as having a global responsibility to implement environmentally sustainable practices in their daily operations. This commitment aims to minimize the ecological footprint of dental practices while maintaining quality patient care. Hence, in order to assess the current state of sustainable dentistry in Alexandria, a cross-sectional study was conducted between March and May 2024, the study employed a structured questionnaire designed by the researcher to evaluate dentists' knowledge, attitudes, and practices toward sustainable dentistry. The questionnaire also assessed perceived challenges and enablers for establishing eco-friendly dental clinics. Following a successful pilot study to ensure validity and reliability, the questionnaire was administered among dentists in Alexandria. The researcher visited dental centers, explained the study objectives, and invited dentists to participate by completing an online Google Form. A mobile bar-code was also created to provide easy access to the questionnaire.

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Additionally, the online link was distributed through official and unofficial dental groups in Alexandria via social media and other relevant applications.

Dental participants (216) were mostly female dentists, aged 20 to 40, married, specialized in one of the different dental specialties, around half of them were working in the academic sector and had over 10 years of experience.

While sustainable dentistry has been gaining attention in some countries, like the UK, and by multiple international associations for several years (Bakar Majidi & Fennell-Wells, 2023; Shellard et al., 2022) this survey revealed limited understanding of sustainable dentistry among participating dentists in Alexandria. Most participants (75.9%) either never encountered the term "sustainable dentistry" or possessed minimal knowledge of the overall concept, this aligns with similar studies. For instance, a previous cross-sectional survey across 17 dental schools in USA found that 75% of respondents were 'not knowledgeable at all' or 'only slightly knowledgeable' in environmentally sustainable dentistry (Gershberg et al., 2022), also an online pilot survey in Bucharest Romania revealed that less than half 41.4% of private dental practitioners were aware of sustainability in dentistry (Didilescu et al., 2023); another cross-sectional survey among dental practitioners in Bhopal city, India reported that only 52.5% of postgraduate and 48.4% of graduate participants were familiar with the term 'green dentistry' (Verma et al., 2020), additionally a study among dental practitioners who worked in private dental practices of twin cities of Hyderabad and Secunderabad, Telangana India found that 60% were not aware of the eco-friendly concept in dental practice (Prathima et al., 2017).

Nearly half of the participants were unsure if their workplaces have officially adopted and implemented a sustainability approach or not, the reason for this might

be due to their lack of awareness about the concept or because their workplaces did not implement any eco-friendly changes.

The questionnaire itself was the most common information source about sustainable dentistry for the participants, followed by social media then awareness campaigns/training. This aligns with findings in Turkey, where social media was the primary source of sustainability information for dentists (Beşiroğlu et al., 2023).

Despite the apparent novelty of the topic, with most participants demonstrating a low level of awareness, nearly half of them showed a moderate level of knowledge (46.7%). The reason for this might be that some aspects of sustainable dental practices, such as the importance of preventive dentistry, amalgam waste management, general recycling practices, and certain clinic management strategies, overlap with their existing knowledge base. Higher knowledge levels (70%) of eco-friendly dental practices were found among dentists in Amman, Jordan (Al Shatrat et al., 2013)

A more positive finding was that 63.4% of participants displayed a high level of attitude toward sustainable dentistry. However, the implementation of sustainable practices remained low at the dental clinics. Similar findings have been reported in a systematic review of 13 articles by (Zia et al., 2024), which found positive dentist attitudes towards environment conservation, but inadequate implementation. Reasons behind this might be the presence of challenges like discernment that exists within the profession not considering or prioritizing sustainability, especially in developing countries, where the main challenges are economic constraints and lack of knowledge.

The poor practice in our survey may be partially attributed to infrastructural limitations at the workplace, like the lack of water and energy-saving technologies, unavailable amalgam separators, absence of waste segregation policies, limited

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reusable products in the market and inaccessible digital technologies. The participant's second most reported challenge was financial constraints, followed by the lack of sustainable products from manufacturers and suppliers. However, the main challenge identified was insufficient knowledge regarding environmental sustainability in dentistry, which likely explains the low implementation rate. This came in agreement with the findings of dental practitioners in Bhopal city, where dentists cited lack of knowledge for not adopting green (Verma et al., 2020). Studies in India (Sen et al., 2017) (Verma et al., 2020), and Romania (Didilescu et al., 2023) reported similarly low levels of awareness, knowledge and practice of ecofriendly sustainable dentistry.

Education during undergraduate training and through professional development activities may encourage environmentally sustainable initiatives for future practice. In our survey, only 22.7% of participants reported receiving information about sustainability through formal education, which aligns with previous studies (Martin et al., 2021). This highlights why many studies recommend integrating sustainability and green practices into the dental curriculum (Antoniadou et al., 2023; Duane et al., 2021; Gershberg et al., 2022; Nassar et al., 2023). Integrating dental sustainability into undergraduate education has the potential to cultivate sustainability-conscious decision-making among future generations of oral healthcare providers.

