A QUALITATIVE STUDY EXPLORING SINGLE-USE PLASTICS AND ENVIRONMENTAL SUSTAINABILITY IN ORTHODONTICS

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Intellectual Property and Publication Statements

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Acronyms

BDA	British Dental Association
BOS	British Orthodontic Society
COM-B	Capability, opportunity, motivation – behaviour change (model)
CPD	Continuing Professional Development
EDA	Eco Dentistry Association
ES	Environmental sustainability
ESG	Environmental sustainability group
FG	Focus group
FGR	Focus group respondent
GIFH	Green Impact for Healthcare
HTM	Health Technical Memorandum
IPC	Infection prevention and control
IR	Industry representative
LCA	Life cycle assessment
MIH	Molar incisor hypomineralisation
QI	Quality improvement
SDCEP	Scottish Dental Clinical Effectiveness Programme
SUP	Single-use plastic(s)
TGG	Training Grades Group, part of the British Orthodontic Society
WHO	World Health Organisation

Abstract

Background: The World Health Organisation labelled climate change 'the single biggest health threat facing humanity'. Healthcare has significant adverse effects on the environment. Single-use plastics (SUP) are one aspect of environmental sustainability that we must address to reduce our impact on the environment. Plastics used in medical equipment are not easily sterilised for re-use, or recyclable, meaning that the majority of healthcare plastic waste goes to incineration or landfill. Orthodontic treatment uses myriad SUP items whilst reusable alternatives exist.

Aim: To explore how the orthodontic community and orthodontic industry in the UK, use and perceive SUP, to understand current practice and identify barriers or facilitators to changing SUP use.

Methods: This qualitative study involved a document review to understand the policies and guidelines that influence the use of SUP in orthodontics that helped to develop topic guides for interviews with orthodontic industry and focus groups with the orthodontic community. These were conducted online, to understand different stakeholders' perspectives and barriers and facilitators surrounding a change in SUP use in orthodontic practice. Data analysis was phenomenological, grounded in the experience of the participants and coded thematically, according to Braun and Clarke (2006). Three focus groups (13 participants) and three interviews were carried out with the UK orthodontic community and company representatives.

Results: Orthodontic industry and the orthodontic community had similar viewpoints. Both interview and focus group participants felt that change is needed and welcomed, but that barriers included infection prevention control, cost and confusion regarding recycling. Participants felt changes must be made at all levels.

Conclusions: This study highlights the complexities associated with transitioning to more sustainable ways of working. These complexities include the need for multiple stakeholders (trade, regulators, clinicians and patients) to accommodate more sustainable practice through improved policies, systems, workflows and education while minimising any negative financial impacts.

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Chapter 1: Introduction

The environmental impact of different industries has become a focal point of addressing global sustainability (World Health Organisation, 2020). Healthcare, as an industry, is not exempt from environmental scrutiny, with single-use plastics (SUP) emerging as a critical area of concern (NHS England, 2022). Orthodontics, a specialty of dentistry, relies heavily on SUP for a variety of different reasons. While these materials offer undeniable clinical benefits, their widespread use contributes significantly to plastic waste, exacerbating environmental degradation and resource depletion.

The need to reconcile the clinical advantages of SUP with their environmental consequences has never been more urgent (World Health Organisation, 2021). As healthcare systems strive to meet sustainability goals, orthodontics faces unique challenges and opportunities. Orthodontists' reliance on plastic aligners, plastic packaging and single-use instruments highlights the conflicting interests between infection prevention protocols and the pressing need to reduce plastic consumption. This research examines these dynamics, exploring the facilitators and barriers to reducing single-use plastics (SUP) in orthodontic care while maintaining high standards of safety and efficiency.

This qualitative study included document review, interviews with representatives from the orthodontic industry and focus groups with the orthodontic community. The aim of these different approaches were to understand the policies and guidelines affecting sustainability within orthodontics and to explore different stakeholders experiences and attitudes in detail. Identification of possible solutions to working more sustainably in orthodontics was the desired impact of this research.

Key themes include the role of regulations in driving or impeding sustainability efforts, the economic considerations of adopting greener practices and the need for behaviour change at all levels. Behavioural factors, such as clinician and patient attitudes toward sustainability, are explored, alongside incorporating sustainability into staff training.

By critically analysing the current state of SUP usage in orthodontics, this research aims to provide actionable insights and recommendations for fostering environmentally sustainable practices. Through a multi-stakeholder approach, it seeks to bridge the gap between clinical necessity and ecological responsibility, offering a pathway toward a more sustainable future in orthodontic care.

The aim of this research is to explore how the orthodontic community and the orthodontic industry in the UK, use and perceive SUP; to understand current practice; and identify barriers or facilitators to behaviour change.

Chapter 2: Literature review of environmental sustainability and single-use plastics within orthodontics

2.1 Climate change and environmental impacts

In 1987, the United Nations Brundtland Commission defined sustainability as “meeting the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). Sustainable development requires an approach that carefully takes into account concerns about the environment, alongside the need for economic growth and development. Today, it is commonplace for businesses to have mandatory sustainability goals, plans or targets.

‘Climate change’ is measured over a long period of time, unlike weather, which can change on a daily or hourly basis. Climate change is described by the National Geographic Society as “a long-term shift in global or regional climate patterns” (National Geographic Society, 2023). It is prudent to acknowledge that climate change has been occurring since climate records began, however when referring to climate change in this document, it is specifically to the rise in global temperatures since the industrial revolution. The World Health Organisation (WHO) has labelled climate change as “the single biggest health threat facing humanity” (WHO, 2021)

‘Environmental impact’ refers to the effects that people have on the environment, which may be in terms of the amount or type of products that are produced and consumed. Different products and processes have varying amounts of environmental impacts, dependent upon the amount of energy or resources required to produce them, their capacity to be reused or recycled or the amount of time required to break them down.

Since the 1980s, there has been a debate as to whether climate change exists and if it could be attributed to human activity. Climate change denial was fuelled by oil and gas companies as well as countries who saw no benefit from cutting back their fossil fuel use (Watts et al. 2019). It is now widely accepted that climate change has been caused by human activities and we must act now to mitigate the effects. Recently, the climate change agenda has been brought to the forefront by groups such as Just Stop Oil and Extinction Rebellion who have taken to large protests and demonstrations in an attempt to force governments around the world to act.

The need for sustainability to be so high on the political, economic and social agenda is clear: climate change is causing devastating impacts across the world, with average temperatures rising to almost 2°C above pre-industrial levels (World Meteorological Organisation, 2021). Extreme weather events such as storms, floods and wildfires are becoming more frequent and are presenting with increasing intensity. Degradation of farmland, loss of biodiversity and destruction of ecosystems are some of the biological costs that the Intergovernmental Panel on Climate Change (IPCC) have warned are no longer preventable as there is a “locked-in” level of global warming causing unavoidable consequences (IPCC, 2021).

2.1.1 Quantification of impact

One measure of environmental impact is described as a ‘carbon footprint’. This is the amount of carbon dioxide released into the atmosphere as a result of the activities of a particular process, individual or organisation. Although the term is frequently used, there are problems associated with using ‘carbon footprint’ (Gaia, 2025). Firstly, it can be difficult to accurately quantify the carbon footprint of a person or organisation. It is also hard for the average person to know whether the carbon footprint given is high or low for the specific item being measured, the numbers are not comparable to anything we can relate to, and therefore can seem meaningless.

Life Cycle Assessment (LCA) is a technique used to quantify the environmental impact of a product or system from the beginning to the end of its ‘life’. LCA accounts for the environmental impact at every stage of a product’s existence and may be seen as a more comprehensive assessment of environmental impact. There are criticisms of carrying out LCA (Gutowski, 2018), the data used to make LCA calculations may be averaged due to a lack of raw data, which can be seen as inaccurate, and the process itself can involve long and technical calculations.

An increase in the use of LCA will provide more information to help determine which materials, products or treatments are more environmentally sustainable (EcoChain, 2025). For example, whether it is more sustainable to use single-use items that create waste but are low-energy in terms of production, or reusable items that are more energy-intensive to produce. In 2020, Duane et al. published an investigation into the environmental sustainability of endodontics by calculating the LCA of a root canal procedure (Duane et al. 2020). Travel was not included in the assessment as it was deemed to be too variable but

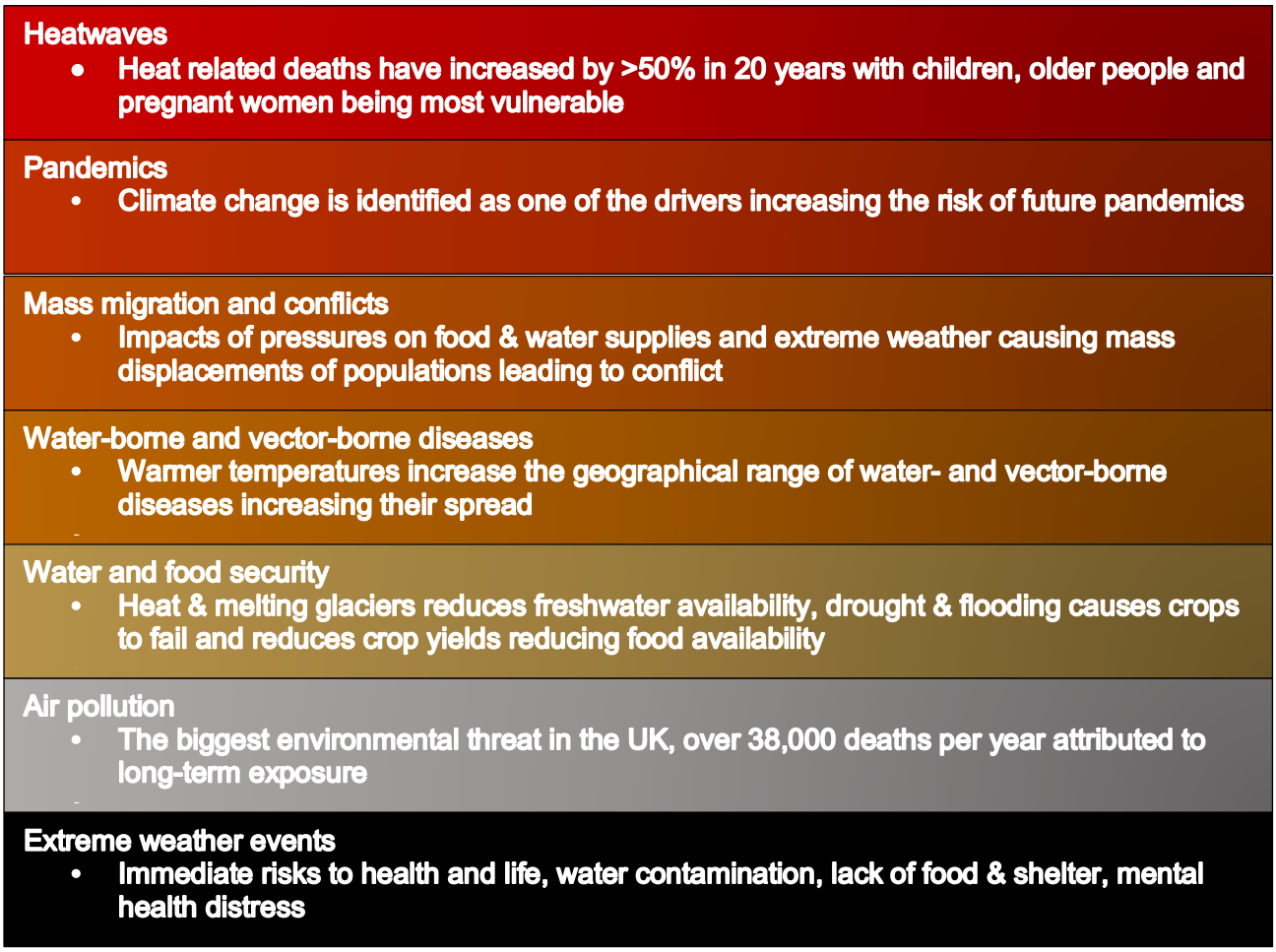
travel is known to be a large proportional contribution to a dental carbon footprint. The study was conducted according to the International Organization of Standardization guidelines (ISO 14040:2006) meaning that other studies can follow a similar methodology and produce comparable results. The authors were clear with their protocol and limitations and this paper provides us with thought provoking data and a numerical value of CO_2 equivalent emissions that can be compared to other dental or healthcare treatments. They found that the five biggest contributors to the overall carbon footprint of endodontic treatment (4.9kg CO_2 equivalent) were dental clothing, surface disinfectant, disposable bibs, single-use stainless steel instruments and electricity use. It would be beneficial to see similar studies in the future looking into the LCA of orthodontic treatments, and interesting to see the LCA comparison between traditional pre-adjusted edgewise appliances and newer, plastic single-use aligner treatments. In the future, LCA data may facilitate patients being given environmental sustainability information as part of their decision-making process prior to treatment.

2.2 Climate change: impact on health

Climate change and human health are intricately linked. Climate change affects human health directly through heatwaves, drought and flooding, as well as indirectly through mass migration of climate refugees (World Health Organisation, 2021). Climate refugees are people who have been forced to leave their traditional habitat, temporarily or permanently, because of marked environmental disruptions.

The potential effects that climate change will have on human health have been modelled by the WHO (Ezzati et al. 2004). Although the WHO predict a small decrease in cardiovascular and respiratory disease related mortality attributable to warmer winters, this small decrease is vastly outweighed by the tremendous increase in morbidity and mortality due to increased spread of air- and water-borne disease, deaths linked with extreme weather events such as coastal flooding, or malnutrition caused by poor crop yields, with developing countries suffering proportionally more negative effects (World Health Organisation, 2021).