The United Kingdom (UK) offers a good example for successful implementation of sustainability in dentistry. This progress is driven by a multifaceted approach (Amarantha Fennell-Wells, 2023). Embedding sustainability principles directly into the dental education to equip future dentists with a strong

foundation in eco-friendly practices (Center-for-sustainable-health-care). Also, government initiatives like the "Greener National Health Service (NHS)" program which plays a crucial role in achieving 'carbon net zero' NHS by 2040 (Stevens, 2020). The UK's public healthcare system provides resources and guidance to dental practices on implementing sustainable measures (Shellard et al., 2022). Furthermore, many dental schools and practices have taken the initiative to set and implement internal policies and protocols that actively promote sustainable practices within the profession (Bakar Majidi & Fennell-Wells, 2023). These combined efforts have yielded positive results ("UK dental practices recognized with green awards," 2024). Studies reveal a promising rise in dentist awareness and knowledge of sustainable dentistry through these interventions (Grose et al., 2018).

Limitations

This cross-sectional study, employing a snowball non-probability sample within a single city, restricts generalizability of the findings to the broader dental practitioner population. Although the sample size of 216 participants has been calculated prior to the study and is adequate for the study's objectives, a larger sample could have provided more robust results. In addition, using an online survey may introduce response bias, because it might have been challenging for some dentists to respond to the online google form, as participants who lack internet access, have unsuitable devices or insufficient technological skills, especially older aged participants, are less likely to respond.

Conclusion

Lack of awareness of sustainable dentistry amongst dentists is highly prevailing. Although dentists in our study show moderate levels of knowledge concerning sustainable dentistry and have a positive attitude, their weak practices are far from acceptable. The highest self-reported challenges to establish an eco-

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friendly dental practice were the lack of sufficient knowledge, financial constraints, and the lack of sustainable products from manufacturers and suppliers, while the highest mentioned enablers were the presence of recycling programs, the presence of modern digital and technological devices and the availability of renewable energy sources.

Recommendations

Sustainable OHC: A Shared Responsibility

Sustainable OHC represents a novel and crucial concept in Egypt. The successful implementation of sustainable practices requires a collective effort, not an individual one. This study serves as a foundational investigation into sustainable dentistry within Egypt and underscores the need for continued research in this critical area. By fostering collaboration between policymakers, dental organizations, and individual practitioners, Egypt can move forward in establishing a more environmentally responsible dental sector, where the development of education, incentives, protocols, and infrastructure will allow OHC professionals to implement sustainable dental practices in their clinics.

For Dental Practitioners

- **Incremental Implementation:** To facilitate the adoption of sustainable practices, dentists are encouraged to begin with low-cost, easily implemented strategies. Initial efforts could focus on powering down unused equipment, replacing single-use materials with those that can be sterilized and reused several times to decrease the amount of waste generated while still ensuring patient safety, and implementing powerful paper waste recycling programs. These foundational steps can pave the way for the incorporation of more comprehensive green initiatives.

For Policymakers

- **Collaborative Sustainability:** Achieving environmental sustainability in dentistry necessitates a collaborative approach. While government leadership is paramount, fostering participation from dental organizations and individual practitioners can create a more impactful and sustainable strategy.
- **Knowledge Dissemination:** The development and dissemination of educational tools and workshops tailored to environmental issues and their impact on dental practices are crucial for raising awareness and knowledge among dentists in the city of Alexandria and Egypt as a whole. These educational initiatives should be designed to equip dentists with the necessary information and skills for successful implementation of sustainable practices within their clinics.
- **Manufacturing:** Proactive measures from decision-makers and senior management are needed to raise awareness among producers and suppliers and to implement policies that govern the manufacturing and sales processes in a more sustainable manner. This will lead to the availability of eco-friendly products in the markets at reasonable and non-exorbitant prices.

For Future Research

- **Expanding the Horizons of Research:** It is recommended to broaden the scope of the research and for future studies to consider including wider geographic areas and a larger sample size to improve the generalizability of the findings. Additionally, the use of multiple data collection methods, including both online and offline approaches, could ensure a more diverse representation of participants.
- **Comparative Analysis:** To gain a broader understanding of environmentally sustainable dentistry the implementation, research efforts should be expanded to include different countries. Comparative analyses can highlight best

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practices, identify potential challenges, and inform the development of universally applicable sustainable dentistry strategies.

- **Evaluating Educational Impact:** Building upon the findings of this study, future research should investigate the impact of educational interventions on the knowledge, attitudes, and practices of dentists regarding sustainable dentistry. This evaluation will provide valuable insights into the effectiveness of these initiatives and inform the development of future educational programs.
- **Economic Feasibility:** Further research could explore the economic benefits associated with environmentally sustainable dentistry in Egypt. This could involve analyzing the potential reductions in water and energy costs compared to conventional dental practices.