Figure 1: Climate change impacts on human health (IPCC, 2023)



Spikes in air pollution are linked with increased numbers of people attending hospital for asthma exacerbations (D'Amato & D'Amato, 2023). Air pollution has also been shown to increase the risk of respiratory bacterial and viral infections (including COVID-19) and chronic inflammation caused by long-term exposure to polluted air increases the risk of lung cancer.

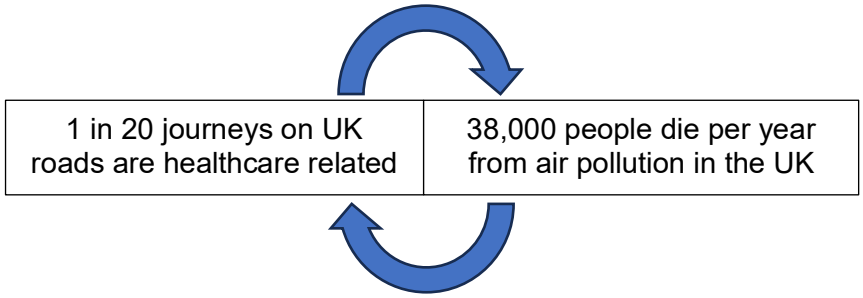
There is currently a lack of published information. One study in Poland reported higher rates of Molar Incisor Hypomineralisation (MIH) in areas with increased levels of air pollution (Glódkowska & Emerich, 2020). The study compared two groups of school children in areas of Poland with differing levels of air pollution. They found that in the area of high air pollution, the prevalence of MIH was over twice as high as in the district where consistently low levels of air pollution were observed. Unfortunately no confounding factors such as socio-economic status in each of the areas were reported but it is an interesting initial finding. More research

is certainly required to determine the aetiology of MIH but this study indicated that there may be a positive correlation between air pollution and MIH.

2.3 Impact of healthcare on climate change

Not only does climate change have an impact on human health, but healthcare also has a significant effect on climate. The healthcare industry, whose goal is to improve the health of the population, makes a major contribution to climate change which then increases morbidity and mortality around the world. Healthcare is an energy- and resource-intensive sector and so in turn has a significant environmental impact (Witty, 2022).

Figure 2: An example of the negative feedback loop between healthcare and climate change



The impact of healthcare upon the environment is from a variety of sources. Medication, such as antibiotics, have negative environmental effects when they are not fully broken down in our bodies and are then excreted: they can cause harm to the surrounding flora and fauna (Polianciuc et al, 2020). Running life-saving equipment day and night in hospitals requires a constant supply of energy which up until recently has almost exclusively come from the burning of fossil fuels. An estimated 10% of the NHS carbon footprint comes from energy used to run buildings (NHS England, 2022). Many of the products that are used in hospital are single-use, which generates a massive amount of waste, much of which is classed as a biohazard and requires incineration. When patients are required to travel to medical facilities, the environmental impact of their travel is attributed to the healthcare sector resulting in 9% of the NHS carbon footprint arising from patient, staff and visitor travel to and from healthcare settings (NHS England, 2022).

The impact of different anaesthetic gases, which are used to make patients unconscious prior to and during surgery, have been widely researched in terms of their environmental harm contributions. Desflurane, which is used frequently in medicine, and nitrous oxide, which is commonly used in dentistry, both have highly damaging impacts on the ozone layer by causing ozone depletion (Bosenberg, 2023). One suggested solution to reduce the

environmental impact of anaesthetic gases is switching to the use of sevoflurane, which has a lower environmental impact but with similar clinical effects. Unfortunately, nitrous oxide cannot be replaced in dentistry – it is unique in what is does and there isn't a substitute. Eliminating nitrous oxide would essentially eliminate inhalation sedation and therefore increase the number of general anaesthetics required for dental treatment.

Considering the few examples here, it is difficult to accurately quantify the contribution of the healthcare sector on climate change. One study however, has reported that if healthcare were a country, it would be the fifth largest greenhouse gas emitter in the world (Karliner et al. 2019). The National Health Service (NHS) accounts for 4% (856 million tonnes) of the United Kingdom total greenhouse gas emissions (NHS England, 2022).

2.4 Impact of dentistry on climate change

Dentistry in the UK contributes 3% of the total NHS carbon footprint, but this figure does not consider the additional impact from the private sector (Duane et al., 2017 and Steinbach et al., 2018). Following a survey commissioned by the General Dental Council in 2024, 67% of people in the UK accessed NHS dentistry, 23% received private and 8% a mixture of the two. Table 1 lists the components that contribute to the overall dental carbon footprint, the biggest being staff and patient travel which accounts for nearly two thirds of the total. These figures should be handled cautiously as they were taken from a paper that is nearly a decade old and were extrapolated from a study carried out in Fife, Scotland. The figures may not be transferrable to the rest of the UK or worldwide, however, the authors did use other sources to collect their data (NHS Business Service Authority and Information Services Division) which increases the robustness of the study. The authors also emphasised that estimating carbon footprints is certainly not an exact science but that carbon calculations are essential if we are to understand better the sustainability of our service.

Table 1: Dental sources of environmental impacts (Duane, 2019a)

Staff and patient travel	64.5%
Procurement	19%
Electricity	7.7%
Gas	7.6%
Nitrous oxide release	0.9%
Waste	0.2%
Water	0.1%

The focus of modern dental care is prevention of disease. A series of studies from the UK investigated different methods of caries prevention and their respective environmental impacts (Duane et al., 2022a, Ashley et al., 2022 & Lyne et al., 2022). For each method of caries prevention, factors such as mineral/metal use, climate change, water use, acidification, ozone depletion and land use were taken into consideration to assess the different methods' overall environmental impact. When comparing biannual fluoride varnish applications, supervised toothbrushing schemes, provision of toothbrushes and toothpaste or water fluoridation, the studies found that water fluoridation had the lowest environmental impact alongside the highest return on investment over 5 and 10 years. This data could be used to support more water fluoridation programmes when considering where to fund sustainable dental public health programmes.

The World Dental Federation (FDI) released a Consensus Statement on Environmentally Sustainable Oral Healthcare (Martin et al. 2022). They defined sustainable oral healthcare as "the provision of equitable, ethical, high-quality, inclusive and safe care with appropriate, effective and efficient use of resources. Through this approach, the healthcare opportunities of current and future generations are respected and protected by actively minimising negative environmental impacts." The consensus statement is signed by delegates from universities, dental organisations and industry across Europe, Asia, Australasia, North America and Africa. The statement represents motivation from the worldwide dental community for reducing the environmental impact of the industry and a drive to make dentistry more environmentally sustainable.

In 2021 a scoping review was carried out looking at awareness and barriers to sustainability in dentistry (Martin et al., 2021). This scoping review was extensive and well conducted. It followed the PRISMA extension for scoping reviews (Tricco et al., 2018) meaning that it searched a wide range of databases and had appropriate inclusion and exclusion criteria. The results were set out in a logical manner by separating the eight sub-topics addressed: environmental impacts (CO_2, air and water), the four R's (reduce, reuse, recycle and rethink), policy and guidelines, biomedical waste management, plastic (single-use products), procurement, research & education and materials.

Of the 128 papers included in the comprehensive scoping review by Martin et al. (2021), almost half (n=60) were considered research articles, almost one third (n = 39) were commentary articles and a fifth (n = 25) were literature reviews. A large proportion of publications on the environmental impacts of dentistry came from the UK and were

published from one author (Duane et al., 2012, Duane et al., 2019b, Borglin et al., 2021, Duane, 2014, Duane et al., 2019c, Duane et al., 2019d and Duane et al., 2019e). From the 1990s until 2021, there had been a steady flow of review and commentary articles on environmental impacts of dentistry, with a small minority of the publications being original research (Duane et al., 2017 and Richardson et al., 2016). From 2021–2023 there has been an increase in the amount of original research worldwide into sustainability in dentistry.

The scoping review by Martin et al. (2021) covered all of dentistry, rather than focusing specifically on orthodontics. Most, but not all, of the data on sustainability in orthodontics can be extrapolated from publications researching sustainability within dentistry. For example, amalgam disposal is one of the first topics that was discussed and published in the area of environmental sustainability and dentistry (Arenholt-Bindslev, 1989). This is not, however, a material that orthodontists regularly use, so whilst it is valuable research about promoting sustainability within dentistry, the data are not transferrable to orthodontics. Much of the research covering the remaining topics from the scoping review can otherwise be extrapolated from dentistry to the specialty of orthodontics.

This literature review has divided the different sources of impact from orthodontics on climate change into the following nine sub-topics: travel, plastics, the four R's, procurement, biomedical waste, materials, policy, research and education and technology (Figure 3).

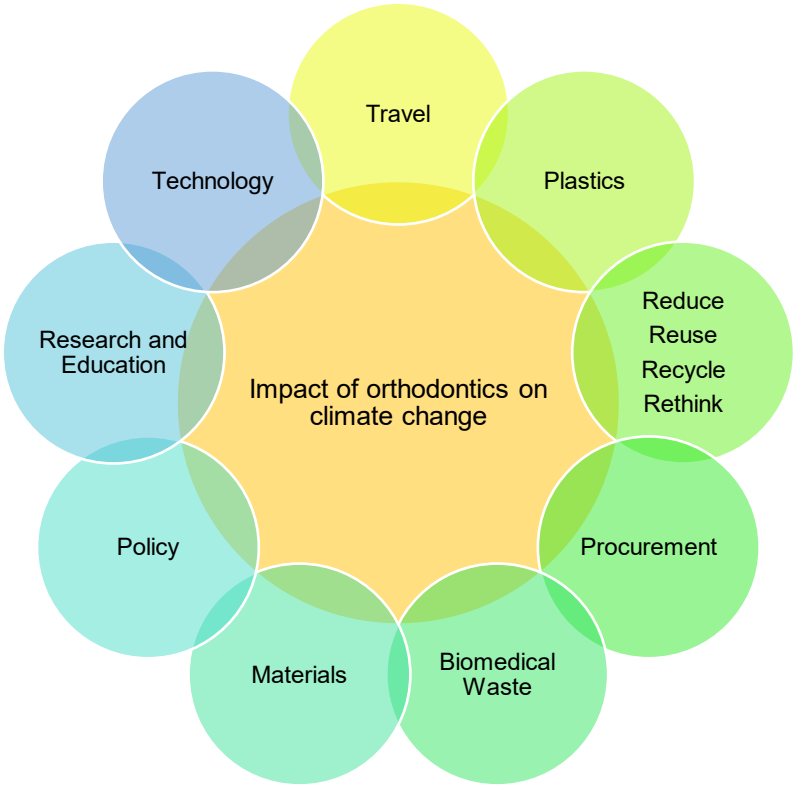


Figure 3: Sources of different impacts from orthodontics on climate change

2.4.1 Travel

Travel is reported to be the biggest single contributor to the dental carbon footprint (Duane et al., 2019a). Although the percentage of total NHS carbon footprint attributed to travel is only 12.3%, due to the nature of dental work requiring multiple regular visits, it is thought that 64.5% of the NHS dentistry carbon footprint can be attributed to travel (Duane et al., 2019f). This means that almost two thirds of the total carbon footprint come from one single contributing factor and any policies to reduce dental-related travel will have a very significant impact.

Patients undergoing orthodontic treatment have regular recall periods (usually every 6-8 weeks) over a long period of time (1-3 years) (British Orthodontic Society, 2025) which is more frequent than most regular dental patients. We can assume therefore, that travel accounts for an even higher percentage of an orthodontic patients' carbon footprint than that of regular dental patients.

One method of reducing staff and patient travel is to employ the use of virtual appointments, where appropriate, in a small proportion of cases there is no intervention planned or required. Virtual appointments involve carrying out consultations over the phone or video conference, which allows both clinician and patient to stay at home and negates the need for potentially environmentally harmful travel. Since the Covid-19 pandemic, there has been an increased use of online appointments and telephone appointments within the NHS as a whole and within in the orthodontic service. A systematic review by Saccomanno et al. (2022) found virtual appointments to be a valuable aid for professionals and patients although they stated that it was difficult to compare tele-orthodontics to seeing patients in person and could only substitute certain appointments such as aligner checks and retainer reviews. The limitation of this systematic review was the small number of articles included (eight) and that no meta-analysis was carried out.

Considering that travel is the single-biggest contributor to the dental carbon footprint, there have only been two publications on the topic of dental associated travel (Duane et al., 2019f and Wainer, 2022) this topic requires further research to be carried out which investigates the reasons behind patients and staff using their chosen modes of transport.

Currently there is a lack of infrastructure to support eco-travel. Only 7.6% of people walk to work in the UK, 2% of people cycle to work and 7.9% take public transport (Office for

National Statistics, 2021). There are a multitude of reasons why so few people in the UK use active travel or public transport. One of the reasons highlighted by the National Travel Attitudes Survey was that 65% of people felt that it was too dangerous to cycle in the UK (Department for Transport, 2023). In the 'NHS Guide for Commissioning Orthodontics' it is acknowledged that in the service design, access to transport links must be considered. There are, however, no specific details in terms of accessing public transport, walking or cycling routes to promote active travel to an orthodontic appointment (NHS England, 2015) and it is not known whether transport links were considered during the recent recommissioning exercise.

2.4.2 Plastics

Single-use plastics (SUP) are a conspicuous environmental issue within dentistry, one that clinicians and patients alike are acutely aware of. One UK study attempted to quantify the amount of single use plastics generated from dental practice and dental hospitals used in a range of common procedures (Martin et al, 2022). They found that an average of 21 SUP items were used in every dental procedure (354g).

Orthodontic departments and practices employ the use of myriad single use plastic (SUP) items such as suction tips, 3-in-1 syringe (air and water) tips, plastic cups, dappens pots, mirrors, probes, rulers, patient bibs, plastic covers for handles and dental chair controls and headrest. For many of these items, a reusable alternative exists. Reasons for single-use items relied upon in orthodontic practice could be explained by their costs benefits, an elimination of infection control worries and streamlining of time-consuming tasks. As life-cycle analysis has not been carried out for the majority of SUP items used in orthodontic practices, it is difficult to quantify whether disposable or reusable equipment has a bigger environmental impact.

Personal protective equipment (PPE), the key material of which is polypropylene, is neither recyclable nor biodegradable and can take almost 500 years to decompose (Waste Free Oceans, 2020). The Covid-19 pandemic caused a significant increase in the amount of PPE used in healthcare. As a result of the pandemic, the World Health Organisation (WHO) called for a 40% increase in PPE manufacturing to meet the needs of healthcare workers worldwide (WHO, 2020). This undoubtedly saved lives and worked to reassure the public that they were being protected when entering a healthcare environment. On 5th May 2023, the United Nations and the WHO declared an end to the Covid-19 pandemic (United Nations News, 2023). It is unknown how long it will take, or if we will ever return to the pre-pandemic

levels in use of PPE. To return to lower levels of PPE use within healthcare, change must be led by an update of local and national policies. Any reduction in use of PPE must be balanced against maintaining public trust in healthcare providers.

'Gloves Off' is a campaign in multiple hospitals in the UK where staff are encouraged to reduce their use of plastic gloves. In one hospital alone staff managed to reduce usage by 21 tonnes, saving £90,000 in the process. The project helped to change behaviour, save money and have a positive environmental impact.

There is limited published literature about SUP within dentistry, and nothing to date relating to SUP specifically within orthodontics. An evidence summary published in 2012 (Nasser, 2012) found no relevant research on the topic of whether plastics used in dentistry act as an environmental pollutant or if we could avoid the use of plastics in the dental practice. This evidence summary is over a decade old and so the answer to the first question as to whether plastics used in dentistry act as an environmental pollutant now seems self-evident. We now know that plastics break down into micro-plastics (pieces of plastic debris under 5mm) and have a widespread polluting effect on the environment (National Geographic Society, 2022). Microplastics have been found to be ingested by small animals and have been found to have made their way into our food chain. The second part of the evidence summary is much more thought-provoking: is it possible to avoid the use of plastics within orthodontics? Despite the evidence review from 2012 with a call for more research looking into plastics within dentistry, very few studies have been carried out in the following decade on this subject.

Martin et al. (2022) highlighted the complexities of reducing plastic use in clinical environments. As this is some of the first research in this area, they established baseline data for which types and how much SUP is used in a range of clinical settings, including the dental setting. They also highlighted that researchers must focus not only on the clinical viewpoint of reducing SUP, but also consider the public perspective and involve industry to fully understand the drivers of SUP use and recycling.

There are opportunities to work more sustainably within orthodontics with previous research highlighting areas that require further investigation including single-use plastics (SUP) in the clinical environment. Plastic causes environmental problems not only from use healthcare but in all industries. There are different types of plastic and not all of these are recyclable. If a plastic can be recycled, there are likely to be challenges with what it can be recycled into (Bucknall, 2020). Regulations do not permit the use of recycled plastics with healthcare

equipment. In addition to this, plastics can only be recycled once or twice, unlike glass or aluminium which can be recycled many times. Even when a plastic can be recycled, not everyone recycles, with only 34% of plastic in the UK being recycled (Domenech et al. 2020). Finally, plastics never decompose, they break down into smaller pieces called microplastics. Microplastics have been shown to cause harm to our ecosystems. To remove the problems associated with microplastics and recycling, the question therefore should be: "Can I reduce my plastic use?"

The problem regarding how much plastic waste is generated from simple dental procedures was raised by Martin et al. (2022). It is evident that the benefits SUP provide, such as their ease-of-use and low cost, have enabled them to become ingrained into the systems we work within. The solution to this specific problem will not come purely from a clinical approach. Stakeholders such as the orthodontic industry will need to be involved, as well as clinicians, to help reduce reliance on SUP in orthodontics. Orthodontic industry, where SUP items are designed, manufactured and sold, is the starting point in the life-cycle of SUP. There is currently no research into the orthodontic industry's views on SUP.

In the Plastics Research and Innovation Fund Conference, Martin et al. (2020) summarised the stakeholder and environmental drivers that influence the nature and final destination of waste plastic generated in healthcare settings.

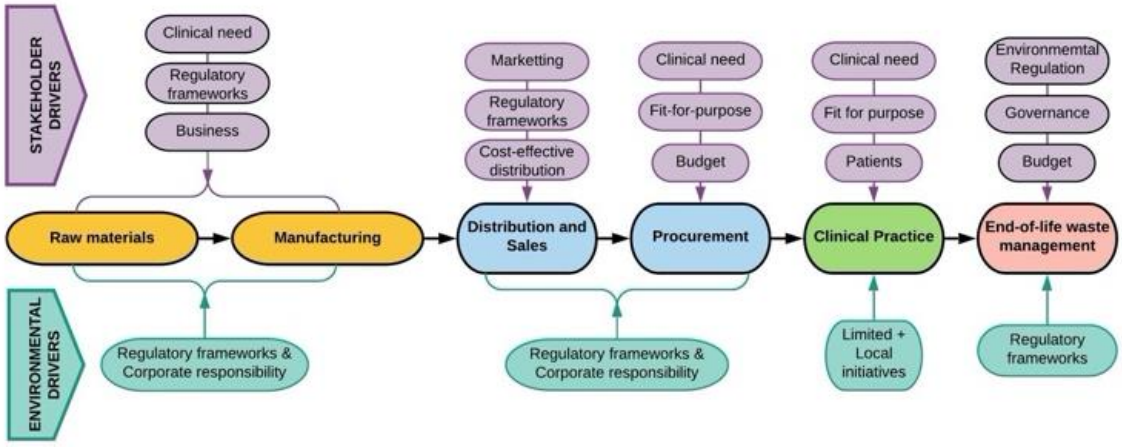


Figure 4: Summary of the stakeholder and environmental drivers that influence the nature and final destination of waste plastic generated in healthcare settings. Figure 4 taken from Martin et al. (2020) with permission from authors

2.4.3 Reduce, reuse, recycle and rethink

Waste management is an important aspect of transitioning to becoming more environmentally sustainable in all industries, including healthcare. Schemes, such as those offered by Terracycle, which recycle dental products such as manual toothbrushes, electric toothbrush heads, toothpastes, floss cartridges and interdental brushes are available at some dental hospitals.

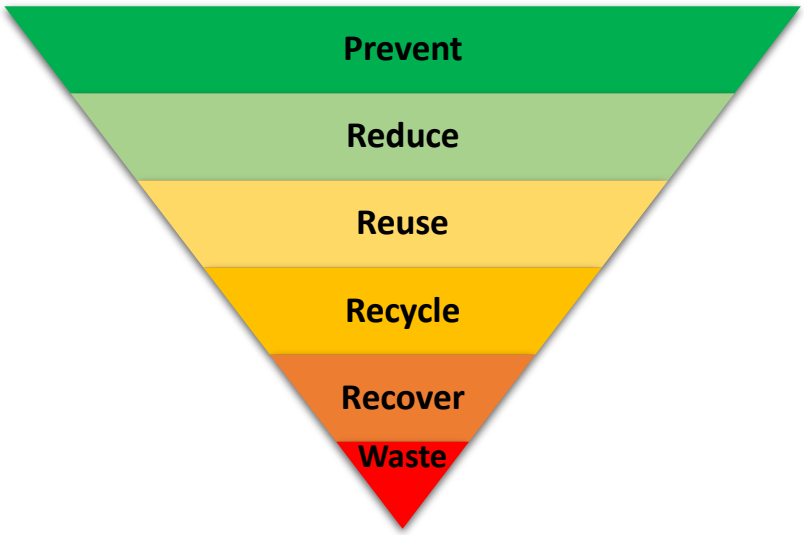


Figure 5: Waste management hierarchy, from most to least preferential options for waste

There are challenges associated with recycling contaminated healthcare plastic waste, the majority of which is treated as clinical waste and ends up incinerated or in landfill. Martin et al. (2020) suggest that more focus should be on reducing demand for plastic products in healthcare through disease prevention, combined with improvements in non-clinical waste recycling.

Authors from across the world have published on the topic of the four R's within dentistry (Volgenant et al. 2023, Lyne et al. 2020 and Neves et al. 2022). There was agreement that high costs were one of the biggest barriers to dentistry becoming more sustainable along with cross infection guidelines.

2.4.4 Procurement

Procurement in orthodontics may be influenced by many factors, including quality and cost. Lower cost single-use items may have a more negative impact upon the environment than a reusable alternative although this would need to be accurately quantified and might vary

between items. Implementing sustainable workflows are likely to involve initial financial outlay. For example, purchasing a digital x-ray machine to negate the need for radiographic films and developing chemicals; buying an intra-oral scanner to reduce the need for traditional alginate impressions using plastic trays; or investing in reusable instruments to reduce reliance on single-use plastics. Decisions such as these are environmental choices that may also save money in the long-term. Although there may initially be a financial advantage when buying cheaper, single-use products, there is almost certainly a higher environmental cost.

The NHS has implemented a Carbon Reduction Plan for the procurement of goods, services and works (NHS England, 2023). Since March 2023 they have stipulated that any company bidding for a contract valued over £5 million must have their own Carbon Reduction Plan which includes but is not limited to: committing to being net-zero by 2045, providing information on the suppliers' UK emissions, upstream transportation and distribution, waste generated in operations, business travel, employee commuting, downstream transportation and distribution. This plan is an encouraging step towards achieving better environmental sustainability and will have an effect on procurement for hospital-based NHS dentistry. However, NHS dentistry is only a small proportion of dentistry carried out within the UK and there are currently no sustainable regulations that affect procurement within the private dental sector.

2.4.5 Biomedical waste management

Biomedical waste management is an area of sustainability within dentistry that is commonly researched, with most publications surround mercury and amalgam (Martin et al., 2021). Research into the knowledge of dental care professionals on biomedical waste management varies across the globe, with some concluding that dentists have "excellent knowledge and practice" (Janani and Jayaraman, 2022) and others that "knowledge of environment friendly waste management was insufficient" (Kamran et al. 2022). Although waste management is not a glamorous topic, it is undeniably important for environmental sustainability. The problem is enormous, with over 590,000 tonnes per year of plastic packaging alone generated by the healthcare sector in the UK (Martin et al. 2020).

A large proportion of our biological waste is made up of plastics in the form of packaging and single-use items. Martin et al. (2020) highlights the reason we use polymers for medical devices: polymers are versatile which allows us to create complex medical devices,

however, the polymers are not easily sterilised for re-use or recyclable. This means that the majority of healthcare plastic waste goes to incineration or landfill.

Biomedical waste is energy intensive to process leading some hospitals to have waste processing centres on site with energy recovery facilities for the incinerated waste (NHS England, 2023a). This is, however, low on the waste management hierarchy in terms of sustainable waste management (Figure 4).

2.4.6 Materials

Research on the topic of sustainable materials within dentistry ranges from recycling plaster of Paris (Shiyo et al. 2020) comparison of disposable and reusable instruments in dental practices (Sowa et al, 2023) and multiple authors have looked into environmental effects of amalgam (Makanjuola et al. 2020, Bakhurji et al. 2017 and Sadasiva et al. 2017).

Research into the materials used in orthodontics can drive change to more sustainable working. In an effort to reduce industrial waste, a team in Japan found that dental models using recycled poly-lactic acid are acceptable for use (Nagata et al. 2023). However, the poly-lactic acid could only be recycled once before it had an effect on the model quality.

Traditional orthodontics uses metal brackets and wires; material that can in theory be recycled, although this is challenging when policies and regulations on sharps and biomedical waste are applied. Plastic aligners have become enormously popular over the past decades. Aligners must be changed every 1-2 weeks, and are constructed using printed plastic models, creating a phenomenal amount of waste from each individual treatment (Slaymaker et al. 2024). It would be useful to compare the environmental impacts from the different treatment modalities so that clinicians and patients are aware which is the more environmentally sustainable treatment choice.

2.4.7 Policy

Numerous national and international policies exist to address climate change and are listed in Table 2.

The triple bottom line (the economy, the environment and the public) is a concept that can be applied when updating or writing healthcare policies. The economic factors examine

whether the policy is affordable now and in the future. The environmental factors consider whether the policy avoids damage to, or improves the natural environment. Finally, the social factors assess whether the policy supports a good quality of life for all affected.

Table 2: National and international policies addressing climate change

The UN Framework Convention on Climate Change (UNFCC)	An international treaty, adopted at the Rio Earth Summit (1992), to tackle global warming. It requires regular meetings of global governments called Conference of Parties (COP).
Intergovernmental Panel on Climate Change (IPCC)	Aims to assess, track and report on the science related to climate change.
The Paris agreement (COP 21, 2015)	197 agreed to limit global temperature rise to no more than 2°C.
The Glasgow climate pact (COP 26, 2021)	The pact is the first climate agreement explicitly planning to reduce unabated coal usage. 190 countries agreed to phase down coal power, resulting in a 76% decrease in planned new coal power plants.
UN Sustainable Development Goals (SDGs)	17 SDGs were adopted in 2015 by all United Nations member states as a blueprint for ending poverty and reducing inequality while simultaneously addressing the climate crisis and restoring degraded ecosystems on land and in the oceans.
Climate Change Act, UK 2008	A legal framework for the UK to cut greenhouse gas emissions to 80% below 1990 levels by 2050.
Social Value Act, UK 2012	Public sector commissioners in England (and some in Wales) must ensure that the money it spends on services creates the greatest economic, social and environmental value for local communities.
Wellbeing of future generations Act, Wales 2015	Legislation that requires public bodies to improve economic, social, environmental and cultural well-being by engaging in sustainable development.
Environment Act, UK 2021	Sets clear statutory targets for the recovery of the natural world in four priority areas: air quality, biodiversity, water and waste, and includes a target to reverse the decline in species abundance by the end of 2030.
The Health and Care Act, UK 2022	The first piece of national legislation in the world to directly address the health profession's response to the climate crisis with new duties & powers right across the NHS. The Act requires NHS England, by law, to comply with the Climate Change Act 2008 and the Environment Act 2021.