References

Journal Articles

- Ajzen, I., & Fishbein, M. (2000). Attitudes and the Attitude-Behavior Relation: Reasoned and Automatic Processes. *European Review of Social Psychology*, 11(1), 1-33. <https://doi.org/10.1080/14792779943000116>
- Antoniadou, M., Chrysochoou, G., Tzanetopoulos, R., & Riza, E. (2023). Green dental environmentalism among students and dentists in Greece. *Sustainability*, 15(12), 9508.
- Beşiroğlu, S., Tagtekin, D., Akmansoy, Ş., Özkuyucu, D., & Alkan, E. (2023). Survey Study on Awareness and Consciousness Level of Sustainability in Dentistry. 5, 80-87.
- Borglin, L., Pekarski, S., Saget, S., & Duane, B. (2021). The life cycle analysis of a dental examination: Quantifying the environmental burden of an examination in a hypothetical dental practice. *Community Dentistry and Oral Epidemiology*, 49(6), 581-593.
- Bourdieu, P. (1990). The logic of practice. *Polity*.
- Dhar, A., & Sridharan, G. (2018). Biomedical waste management in dental clinics-a review. *Int J Med Sci*, 5(5), 1-3.

- Didilescu, A., Pantea, M., Sfeatcu, R., & Imre, M. (2023). Aspects Regarding Sustainability among Private Dental Practitioners from Bucharest, Romania: A Pilot Study. *Healthcare* 2023, 11, 1326. *healthcare*.
- Duane, B., Dixon, J., Ambibola, G., Aldana, C., Coughlan, J., Henao, D., Daniela, T., Veiga, N., Martin, N., & Darragh, J. H. (2021). Embedding environmental sustainability within the modern dental curriculum—Exploring current practice and developing a shared understanding. *European Journal of Dental Education*, 25(3), 541-549.
- Duane, B., Lee, M. B., White, S., Stancliffe, R., & Steinbach, I. (2017). An estimated carbon footprint of NHS primary dental care within England. How can dentistry be more environmentally sustainable? *British Dental Journal*, 223(8), 589-593. <https://doi.org/10.1038/sj.bdj.2017.839> .
- Gershberg, N. C., Lee, J., Murphree, J. K., Parchure, A., & Hackley, D. M. (2022). US students' perceptions on environmental sustainability in dental school. *Journal of Dental Education*, 86(4), 482-488.
- Grose, J., Burns, L., Mukonoweshuro, R., Richardson, J., Mills, I., Nasser, M., & Moles, D. (2018). Developing sustainability in a dental practice through an action research approach. *British Dental Journal*, 225(5), 409-413. <https://doi.org/10.1038/sj.bdj.2018.738>
- Hiltz, M. (2007). The environmental impact of dentistry. *J Can Dent Assoc*, 73(1), 59-62.
- Martin, N., Sheppard, M., Gorasia, G., Arora, P., Cooper, M., & Mulligan, S. (2021). Awareness and barriers to sustainability in dentistry: A scoping review. *Journal of Dentistry*, 112, 103735.
- Mulligan, S., Smith, L., & Martin, N. (2021). Sustainable oral healthcare and the environment: challenges. *Dental Update*, 48(6), 493-501. <https://doi.org/10.12968/denu.2021.48.6.493>
- Nassar, M., Shalan, W., Al-Janaby, U., Elnagar, H., Alawadhi, M., Jaser, S., & Joury, E. (2023). Cross-Sectional Survey Exploring Environmental Sustainability in Dental Education in the United Arab Emirates.
- Pichler, P.-P., Jaccard, I. S., Weisz, U., & Weisz, H. (2019). International comparison of health care carbon footprints. *Environmental research letters*, 14(6), 064004.

Awareness, Knowledge, Attitude and Practice Towards Sustainable Dentistry Among Dental Practitioners in Alexandria: A Cross-Sectional Study