Data from a survey into orthodontists feelings on environmental sustainability highlighted the exasperation felt by orthodontists about policy makers and their perceived draconian guidance, which seemingly fails to take into account the environmental impact of policy relating to decontamination and sterilisation (Brierley et al., 2025). One participant is quoted saying “Ask the CQC whether they are sustainable. They don’t care about sustainability.” This feeling is reflected in the FDI consensus statement on environmentally sustainable oral healthcare, which highlights that many policies fail to consider their environmental impact and suggest that a common ground should be found between conflicting priorities (Martin et al., 2022).

In the UK, the document Health Technical Memorandum (HTM) 01-05 (Department of Health, 2021) sets out best practice for decontaminating reusable instruments in primary care dental practices. The document describes the different stages and methods of disinfection of dental instruments. Policy decisions can have huge environmental impacts. The recommendations made in HTM 01-05 demand the use of vast amounts of energy and water with no obvious consideration for the environmental impacts of the policies. The idea that decontamination of instruments to ensure there is no risk of cross-contamination of viruses or bacteria should be prioritised over environmental sustainability is one that may need to be challenged, and policies may need to be rewritten with more environmental consideration.

‘Health Technical Memoradum 07-01: Safe and sustainable management of healthcare waste’ is a recent policy document (2022) that provides a framework for healthcare organisations to meet sustainable targets. The guidance focuses on environmental protection, circular economy, improved social outcomes and reducing carbon emissions. This move to focus on sustainability in healthcare is a much needed one and HTM 01-07 is leading the way in terms of the impact policy documents can have.

There is evidence of a change within dental sector policy to be more environmentally sustainable. Recent guidelines have included consideration for their environmental impacts (Scottish Dental Clinical Effectiveness Programme, 2022). The updated Scottish Dental Clinical Effectiveness Programme (SDCEP) coagulation guidelines highlight that patient travel is a significant contributor to the dental professions’ carbon footprint. They make four suggestions to help minimise patient travel and reduce the risk of wasted appointments. This is one of the first signs of policy makers for dentistry considering sustainable practice when delivering guidelines. This kind of action will hopefully make clinicians aware that their

clinical decisions have environmental impacts and encourage other policy makers to include sustainable considerations in their future publications.

2.4.8 Research & education

Research into environmentally sustainable solutions are needed to generate knowledge then education is required to share the knowledge. This is done in the hope that it promotes awareness and positive attitudes which will eventually lead to behaviour change at different levels.

Research by Borglin et al. (2021) and Duane et al. (2020) have investigated the life cycle assessment of different dental procedures. This is vital research as it provides data on previous unknowns, such as a quantifiable impact per patient or procedure. This will help to inform us of ways in which we can work more sustainably in the future. Other research has compared the impacts of disposable and reusable dental exam kits, there are many factors to consider when deciding to use disposable or reusable equipment and this study works to provide more information to help teams make informed choices (Byrne et al. 2022). Their conclusions were that the single-use examination kit poses greater ecological and human health threat than does the reusable examination kit.

Further research could benefit orthodontists by providing clarity on the decisions that have positive environmental impacts. In the future, information may be included with procurement about each products' environmental impact so that buyers can make fully informed decisions. This could be taken one step further and patients could be given information regarding the environmental impacts of different treatment options. Although it is common practice when consenting a patient to provide them with all relevant information that is involved with their healthcare, some may argue that information on environmental sustainability is not necessarily relevant. There may also be an argument that patients already struggle to take everything into account when deciding on different treatment options, and that to provide them with even more information, such as environmental impacts of treatment, may be over burdensome. It may be the best option if the information is there for those who wish to hear about it, and not given to those who are not interested or do not wish to take the environmental burden into account.

Research and education are fundamental aspects of discovering and implementing environmentally sustainable practices. Three studies from the UK, America and Saudi Arabia focused on the level of knowledge of dental school students on environmentally

sustainable dentistry. All three studies echoed the same results and showed that although levels of interest in environmentally sustainable dentistry is high, knowledge levels on the topic was low (Jamal et al., 2022, Joury et al. 2021 and Duane et al., 2021).

As well as the need for more research, Duane suggests that educators must introduce sustainability into dentistry from an undergraduate level so that future generations of dentists are taught basic sustainability principles (Duane et al., 2021). This viewpoint is reflected in a qualitative study that asked UK orthodontists who should be raising awareness about environmental issues, 71% said that it is an issue for universities and other educational bodies (Brierley et al., 2025). One of the outcomes from the Association for Dental Education in Europe (ADEE) sustainability workshop at the annual conference in Berlin in 2019, was that “the majority of academics were unclear about the concept of sustainability”. In response to this, the ADEE put together eight pillars which promote best practice for dental teaching on sustainability: energy use, pedagogy, waste, prevention, biodiversity, procurement, decontamination and travel.

There has been an increasing volume of research on sustainability in dentistry, between 1992 and 2021, there were 128 papers published on the topic of sustainability in dentistry (average 4.4 per year) then between 2021 and 2023 another 40 papers were published (average 13.3 per year). Environmental sustainability is now being incorporated into dental undergraduate and postgraduate training, so that the issue is highlighted early for clinicians’ in their careers (Duane et al., 2021). Dental trainees are expected to build environmental sustainability into any audit or quality improvement project that they undertake as part of specialty training. Ahmed et al. (2023) highlights that it is not only dentists and orthodontists who can educate themselves on environmental sustainability, but also any stakeholders and the public, leading to change from all levels and perspectives.

2.4.9 Technology

The use of digital aids within orthodontics may have a positive effect on environmental sustainability. One example of technology aiding sustainability in orthodontics is the use of digital scanners. The increased use of intra-oral scanners means that fewer trips are made between clinics and laboratories. Scans can be sent digitally and digital scans can be re-printed if necessary, whereas previously patients were recalled for repeated impressions if the model was lost or broken. Using digital scanners as opposed to traditional impressions and models eliminates the need for impression materials and trays. As of yet, no research has looked into the environmental impacts of physical impressions compared to digital

impressions, so we cannot say which method is more environmentally sustainable. The energy required to take digital scans and store the data for digital models must also be considered when comparing the two methods' environmental impacts.

The use of remote monitoring platforms, such as Dental Monitoring™, may lead to a reduction in the number of patient face-to-face appointments as orthodontists can track their patients' progress using videos and photos uploaded by the patient. More research is certainly needed in this area, but initial data would suggest that it will have positive environmental effects due to reduction of travel required for patients and clinicians. One recent randomized-controlled trial by Lam et al. (2023) found that the use of Dental Monitoring™ meant that patients visited the practice between 1-2 fewer times over the course of orthodontic aligner treatment when compared to those who did not use it. As fewer appointments are planned, fewer visits are carried out throughout treatment and a sustainability benefit will result. This independent study was well-conducted and is the first randomised controlled trial to examine Dental Monitoring™ as an adjunct to aligner therapy. Care must be taken when implementing remote monitoring as it has disadvantages such as being unable to monitor patients' periodontal health, inability to take accurate records and a lack of face-to-face contact reduces our ability to safeguard patients.

In other specialties of dentistry, it is feasible to reduce patient visits by adopting a more intense prevention regime and therefore removing the need for further treatment. This is currently not feasible in orthodontics due to the necessity of regular 6-8-week visits. Orthodontic clinicians may have more of a positive impact on the environment by focusing on ways of reducing the number of emergency visits by patients or by keeping their mechanics as effective as possible to reduce overall treatment times and therefore reducing the total number of visits per patient. Where possible, orthodontic appointments could be carried out remotely, such as for confirmation of treatment plans or post-treatment reviews.

2.5 Attitudes and behaviours

Prior to making changes that may improve sustainability within orthodontics, the factors affecting decision-making of orthodontists when addressing environmental sustainability should be explored. This topic was addressed in a recent survey, looking into orthodontists' knowledge, attitudes and practices in relation to environmental sustainability (Brierley et al., 2025). Everyday decisions, such as how to travel to work, procurement options and patient recall intervals – which all have an environmental impact – were addressed in this study.

The survey by Ahmed et al. (2023) was the first preliminary research looking specifically into orthodontists' knowledge and attitudes towards environmental sustainability. It was an online survey circulated by the BOS and the authors acknowledge that respondents may have introduced self-selection bias, as only those interested in the subject may have responded, causing the results to show unusually high interest in the subject.

Similar qualitative studies have been carried out in Ireland (Diffley et al., 2019) and the Netherlands (Volgenant et al., 2023) assessing the dental professions' levels of interest and knowledge about environmental sustainability. The study by Diffley et al in Ireland was a questionnaire-based study that collected data by visiting practices, attending conferences and local branch meetings which gave them a good sample size of 735 responses. The study found that although the dental profession showed interest in environmental sustainability, more research was needed before policies could be introduced with the aim of increasing awareness about environmental sustainability within the dental profession in Ireland.

The study that was carried out in the Netherlands (Volgenant et al. 2023) went further than questioning dentists. Participants in this study included: dentists, dental hygienists, dental assistants, managers, and owners of dental practices and suppliers of dental goods. Having a more inclusive group of participants meant that there was a broader range of opinions regarding what is needed to improve environmental sustainability within the dental profession. In a conference abstract by Martin et al. (2020) which contemplated the challenge of waste plastics in the clinical environment, they highlighted the importance of bringing in leaders from the dental industry and also the views of the public in order to make successful long-term change in the environmental sustainability of dentistry.

Interestingly, the study from the Netherlands (Volgenant et al. 2023) found that women felt more involved with planetary health when compared to men. This finding may also be reflected in the UK qualitative study where 50% more females engaged with the questionnaire than males. This factor may work in the dental professions favour in the future, as significantly more women are being accepted into dental education, therefore a higher proportion of environmentally interested people may be entering the profession. More female than male NHS dentists were recorded in England in 2018/19, and this trend continued in 2019/20 and 2020/21 (Michas, 2023).

The attitudes and behaviours of a group or profession are vitally important when addressing an issue as broad as environmental sustainability. The inability of the dental profession to

adapt to change, or their rigidity in terms of behaviours and attitudes, has been suggested to be the greatest challenge in achieving sustainability (Martin et al. 2022). Many of the unsustainable habits within orthodontics are in ingrained in our individual routines, or the larger systems and processes within which we work. This opinion is reflected in a qualitative study recently carried out where the authors highlighted concerns about the effect of legislative bodies (Brierley et al., 2025). One interviewee stated “without government intervention on an international industrial global level […] and without a significant culture shift in recycling and reduced consumption across the entire first and second world, we will be virtue signalling at worst and salving our conscience at best.”

The COM-B model for behaviour change suggests that we must first understand what produces any behaviour to then be able to influence behaviour (Michie et al., 2014). The model explains how behaviour is produced by a combination of capability (C), opportunity (O) and motivation (M). Each of these components interacts with and influences each other, so in order to create behaviour change, one of the components must be targeted. Consider the case: an orthodontist wants to use more sustainable products in their clinic and they have the authority in their practice to make a procurement change however they cannot find any sustainable alternatives when searching for them. In this case, motivation refers to the orthodontist’s urge to make a sustainable change, capability refers to the orthodontist’s ability to make procurement changes and opportunity refers to the lack of available products on the market. In this scenario, the opportunity to buy sustainable products is not available and therefore the orthodontists cannot demonstrate sustainable behaviour. In order to change this behaviour, industry must introduce a range of sustainable products and provide the opportunity for orthodontists to use them.

2.6 Facilitators & barriers

2.6.1 Capabilities

Ahmed et al. (2023) sets out where there are facilitators for change within orthodontics. These include staff training, courses, sustainable frameworks and guidelines. As environmental sustainability climbs higher on the world agenda, individuals seek to promote change and there is increasing demand that organisations must also make changes to become more environmentally friendly. Healthcare organisations are building environmental sustainability into their staff training, such as the online e-Learning for Healthcare modules which are available to NHS staff to raise their awareness about sustainability in dentistry.

There are courses, such as ‘Sustainable Dentistry’ offered by the Centre for Sustainable Healthcare which provide training opportunities to drive change. Governments and organisations have environmental sustainability built into their frameworks now that ensure that any new contracts must comply with environmental sustainability contractual requirements. Guidelines such as those from the SDCEP on anticoagulation (Scottish Dental Clinical Effectiveness Programme, 2022) have incorporated environmental considerations are an example of how guidance and policy is helping improve environmental sustainability.

2.6.2 Opportunities

On the surface it may seem as though efforts are being made from all stakeholders to ensure that environmental sustainability is a priority, however, we must assess at what level the changes are being made. Most change suggested in the research is at an individual level, which although useful, will have limited impact. There are no downsides to making personal changes, however individuals may struggle to make meaningful change if it causes them inconvenience, or increased effort, time or expense. A better approach may be to enforce change at a system or organisational level. Maxwell and Mirsa (2016) advise that the first step to approaching a social problem is to understand the system within which it sits. Without looking at the system as a whole and understanding the intricacies of interdependency between different stakeholders and what influences them, the changes implemented may be ineffective. Rather than advising individuals, it may be better to target change at a system level. For example, change could be implemented by updating Health Technical Memorandum (HTM) 01-05 to consider environmental impacts of decontamination and sterilisation. Go one step further and make changes at an organisational level, dental companies could ensure that their products are part of a circular economy and that products do not end up in landfill. Changes on these levels will undoubtedly have a bigger impact than at an individual level but could be exponentially more difficult to implement and enforce.

Encouragingly, there are many facilitators for environmental sustainability within orthodontics (Centre for Sustainable Healthcare, 2020). Use of tools such as the Green Impact for Healthcare (GIFH) toolkit, which works as a guide to initiate sustainable policies within a practice, may be a way of raising awareness that sustainable choices in orthodontics are also economically beneficial choices. The GIFH claims to be able to save practices around £1000 a year if they implement just two sustainable actions. It seems self-evident that if we can encourage practices and hospitals to use less energy, then in turn they will save money on their energy bill. This mutual benefit could be used to promote the introduction of environmental sustainability to those who may not have otherwise been interested, had it not

been for the positive financial implications. Part of the toolkit is to motivate practices as they work towards different levels of awards which can then be displayed for patients to see. With the increase in interest in environmental sustainability, the Green Impact awards may act as an incentive for patients to attend that particular orthodontic practice.

Another driver to support environmental sustainability has been launched by the Eco Dentistry Association (EDA), based in America. The EDA offers a certification programme whereby practices can be rewarded based on their sustainable dental processes and procedures, office administration and marketing, office design, furnishings or construction (Eco Dentistry Association, 2023). Patients can then search for an eco-dentist or dental practice to visit to ensure that their healthcare has values that lines up with their own. Upon enrolment with the EDA certification programme, there is a checklist of standards that must be met to prevent ‘Greenwashing’. Greenwashing is the practice of claiming to have products or services that have a positive environmental impact, to bring in more business or increase profits, when in fact they have little or no environmental benefit. Unfortunately, the practice of greenwashing lowers public confidence in environmental policies and acts as a barrier to sustainability within orthodontics. Checklists such as the one used by the Eco Dentistry Association are therefore a valuable and necessary tool.

Lack of knowledge is a barrier to orthodontics becoming more environmentally sustainable. In the coming years this lack of knowledge should hopefully be addressed with an increasing amount of research being carried out into the subject. Combine that with the implementation of embedding sustainability into undergraduate dental education and a generalised increased interest in environmental sustainability. The British Orthodontic Society has addressed the lack of knowledge by creating a working party for Corporate and Social Responsibility which aims to educate the members of the BOS in how to become more sustainable at work and provide practical tips and solutions on how to implement environmental sustainability as an orthodontist (British Orthodontic Society, 2023).

Table 3: Environmental resources for dental professionals (adapted from Ahmed et al., 2023)

Educational resources		
e-Learning for Healthcare	3 modules available aimed at raising awareness on environmental sustainability in the NHS and dentistry	https://www.e-lfh.org.uk/supporting-dental-colleagues-to-lead-on-sustainable-change/
Pro-Dental CPD course	4 CPD courses aimed at raising awareness on sustainability in dentistry	https://www.prodentalcpd.com/module1725/p300-sustainability-in-dentistry-foundation-course
Sustainable Green Dentistry	Website aimed at raising awareness and enabling positive change	
Guidelines and toolkits		
Centre for Sustainable Healthcare Sustainable Dentistry: How to Guide for Dental Practices	Practical resource to help dental teams make their practice more sustainable and guidance on how to lead a sustainability project	https://sustainablehealthcare.org.uk/activity/sustainable-dentistry-guide/
Reduce, reuse, recycle policy	Resource raises awareness and offers practical and environmentally sustainable solutions to waste disposal	https://www.recyclenow.com/how-to-recycle/how-to-reduce-waste
The UK Plastic Pact initiative led by WRAP	Website aimed at raising awareness of plastic use and helping others reduce and recycle used plastic	https://www.wrap.ngo
Green Impact for Health Toolkit	Resource aimed at helping practices make more environmentally conscious decisions	https://greenimpact.nus.org.uk/green-impact-for-health/
BDJ special edition	A collection that looks at sustainable dentistry and includes the papers from the BDJ Eco Focus Issue, highlighting practical measures to reduce carbon footprint	https://www.nature.com/collections/djidaaddgi
Scottish Dental Clinical Effectiveness Programme Anticoagulation Guidelines	Guidelines that include environmental considerations alongside clinical	https://www.sdcep.org.uk/published-guidance/anticoagulants-and-antiplatelets/

Organisations		
Carbon Trust	Guide to achieving net-zero goals	https://www.carbontrust.com/
Centre for Sustainable Healthcare	Website offering strategic input and consultancy on sustainable healthcare research and practice to national and local programmes	https://sustainablehealthcare.org.uk/
Global Action Plan	Environmental charity focusing on planetary health and human health	https://www.globalactionplan.org.uk/
Eco Dentistry Association	Certification programme for eco-practices	https://ecodentistry.org/

2.6.3 Motivation

Environmental sustainability is not a simple problem to address, multiple stakeholders must be considered when making changes to orthodontic workflows. Different stakeholders have conflicting priorities when trying to balance healthcare and sustainability. Whilst highlighting the complexities of addressing sustainability within dentistry and how to approach these problems, Duane et al. (2019b) suggests that more research is needed into both what stimulates people on a personal level and also the external drivers that work at a higher system level, that feed into the practice of environmental sustainability.

2.7 Impact of the research

It is imperative that every aspect of our lifestyle, including our working environment, is critically assessed to see how our carbon footprint can be decreased to reduce the negative effects of further climate change. As healthcare workers who aim to improve the lives of our patients, we have a duty to think about how our work impacts the environment we all live in.

Qualitative research is ideal for exploring subjects that have not been widely researched. Although there has been initial research looking into plastic waste within dentistry, no research to date has focused specifically on SUP within orthodontics. This qualitative study will provide an evidence base that helps to understand the experiences and behaviours of the orthodontic community meaning that future work can look to modify current practices and patterns of human behaviour to be more sustainable.

SUP within orthodontics have been shown to have widespread negative effects on the environment. SUP in other industries have been banned or regulated: we have seen bans on plastic straws, wet-wipes and compulsory payments for plastic bags in supermarkets. Previous research highlighted that clinical plastic waste is a concern for orthodontists (Brierley et al., 2025), dentists (Martin et al., 2022) and other healthcare specialties (Martin et al., 2020).

The study will explore when, how and why SUP are used and the British orthodontic community's perceptions of use of SUP. The community involved is made up of different stake holders including clinical teams and representatives of the orthodontic industry. This will provide an in-depth understanding of the current working environment and how this makes orthodontists feel, which is an area which has not yet been explored. Perceptions of barriers and facilitators will be discussed to understand what would need to be put in place to reduce the use of SUP in the delivery of orthodontic care. This will hopefully lead to clear recommendations for action.

It is hoped that one of the outcomes of this research will be to make sustainable recommendations at individual, organisational and national policy level. These recommendations will encourage working more sustainably in orthodontics, but also to effect change at higher system and organisational levels, that will have a wider impact. Much of the literature that is referenced in this review was based on research in a dental setting rather than specifically orthodontics, therefore it may be that some of the results of this research are applicable to the wider dental setting.

The results of this research should be of valuable to any member of orthodontic community who has an interest in environmental sustainability, as they look to reduce the impact their work has on the environment. It is hoped that the recommendations will encourage the orthodontic industry to work more sustainably and provide sustainable solutions to those seeking them.

Chapter 3: Aims and objectives

3.1 Aim

To explore how orthodontic teams and orthodontic industry in the UK use and perceive single-use plastics (SUP), to understand current practice and identify barriers or facilitators to changing SUP use.

3.2 Objectives

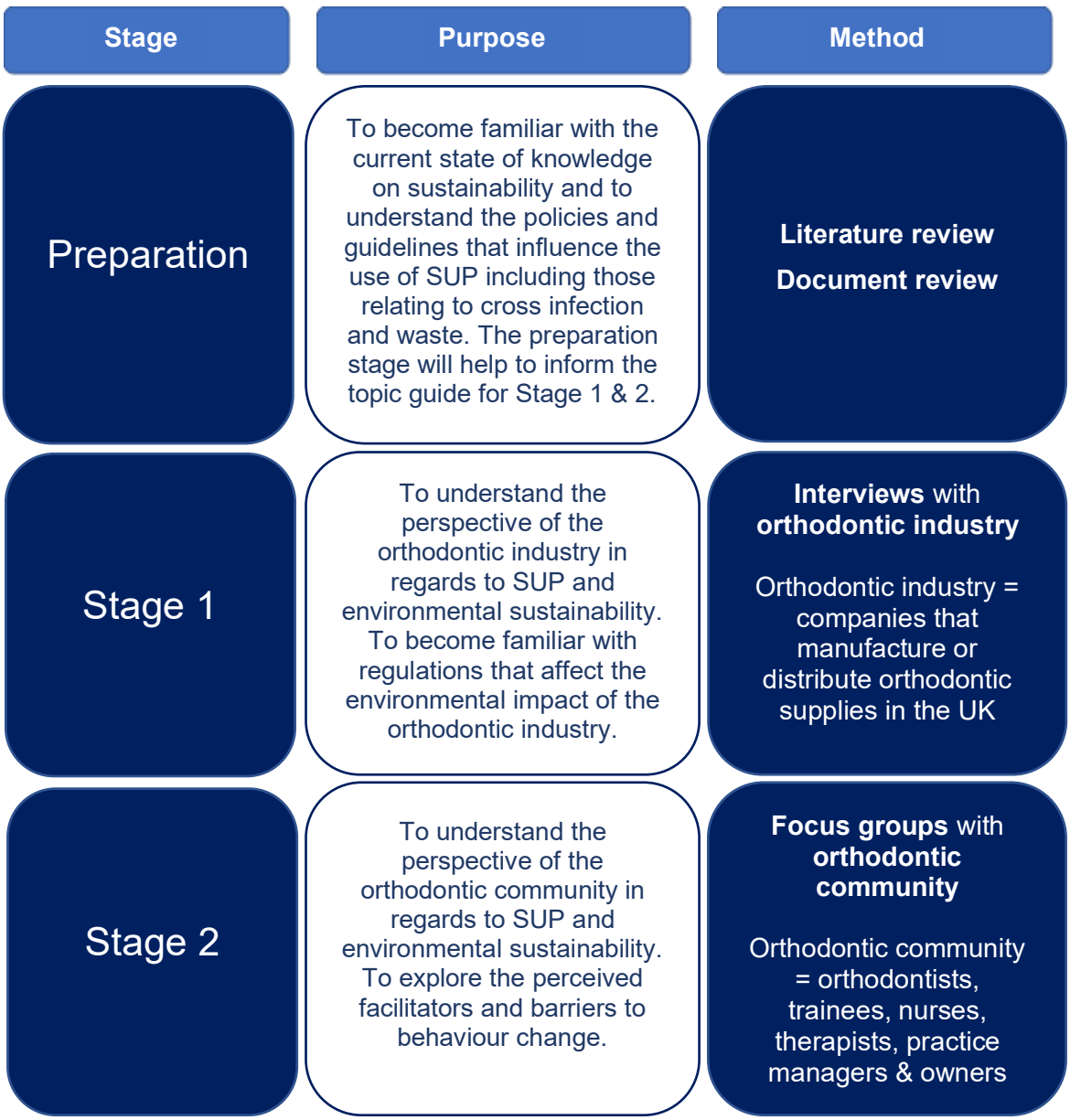
1. To understand published policies and guidelines that influence the use of SUP in orthodontic practice in the UK
2. To examine UK orthodontic industry's perceptions of use of SUP and environmental sustainability
3. To examine UK orthodontic community's perception of use of SUP in the clinical environment and to explore perceived barriers and facilitators surrounding a change in SUP use in orthodontic practice

Chapter 4: Methods

4.1 Design

Qualitative study using interviews and focus groups. The key stages are outlined in Figure 6.

Figure 6: Outline of research stages and methods



To meet the first objective of understanding the published policies and guidelines that influence the use of SUP in orthodontic practice in the UK, the document review was carried out. To meet the remaining objectives of examining UK orthodontic industry's perceptions of

use of SUP and environmental sustainability and examining UK orthodontic community's perception of use of SUP in the clinical environment and to explore perceived barriers and facilitators surrounding a change in SUP use in orthodontic practice, the interviews and focus groups were carried out. The data from interviews and focus groups was thematically analysed, barriers and facilitators were identified and then the data was mapped to the COM-B framework.

4.2 Governance

Ethical approval was sought and obtained from the University of Leeds Dental Research Ethics Committee (Reference: 230124-CS-003). Principals for ethical treatment of participants were followed. General Data Protection Regulation (GDPR) requirements were fulfilled. Best practice for research was followed.

4.3 Population and setting

The primary perspective for this research is the orthodontic community and the orthodontic industry (Table 4). The orthodontic community includes orthodontists, orthodontic trainees, nurses, therapists, managers and practice owners.

Companies that manufacture and supply orthodontic products (known as 'orthodontic industry') in the UK will be included in the first stage to understand the perspective of orthodontic industry in relation to SUP and environmental sustainability.

It is beneficial to understand the perspective of orthodontic industry prior to conducting the Stage 2 focus groups. By speaking to the orthodontic industry representatives, the aim is to become familiar with regulations that have an effect on the environmental impact of the orthodontic industry. This information is important to learn prior to conducting the focus groups, as it may allow better directing of the conversation and it allows us insight into the context. Orthodontists can only operate using the products that are produced, which limits their environmental influence. The aim of speaking to industry first is to understand the tools with which orthodontists work, to better understand how this influences the decisions they make.