- Prathima, V., Vellore, K. P., Kotha, A., Malathi, S., Kumar, V. S., & Koneru, M. (2017). Knowledge, attitude and practices towards eco-friendly dentistry among dental practitioners. *J Dent Res*, 4, 123.
- Saito, M. (2019). Minamata convention on mercury-our challenges and its future. *Journal of Environment and Safety*, 10(2), 95-97.
- Schrader, P. G., & Lawless, K. A. (2004). The knowledge, attitudes, & behaviors approach how to evaluate performance and learning in complex environments. *Performance Improvement*, 43(9), 8-15. <https://doi.org/https://doi.org/10.1002/pfi.4140430905>
- Sen, N., Bhat, N., Shah, R., Goyal, K., Patel, D., & Mandal, A. (2017). Assessment of knowledge, attitude and practices regarding green dentistry in Udaipur, Rajasthan, India: A revolutionary challenge for dentists. *Int J Recent Sci Res*, 8(12), 22202-22208.
- Smith, L., Ali, M., Agrissais, M., Mulligan, S., Koh, L., & Martin, N. (2023). A comparative life cycle assessment of dental restorative materials. *Dent Mater*, 39(1), 13-24. <https://doi.org/10.1016/j.dental.2022.11.007>
- Tawade, S. U., Dhamande, M. M., Dubey, S. A., Sathe, S., Selukar, M. S., & Pathak, A. (2024). Sustainable Dentistry: A Comprehensive Review of the Recycling Techniques for Gypsum Products in Prosthodontics. *Cureus*, 16(3), e55997. <https://doi.org/10.7759/cureus.55997>
- Tibau, A. V., & Grube, B. D. (2019). Mercury contamination from dental amalgam. *Journal of Health and Pollution*, 9(22), 190612.
- UK dental practices recognised with green awards. (2024). *British Dental Journal*, 236(4), 242-242. <https://doi.org/10.1038/s41415-024-7145-x>
- Verma, S., Jain, A., Thakur, R., Maran, S., Kale, A., Sagar, K., & Mishra, S. (2020). Knowledge, Attitude and Practice of Green Dentistry among Dental Professionals of Bhopal City: A Cross-Sectional Survey. *JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH*, 14. <https://doi.org/10.7860/JCDR/2020/43406.13637>
- Wilson, G. J., Shah, S., & Pugh, H. (2020). What impact is dentistry having on the environment and how can dentistry lead the way? *Faculty Dental Journal*, 11(3), 110-113.
- Yasny, J. S., & White, J. (2012). Environmental implications of anesthetic gases. *Anesth Prog*, 59(4), 154-158. <https://doi.org/10.2344/0003-3006-59.4.154>

- Zia, N., Doss, J. G., John, J., & Panezai, J. (2024). Sustainability in Dentistry: Assessing knowledge, attitude, and practices of dental practitioners about green dentistry. *Pak J Med Sci*, 40(1Part-I), 233-241. <https://doi.org/10.12669/pjms.40.1.7606>

Books

- Basu, M. (2023). Impact of Mercury and Its Toxicity on Health and Environment: A General Perspective. In N. Kumar (Ed.), *Mercury Toxicity: Challenges and Solutions* (pp. 95-139). Springer Nature Singapore. https://doi.org/10.1007/978-981-99-7719-2_4
- Chartier, Y. (2014). *Safe management of wastes from health-care activities*. World Health Organization.
- Duane, B. (2022). *Sustainable dentistry: making a difference*. Springer.
- Hashemizadeh, A., Lyne, A., & Liddicott, M. (2024). *Reducing single use plastics in dental practice: a quality improvement project*. <https://doi.org/10.21203/rs.3.rs-3928755/v1>
- Shellard, I. J., Martin, N., Mulligan, S., & Hatton, P. (2022). *Consensus on environmentally sustainable oral healthcare: a joint stakeholder statement*. White Rose University Press.
- Steinbach, I., Stancliffe, R., Berners-Lee, M., & Duane, B. (2018). *Carbon modelling within dentistry Towards a sustainable future Carbon modelling within dentistry: towards a sustainable future*.
- Wessman, W. L. (2007). *The nature of thought: Maturity of mind*. University Press of America.
- **Reports**
- Fennell-Wells, Amarantha & Malaga, Elizabeth & Kandhari, Sunmeet & Morley, Claire & Oliver, Rachel & Tebbutt, Jessie & Venugopal, Sumalatha & Gadhia, Tej. (2023). *Sustainability in dentistry: Leading for change*.
- Bakar Majidi, D. B., & Fennell-Wells, A., Klass Charlotte. (2023). Clinical guidelines for environmental sustainability in dentistry. In (pp. 38). UK: Trinity College Dublin (Republic of Ireland), NHS England (London), and the Office of the Chief Dental Officer England.
- Stevens, S. (2020). *Delivering a 'Net Zero' National Health Service*. NHS.

Awareness, Knowledge, Attitude and Practice Towards Sustainable Dentistry Among Dental Practitioners in Alexandria: A Cross-Sectional Study

- WHO. (2023). *Global oral health status report: towards universal health coverage for oral health by 2030. Regional summary of the African Region.* (9240070761).

websites

- Center-for-sustainable-health-care.<https://sustainablehealthcare.org.uk/what-we-do/sustainable-specialties/sustainable-dentistry>
- UN. (2015). *The 17 United Nations Sustainable Development Goals.* <https://sdgs.un.org/goals>.