Table 4: Eligibility criteria for study participants in Stage 1 & 2

	Stage 1	Stage 2
Role	▪ Any company that manufactures or distributes orthodontic products	▪ Specialist orthodontist ▪ Orthodontist in training (specialty trainees) ▪ Orthodontic therapist ▪ Orthodontic nurse ▪ Orthodontic practice/department manager/owner
Setting	• Working in the UK	• Working in the UK • Working in a primary care (practice) or secondary care (hospital) setting • Working in a private, National Health Service (NHS) or mixed funding setting

4.4 Theoretical approach and research paradigm

The research paradigm, or the philosophy, of this study was constructivist. This means that by starting with a broad topic, participant engagement guided data collection and construction of a theory (Delmas & Giles, 2023). The constructivist intention was to develop an understanding of orthodontic teams' experiences of SUP and environmental sustainability. The aim was to understand the meaning and context behind human actions, social phenomena, and cultural practices and therefore an interpretive approach was used.

The qualitative approach for this project was phenomenological with an inductive approach and with the aim to understand the perceptions of SUP and experiences of individuals working in the orthodontic setting. Phenomenology is a method commonly used in qualitative research that aims to understand individuals' perceptions or experiences to understand certain phenomena (Delmas & Giles, 2023). The purpose of this project was to understand more about orthodontic teams' experiences of environmental sustainability and SUP. The inductive approach relates to the fact that the interview and focus groups allowed specific observations to be made, then patterns were identified from the data.

The level of approach was interpretive in order to understand the meanings and interpretations that people assign to actions. Data was collected through literature review, document review, interviews and focus groups which was then analysed.

4.5 Recruitment and enrolment

4.5.1 Stage 1 recruitment and enrolment

Stage 1 involved one-to-one interviews with representatives from the orthodontic industry. A list of the ten best-known UK orthodontic supply companies was compiled then these companies were emailed to see if they would be willing to take part in an interview. Follow up emails were sent one month after the initial emails to contact the companies who had not yet replied. When companies replied, they were asked firstly whether they had a 'sustainability officer' and secondly who would be best suited to take part in the interview. A participant information sheet, topic guide and consent form were all sent to the nominated interviewee prior to the interview taking place. No demographic data was collected for the industry representatives because this could compromise anonymity and this may have dissuaded companies from taking part in the research.

Sampling saturation was reached for Stage 1 when all ten orthodontic companies who were invited to take part in the interviews had either accepted or declined the invitation.

4.5.2 Stage 2 recruitment and enrolment

Stage 2 involved focus groups with members of the orthodontic community. Potential participants were approached via two different means: by emailing a list of contacts from a previous study (Ahmed et al. 2023) where participants had indicated that they would be willing to take part in future research, and via a recruitment email that was sent out via the British Orthodontic Society (BOS) to members of BOS subgroups including the consultant orthodontist group, orthodontic teachers and trainers group, orthodontic specialists group, practitioner group and training grades group. Where certain participant groups (practice managers and practice owners) may not have received the email from BOS, snowball sampling was used by requesting BOS members to forward the email onto other colleagues. The same email was sent to those from the contact list and from the BOS. The email included an explanation of the study along with the participant information sheet, a demographics form and consent form. Interested parties were asked to reply via email to the lead researcher (CS) with their completed consent and demographics forms if they wished to take part.

The data collected about focus group participants' demographics was limited to: the country in which they worked (England/Scotland/Northern Ireland/Wales), their work setting (hospital/practice/mixed) and the funding system by which they were remunerated (NHS/private/mixed).

Sampling saturation was reached for Stage 2 when no further respondents expressed an interest in participating in a focus group.

4.6 Data collection

4.6.1 Interviews and focus groups

Interviews and focus groups were conducted virtually using Microsoft Teams®. Data were collected virtually for the convenience of one researcher being able to conduct all interviews and focus groups, and to encourage the participants to take part by being able to log on with minimal interruption to their day. The research team agreed that travel for interviews or asking participants to travel for a face-to-face focus group could not be justified, as it was directly at odds with the research topic of environmental sustainability. All participants were familiar with this type of technology and using it regularly for individual or group meetings. A scoping review in 2025 looking at data collection methods found that virtual data collection was likely to generate similar themes to that collected in person (Roberts et al., 2025).

Interviews and focus groups were video-recorded using the in-built functions. The three interviews and three focus groups were all facilitated by one researcher (CS), with two supervisors (CB and KVC) moderating one focus group each. Interviews took place between 5th June and 7th August 2024; focus groups took place between 8th and 26th August 2024. The lead researcher (CS) adopted a flexible framework for questioning, using open questions to elicit data from participants and probing to focus on relevant details.

4.6.2 Topic guide development

Following a review of the literature and the document review looking at policies and guidelines affecting SUP in orthodontics, a topic guide for the Stage 1 interviews was developed. This topic guide was then sent out to interviewees prior to the interviews so that they had an idea of what they would be questioned about. This was done to reduce their

apprehension about the interview and to allow them to prepare and feel relaxed throughout the interview process (Haukås and Tishakov, 2024).

The topic guide for Stage 2 was then developed based on the data collected from Stage 1, in parallel with the analysis using a constant comparative technique (cycling between data collection and analysis). This was done to allow a question-response style interaction between the answers from orthodontic industry representatives, and the questions posed to the orthodontic community taking part in the focus groups. The same topic guide was used for all three focus groups in Stage 2, however when participants focused on different topics in separate focus groups, each conversation was allowed to develop without input from the moderators. When a topic was exhausted, the moderator would bring the group back to the topic guide.

4.6.3 Researcher characteristics

CS is the primary investigator in this study, conducted as part of a Masters by Research. At the time of carrying out the research, CS is in a specialist training pathway for orthodontics and many research ideas stemmed from personal experiences and observations as a clinician. As a trainee, CS works in two U.K. orthodontic departments: in London and in Southend. Clinical experiences and informal conversations with colleagues highlighted the challenges associated with adopting and promoting environmental sustainability in the workplace. A lack of available guidance in the literature to support sustainable efforts was disappointing, though not surprising. CS's supervisors emphasised the value of qualitative research methods, especially given the limited information available on the topic, and CS used personal insights from orthodontic practice, along with existing research, to shape a study focused on single-use plastics and environmental sustainability within orthodontics.

There were three female supervisors involved in the project. KVC is a lecturer in Behavioural Science for Dental Public Health at the University of Leeds throughout the project with expertise in qualitative research methods. SB & CB are consultant orthodontists and both have a keen interest in environmental issues within orthodontics and had experience conducting research. Both SB and CB were able to bring knowledge from orthodontics and conducting qualitative research. SB and CB are both members of the BOS Corporate Social Responsibility working party, which deals with promoting environmental issues within orthodontics.

4.6.4 Researcher training

CS had limited experience with qualitative research so funding was secured to allow attendance at courses in qualitative research methods, including sufficient funding for conducting the interviews and focus groups. Along with her formal training, CS was also able to draw on the expertise of her supervisors, who were experienced in qualitative research.

The formal courses attended increased knowledge, competence and confidence in moderating. It emphasised the importance of listening, and eliciting and probing skills. The courses taught about developing topic guides and stimulus material and allowed real-life practice of moderating part of a group with feedback and coaching.

4.6.5 Researcher reflexivity

The first step in personal reflexivity for CS involved managing assumptions about environmental sustainability. Personally committed to environmental consciousness, CS had adopted a vegetarian lifestyle, preferred public transport or cycling, and avoided long-haul flights. During the literature search, CS uncovered various environmental issues within orthodontics that had previously gone unnoticed, leading to some stress over the magnitude of these challenges and a desire to make a substantial impact with the research. Initially, this led to attempts to plan larger projects beyond the scope of a part-time Masters by Research. After discussions with supervisors, who highlighted their own interests and strengths in qualitative research, CS was able to develop a study that was well-supported, aligned with personal interests, feasible to complete, and valuable for the field.

During the study, CS was an ‘insider’, researching within the specialty while being a specialty trainee and working alongside colleagues who also acted as participants. These professional and sometimes personal relationships influenced interactions in interviews and focus groups. CS carefully considered how these relationships, and the context, might ultimately impact data collection, recognising that prior discussions on sustainability with participants might shape responses. Moreover, CS was attentive to how power dynamics might influence interactions with participants, particularly with senior colleagues or those in similar training roles. To address potential influences of power dynamics during focus groups, all participants were allowed to remain anonymous, joining with different names and cameras turned off if they preferred. This approach ensured that participants who might otherwise feel pressured to align with certain views on environmental sustainability could freely express their thoughts without identifiable attribution. In practice none of the

participants used this offer and all seemed confident in giving opinions, no matter their workplace or role.

Techniques to enhance trustworthiness and credibility included triangulation and reflexivity. Triangulation, involving the use of multiple data collection sources and methods (such as documents, interviews, and focus groups) to corroborate information from different perspectives, allowed for cross-verification of findings. Reflexivity through personal reflection, discussions with supervisors and external people about the project, encouraged CS to acknowledge personal biases and preconceptions throughout the research process. This awareness of biases helped minimise their influence, supporting a more objective stance in data collection, analysis, and interpretation. The self-awareness gained from reflexivity aided in reducing potential distortions in the findings. However, the philosophical approach came from a scientific approach that challenges positivist notions of a 'neutral, detached, objective observer'. Although it is worth acknowledging tools to recognise bias, it is also acceptable to recognise that knowledge is partial and subjective and therefore absolute objectivity may never be possible.

4.7 Data management

Video-recordings were then sent to a University of Leeds-approved transcription service and typed transcripts were returned. Once the transcripts had been checked against the recordings for accuracy, the recordings were deleted. All data was kept on an encrypted laptop and data was also stored on a University of Leeds approved secure server, OneDrive. The transcripts were pseudo-anonymised by giving each participant a unique alpha-numeric identifier.

4.8 Data analysis

Analysis was grounded in the experiences of the participants. The development of the coding framework was informed by accumulating data and developed and refined through discussions between the research team then applied systematically to further data. Thematic categories identified in interviews and focus groups were explored and tested. Recommendations for the framework approach were taken from published guidance into qualitative data analysis of healthcare research (Smith & Firth, 2011).

Framework analysis can be divided into three stages, although these often ran concurrently: 1) data management: gaining a deep understanding of the data by thoroughly reading and re-reading transcripts, 2) descriptive accounts: interpreting and processing the coded data in a way that initially did not exclude potential themes and 3) narrative accounts. The data management stage involved gaining a deep understanding of the data by thoroughly reading and re-reading it. Initial themes and categories were identified, a coding framework was created, then data was systematically assigned to the appropriate themes and categories within the coding structure.

Once the thematic framework analysis was carried out according to Braun and Clarke, barriers and facilitators to changing SUP use were identified from the data and then the themes were mapped to the COM-B framework. A mapped final list of themes into COM-B framework is found in Table 10.

The data was managed using an Excel spreadsheet whereby different tabs represented the themes and rows for different respondents. Descriptive analysis involved interpreting and processing the coded data in a way that initially did not exclude potential themes. Where possible, themes were refined and grouped or linked with others, and relationships between the themes helped to develop a deeper understanding of the data. The process formed larger topics that summarised the data's complexity.

The final phase of exploratory analysis identified patterns and connections within the concepts and themes. It required revisiting the original data and previous analytical steps to ensure accurate representation of participants' perspectives and minimise misinterpretation. The aim was to interpret the concepts and themes, derive meaning, and consider their broader applicability or implications.

Chapter 5: Document review

5.1 Introduction

A narrative review of the policies and guidelines published that affect the use of single-use plastics, decontamination or waste management within orthodontics. This review intended to provide an understanding of the policies and guidelines that may influence environmental sustainability issues in orthodontics in the UK such as: the use of single-use plastics (SUP), decontamination or waste management. It looked at the kinds of information available to orthodontic teams when they are searching for help, advice or guidance in relation to single-use plastics, decontamination or waste management. Data were identified then analysed to see if the publications agreed with one another. The documents were analysed to see the kind of language used and techniques employed to encourage orthodontic teams to change their behaviour to become more environmentally sustainable. This review will help to direct Stage 2 of the project which involves interviews and focus groups.

5.2 Aim and objectives

5.2.1 Aim

To provide an understanding of the policies and guidelines that influence environmental sustainability issues in orthodontics in the UK.

5.2.2 Objectives

1. To discover what guidance is available to orthodontic teams regarding management of single-use plastics, decontamination and waste management
2. To identify which different sources have published guidance and which topics are covered
3. To identify views that are supported by all publications and find any conflicting viewpoints when comparing between documents
4. To analyse the language used
5. To analyse the techniques employed to elicit behaviour-change

The methodology for the document review is detailed in Chapter 4.2: Document review method and materials.

5.3 Document review methods and materials

5.3.1 Eligibility criteria

The ECLIPS framework was used to structure a research question related to healthcare management (Andrew et al., 2019).

Table 5: Eligibility criteria for document analysis

ECLIPS framework	E – Expectation	To analyse the published policies or guidelines that relate to single-use plastics, decontamination or waste management, within orthodontics. I want to analyse the language in the documents and technique used to elicit behaviour change.
	C – Client group	Orthodontic community: patients, staff & industry
	L – Location	UK dental settings in primary, secondary or tertiary care settings under NHS or private funding
	I – Impact	Improved environmental sustainability in the orthodontic community (e.g. reduction of SUPs, cross infection policies that support sustainable practice, waste reduction and recycling promotion)
	P – Professionals	Orthodontic staff & orthodontic industry
	S – Service	Orthodontic clinics & departments
Exclusion criteria	Any relevant documents that are not in the English language, or do not affect UK orthodontics.	
Study design	Any guideline or policy that has the potential to affect single-use plastic use, decontamination procedures or waste management in an orthodontic setting in the UK.	

5.3.2 Information sources, search strategy and selection

The search strategy included orthodontics and terms related to single-use plastics, decontamination and waste (Appendix I). Comprehensive searches, without date restrictions, but with English language restrictions, were conducted using the following electronic databases: PubMed, Embase, MEDLINE and EMCARE. Databases searched from inception until 01/02/2024. Unpublished or “grey” literature was searched using NHS

Barts Health Trust intranet, World Health Organisation (WHO), Google Scholar, OpenGrey, Directory of Open Access Journals and Digital Dissertations. Hand searching was performed from the reference lists of the full text articles considered eligible for inclusion. Full text assessments of the documents for inclusion in the review was performed.

5.3.3 Data items and collection

The following characteristics were recorded from the documents included: title, year of publication, authors, document design, target audience, the type of language used, any incentives used to elicit behaviour change and salient points relating to single-use plastics, decontamination or waste within orthodontics. Data was managed using Endnote online reference management software.

5.4 Results of document review

5.4.1 Study selection and characteristics

In total, 1066 records were initially identified and after removal of 63 duplicates, 1003 were screened for eligibility. Title and abstract screening resulted in the identification of 25 documents that were suitable for full-text review. Eighteen documents were excluded (Appendix II). In the end, seven documents were included in the document review (Table 6) as illustrated in the search flow diagram (Figure 7).

Figure 7: Document review selection flow diagram

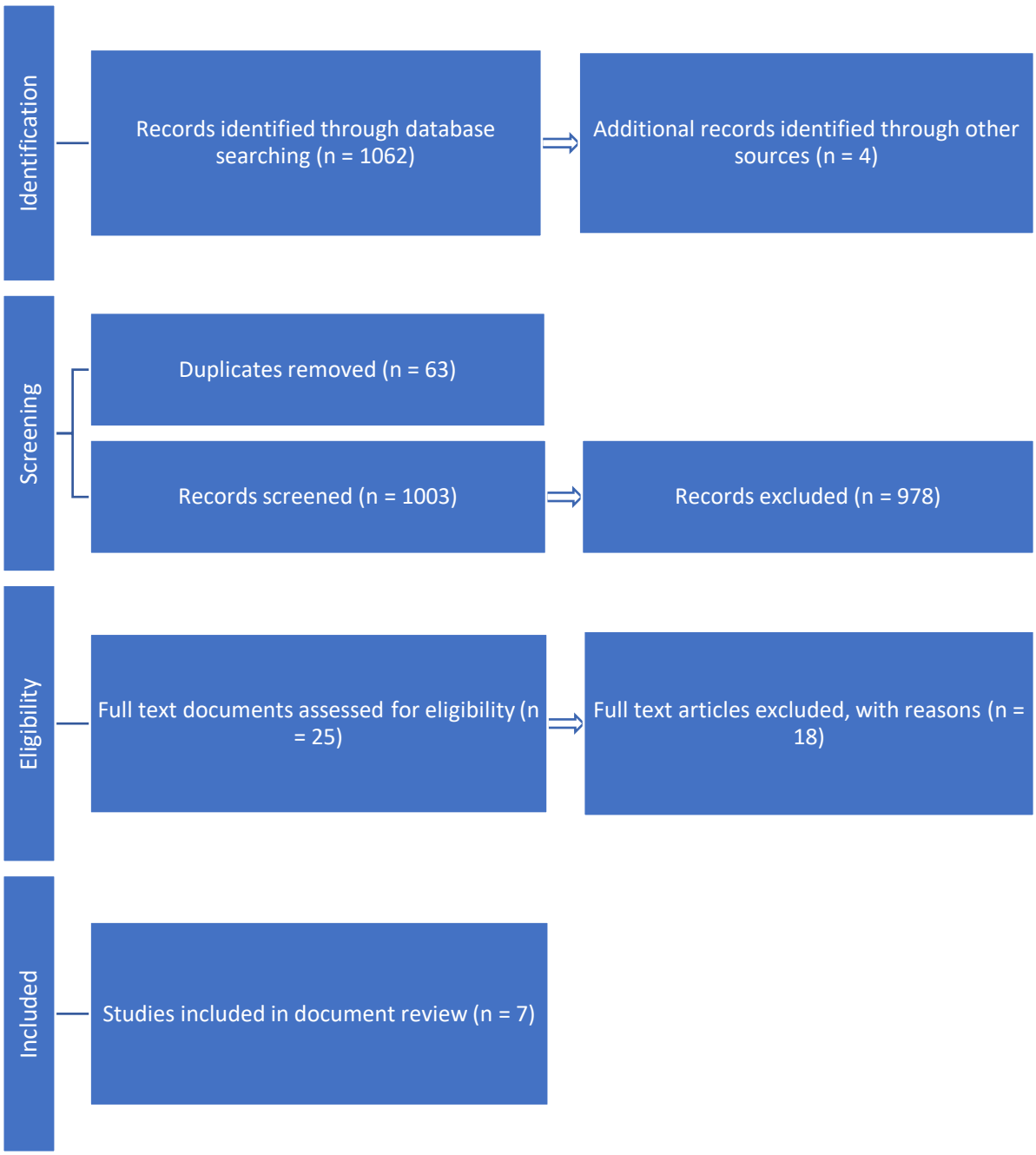


Table 6: Summary of documents included for analysis

Document title	Year	Authors	Document type	Distribution	Language used	Incentives
Clinical guidelines for environmental sustainability in dentistry	2023	Bakar, M. Duane, B. Fennell-Wells, A. & Klass, C.	Clinical guideline	Dental teams, education organisations, government establishments (nationals, regional and local), national regulatory organisations and public health professionals	Gentle encouragement "dental teams should consider…"	Visual prompts are included next to recommendations, such as: - Cost of actions (monetary incentives) - Ease of implementation (time to achieve)
HTM 07-01: safe and sustainable management of healthcare waste	2022	NHS England	Organisational policy	The guidance has been developed to a level of technical detail to facilitate the compliant and safe management of healthcare waste. It is primarily targeted at individuals involved in or having specific responsibility for managing waste for an organisation providing NHS services.	Varying levels of guidance: "Must" is used when indicating compliance with the law. "Should" is used to indicate a recommendation (not mandatory/obligatory), i.e. among several possibilities or methods, one is recommended as being particularly suitable – without excluding other possibilities or methods. "May" is used for permission, i.e. to indicate a course of action	None

					permissible within the limits of the HTM."	
Waste Management Policy	2020	Waste Manager – Barts Health NHS Trust	Organisational policy	Barts Health: Director of Estates & Facilities Estates & Facilities Managers Health & Safety Managers Capital Projects Teams PFI Providers Infection Control Teams Matrons, Sisters & Charge Nurses Non-Clinical, Clinical Support & Clinical Managers Hard & Soft FM Contract Service Providers	Strict guidance: "staff will be required…" "staff will ensure…" "staff must not…"	Disciplinary measures if not followed: "1.8 Failure to follow the requirements of the policy may result in investigation and management action being taken as considered appropriate. This may include formal action in line with the Trust's disciplinary or capability procedures for Trust employees, and other action in relation to organisations contracted to the Trust, which may result in the termination of a contract, assignment, placement, secondment or honorary arrangement."
HTM 01-05: decontamination in primary care dental practices	2013	NHS England	Organisational policy	All staff involved in decontamination in primary care dental services. All members of a dental team providing primary care dental services.	Clear guidance and advice: "To help dental practices to improve their decontamination procedures, this document describes the specific benchmarks by which compliance with **essential quality requirements** and **best practice** can be achieved and demonstrated." Compliance for either	None

					‘essential quality requirements’ or ‘best practice’ is defined clearly.	
SDCEP Practice Support Manual (Sustainability chapter)	2024	Scottish Dental Clinical Effectiveness Programme	Organisational published guidance	Dental teams across Scotland, primarily aimed towards practice owners and managers	Gentle encouragement: “Encourage the team…” and “Consider…” Direct recommendations: “Switch to green energy supplier, where practicable”	One sentence: “Some of these suggestions may have wider benefits including costs savings, convenience and increased well-being.”
Environmentally sustainable health systems: a strategic document	2017	World Health Organisation	Organisational published guidance	Health systems across the world	Gentle encouragement: “Possible actions to include…”	Chapter ‘Opportunities and benefits’ split into: - Health protection and promotion - Financial benefits - Other opportunities
Sustainable Dentistry: How-to Guide for Dental Practices	2018	Harford, S. Ramasubbu, D. Duane, B. and Mortimer, F. on behalf of the Centre for Sustainable Healthcare	Organisational published guidance	Dental teams	Direct recommendations: “Purchase less” “Reduce paper use”	Visual prompts included next to recommendations, such as: - Ease of implementation - Cost of actions - Return on investment - Environmental impacts

Table 7: Topics covered in each document analysed

Document	Single-use plastics	Decontamination	Waste
Clinical guidelines for environmental sustainability in dentistry	X		X
HTM 07-01: safe and sustainable management of healthcare waste			X
Waste Management Policy			X
HTM 01-05: decontamination in primary care dental practices	X	X	
SDCEP Practice Support Manual (Sustainability chapter)			X
Environmentally sustainable health systems: a strategic document			X
Sustainable Dentistry: How-to Guide for Dental Practices	X		X

5.4.2 Single-use plastics

The topic of single-use plastics is covered in three of the documents included in this review: 'Clinical guidelines for environmental sustainability in dentistry', 'HTM 01-05: decontamination in primary care dental practices' and 'Sustainable Dentistry: How-to guide for dental practices.' The document 'Clinical guidelines for environmental sustainability in dentistry' clearly states that the actions it proposes are given in order to "[reduce] single-use plastics in dental practices" (Figure 8). These guidelines provide advice that is applicable at different levels and for a variety of roles e.g. dental teams, national regulatory organisations and government. The document suggests that all of the actions that a dental team can undertake to reduce SUP will be easy to implement in a short amount of time whereas the actions for government, national regulatory organisations and public health professionals to undertake will cost more money and take a longer amount of time to implement. There is no mention of what level of effect each action will have, something which may have been useful for readers when deciding which action to focus their efforts on. All recommendations are positive actions to implement e.g. you *should* do X, rather than negative e.g. you *should not* do X.

The document ‘Sustainable Dentistry: How-to guide for dental practices’ follows a similar layout as the ‘Clinical guidelines for environmental sustainability in dentistry’. It describes clearly how SUPs contribute to the large amounts of dental waste that are produced by dental practices and provides suggestions for how this can be reduced. The diagrams next to all of the recommendations regarding plastic reduction suggest that the actions are easy to implement, will have either low or moderate cost associated with them, provide low or moderate return on investment and have a low or moderate environmental impact. Similar to the ‘Clinical guidelines for environmental sustainability in dentistry’, all suggested actions are positive actions rather than telling the reader what they shouldn’t do.

Both the ‘Clinical guidelines for environmental sustainability in dentistry’ and ‘Sustainable dentistry: how to guide for dental practitioners’ encourage the reader to make changes by using visual prompts next to each suggested action. The visual aids indicate whether there will be financial or environmental benefits to their actions, showing that the authors have considered the triple bottom line (financial, social, environmental impacts).

In contrast to the previous two documents that aim to reduce SUP used in dental care, ‘HTM 01-05: Decontamination in primary care dental practices’ promotes the use of SUP in multiple ways. HTM 01-05 is written from the perspective of setting best practice for decontamination. The advice is based on the principle that, by using a brand-new instrument (i.e. single-use instrument) this will guarantee that it is clean and sterile, hence the promotion of single-use items: “Where instruments are difficult to clean, consideration should be given to replacing them with single-use instruments where possible.” Other methods of SUP promotion includes the multiple mentions of single-use disinfectant wipes, which has been shown to have a greater environmental impact associated with their production, procurement, storage and disposal (Boyce, 2021). Authors have called on HTM 01-05 to be re-written with more consideration for environmental sustainability (Duane et al., 2022b) as there is currently no consideration for the triple bottom line.

5.4.3 Decontamination

Only one document found during this review covers decontamination policies that affect orthodontic teams in the UK, HTM 01-05: Decontamination in primary care dental practices. Health Technical Memorandum are a series of documents produced by the Department of Health that set out best practice. The document does indeed set high standards for decontamination, but fails to consider the ‘triple bottom line’ (financial, social and

environmental costs). One study showed that the financial cost of decontamination rose by 58% when HTM 01-05 was brought into effect (Richardson et al., 2016).

HTM 01-05 is set out clearly and is thorough in its level of detail, with no ambiguity for readers of the document. The language is clear that the document aims to put pressure on dental practices to constantly be improving standards, so that patients can have good faith they are being treated in a safe place. The majority of statements are recommendations, with “should” being used 285 times throughout, whereas “must” is saved for statements that have a regulation associated with them e.g. “All steam sterilizers are subject to the Pressure Systems Safety Regulations 2000 and *must* be examined periodically by a Competent Person”. ‘Must’ is only used 25 times throughout.

There is no kind of encouragement technique used throughout HTM 01-05, perhaps as it is a government document there is a level of expectation that it will be followed, as failure to do so may result in patients being put at risk and negative repercussions for the practice.

5.4.4 Waste

Waste management is discussed in six of the seven documents in this review, perhaps reflecting its importance in environmental sustainability. ‘Clinical guidelines for environmental sustainability in dentistry’ clearly sets out eight areas for waste management to be addressed. In each area, there is advice targeted at different levels, from dental teams to educational organisations and governments. Each level has actions suggested that are accompanied by a visual aid as to how long the action will take to implement and how much it will cost. Actions for dental teams are low cost and can be completed in a short amount of time, whereas the actions for educational organisations, governments and public health professionals cost more and will take longer to implement. All suggested actions are positive ones, as opposed to dictating what not to do.

HTM 07-01 is the government document from the Department for Health on ‘Safe and sustainable management of healthcare waste.’ All areas of healthcare are addressed in this document, helpfully there is a table that demonstrates which sections of the document are relevant for dental teams. The document clearly states in the preface that the guidance is not mandatory but that they have used different modal verbs to “convey notions of obligation, recommendation or permission”. The document explains how it aligns with the NHS goal of achieving ‘Net Zero by 2045’ as well as other national and European legislative targets. It is very clear on how to classify and manage different types of clinical and non-

clinical waste with diagrams and flow charts to aid explanations. There is nothing to incentivise readers to follow this guidance, it perhaps relies on the legislative frameworks that it is based upon to provide the motivation to follow the guidance.

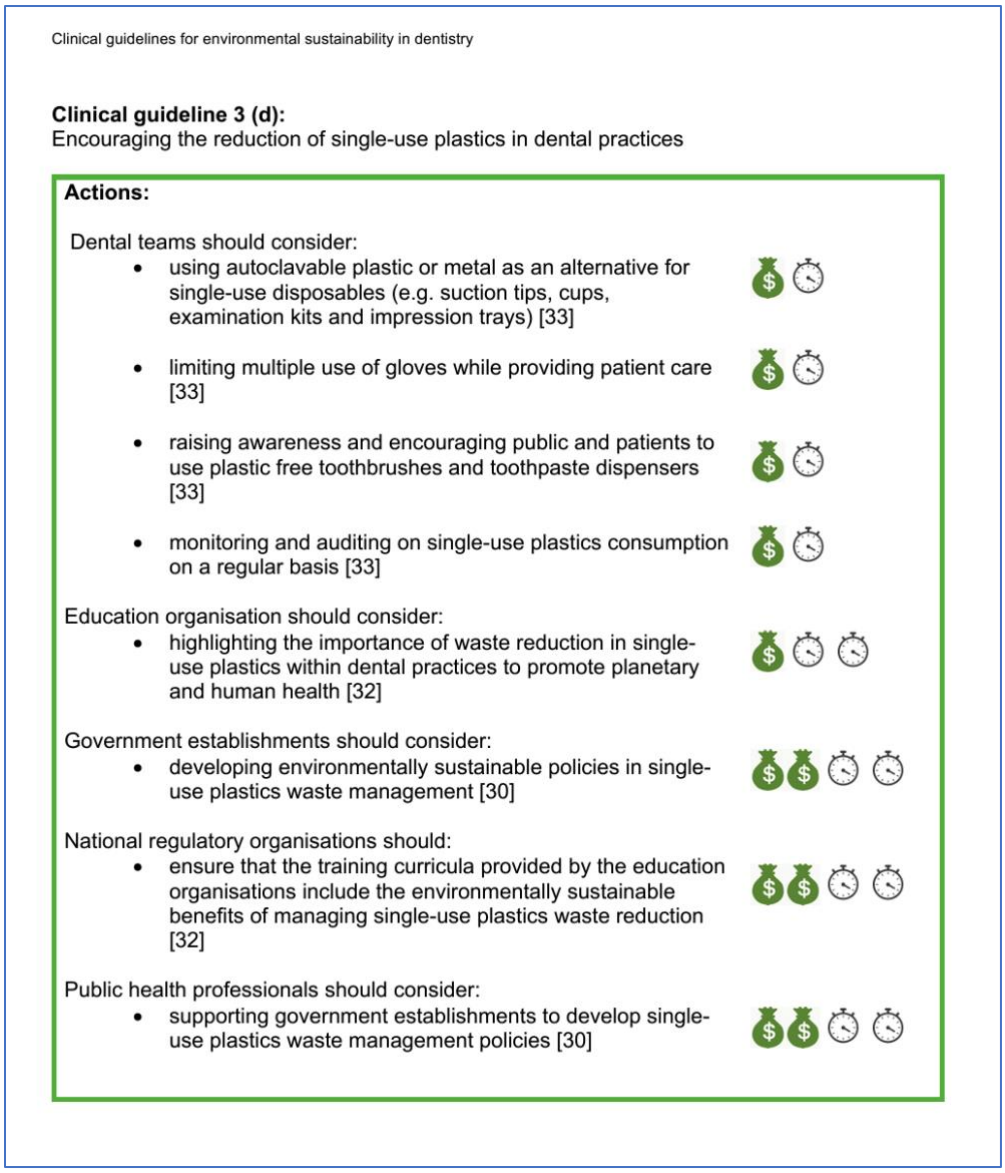
Barts Health Waste Management Policy is the most dictatorial of all the guidance or policies in this review. It has the smallest target audience, written directly from employer to employees, so it could be argued that it can go into a greater level of detail and specifics. The language used in this document is more direct than the other documents and although there are 259 examples of positive recommendations “staff must…”, there are 15 examples of use of negative recommendations “staff must not…” which is not demonstrated in the other policies and guidelines in this review. The document is clearly set out and easy to follow, with each point numbered for reference. There is no motivational technique used to encourage staff to follow the guidance, the opposite is seen where non-compliance is threatened with ‘formal disciplinary action’ or ‘termination of a contract’.

The SDCEP Practice Support Manual has only one chapter on sustainability and within that chapter just a few brief bullet points on waste management. The points are generalised and the language is of gentle encouragement. All points are positive actions for readers to undertake. The information is easy to follow and there is no incentive given to undertake the advice.

The WHO publication ‘Environmentally sustainable health systems: a strategic document’ has the widest distribution and is the most generalised of all the documents in this review. It is written to address all healthcare systems, and does not mention dentistry or orthodontics specifically, but the majority of information included can be extrapolated to apply to orthodontics e.g. “minimizing the production of general non-hazardous waste through adequate classification, waste reduction, reuse and recycling”. There is no incentive given for readers to follow the advice, but a sentence on the negative effects when the advice is not followed: “Poor management of health-care waste exposes health care workers, waste handlers and the community to infections, toxic effects, injuries, and poisoning and pollution by toxic elements or compounds such as mercury or dioxins that are released during incineration” (Chartier et al., 2014). This document seems to consider social and environmental impacts, two out of the three points that make up the triple bottom line.

The Centre for Sustainable Healthcare has produced the document ‘Sustainable Dentistry: How to guide for dental practice’ which discusses waste management in a chapter which is broken down into nine different areas for action. The introduction to the chapter explains the

importance of proper waste management. Each recommendation is accompanied by a diagram to represent how easy the action will be to implement, the financial cost, return on investment and environmental impact. Each sub-section has a real-life example and modelled example of how the recommendations can be put into action, as well as links to useful resources. The information is logically laid out and easy to follow. Readers are incentivised to follow the recommendations by calculating the money saved or carbon saved, with a link to a carbon calculator provided.


Clinical guidelines for environmental sustainability in dentistry

Clinical guideline 3 (d):
Encouraging the reduction of single-use plastics in dental practices

Actions:

Dental teams should consider:

- using autoclavable plastic or metal as an alternative for single-use disposables (e.g. suction tips, cups, examination kits and impression trays) [33]
- limiting multiple use of gloves while providing patient care [33]
- raising awareness and encouraging public and patients to use plastic free toothbrushes and toothpaste dispensers [33]
- monitoring and auditing on single-use plastics consumption on a regular basis [33]

Education organisation should consider:

- highlighting the importance of waste reduction in single-use plastics within dental practices to promote planetary and human health [32]

Government establishments should consider:

- developing environmentally sustainable policies in single-use plastics waste management [30]

National regulatory organisations should:

- ensure that the training curricula provided by the education organisations include the environmentally sustainable benefits of managing single-use plastics waste reduction [32]

Public health professionals should consider:

- supporting government establishments to develop single-use plastics waste management policies [30]

Figure 8: Clinical guideline 3(d): Encouraging the reduction of single-use plastics in dental practices. Note advice aimed at different levels, and accompanied by diagrams to demonstrate cost and ease of implementation.

5.5 Discussion

All of the documents in this review include information that has the potential to affect, to varying degrees, either single-use plastics, decontamination or waste management within orthodontic practices and departments across the UK. The publications range from government documents that are over a decade old (HTM 01-05, 2013) to national guidelines that were published in 2024 (Clinical guidelines for environmental sustainability in dentistry). The intended distribution ranges from a single health care Trust in the UK (Barts Health Waste Management Policy), to worldwide health systems (WHO Environmentally sustainable healthcare systems: a strategic document).

All documents are easy to follow and give clear advice, some being more specific with details than others. The language used across the documents is generally of neutral tone or encouraging advice giving, apart from in the Barts Health Waste Management Policy where the language is more direct and authoritarian. This kind of gentle advice and encouragement may not be enough to elicit behaviour change within the orthodontic community. For example, when comparing the ‘Clinical guidelines for environmental sustainability within dentistry’ to other well-known guidance documents used within dentistry in the UK, such as the Delivering Better Oral Health Toolkit, the language used is much vaguer and more suggestive rather than clear and direct. This could mean that the document does not have the desired positive environmental effect that is intended with its’ publication, due to the advice being given in such an optional tone.

Although many of the documents include explanations as to why taking steps towards improved environmental sustainability is important, for financial, social or environmental benefits, the majority of recommendations are given as guidance for the reader to decide whether or not to implement. Two documents use diagrams to demonstrate potential benefits of implementing actions e.g. financial gain or positive environmental impacts. However, where no incentive is given, the authors are in effect relying on altruism of the reader to decide whether or not to put into practice a new behaviour without a real incentive. The COM-B behaviour model would have us believe that this method will be ineffective, as there needs to be Capability, Opportunity and Motivation for a Behaviour to change. Although orthodontic teams may be capable of eliciting change, and have the opportunities available to them, it may have been helpful for the authors of these documents to think more about what will motivate the readers to make changes. Many of the recommendations given are directed at the dental team, who are expected to change their behaviours and implement

these sustainable changes, whilst also prioritising the patient and going about their clinical duties. This may be seen as a barrier to making sustainable changes, as sustainability can be viewed as a low priority or a burden on top of daily clinical work.

There was only one example found where the advice from the documents gave conflicting messages. HTM 01-05 recommends that if items are difficult to clean then single-use items should be procured, whereas the Clinical guidelines for environmental sustainability in dentistry says to prioritise reusable items over single-use items. Other than this example, all documents were in agreement with their suggestions for making changes to reduce SUP used in the dental environment.

5.6 Conclusion

There is a moderate number and wide range of documents from different sources available to orthodontic teams in the UK. Each of the documents include information that has potential to impact orthodontic teams' use of SUP, decontamination procedures or waste management. The recommendations included within these documents are generally in agreement across the board: reduce the number of SUP via various different techniques and practice efficient waste management. There is one document (HTM01-05) which does not directly promote the use of SUP, but dictates a level of decontamination so high that use of SUP becomes preferable over following these regulations.

The level of detail as to implementing the advice varies between documents. The language used within the documents is usually encouraging or suggestive of change, however if real behaviour change is the aim then more direct language would be required. Some of the publications explain that there is potential for financial gain or positive environmental impacts if their advice is followed, but many rely purely on altruism for the readers to follow the recommendations. If behaviour change is the goal then clear, evidence-based links should be made between working more sustainably and monetary savings.

5.7 Reflective log

After carrying out this document review, I learned that there is published guidance available to orthodontic teams on environmental issues, however it is by no means didactic in terms of what should be done in order to work more sustainably. I feel that this is a shame because when advice comes across as optional and readers are given a choice, I believe that they

will choose *not* to follow the given advice, especially if it means they have to invest more time or energy to follow the guidance. Although many different pieces of advice are given in the documents that were reviewed, I feel that it is still unclear how much of a positive impact making the changes will have on the environment. I think this ambiguity will work as a barrier to anyone trying to follow the guidance. What incentive is there for someone to change their behaviours if they don't see a direct benefit and they have no way of knowing that they are making a positive impact?

Although I found documents that were applicable to improving sustainability in orthodontic practice in the UK, none of them were orthodontic specific. There is a gap in the market and if there were to be specific guidance published for orthodontic teams, I wonder if it may work as a stronger motivator to change their behaviour rather than reading generic dental guidance.

The document review has prompted me to ask about these publications in the focus groups during Stage 2 of my research project. I am curious know if orthodontic teams are aware of the guidance available to them and what they thought of it. I would like to know if they were inspired to change their behaviour after reading the documents or if they came away feeling confused and demotivated as I did.

Chapter 6: Results of Stages 1 & 2

6.1 Participant characteristics

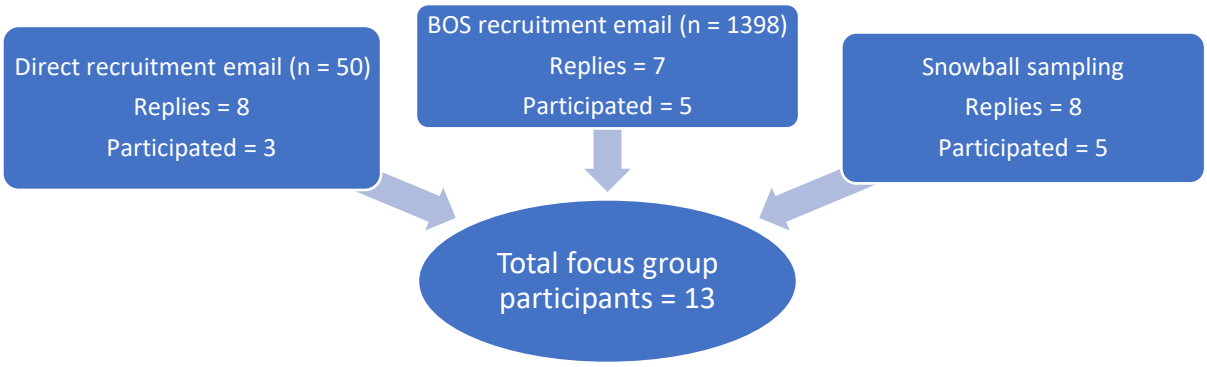
In Stage 1 of the study, 10 orthodontic companies were contacted to take part and three accepted the invitation to interview. The companies taking part manufactured and/or distributed orthodontic products across the UK and were of varying sizes of business. The research team felt that the three companies who accepted the invitation represented a range of manufacturers and distributors of varying sizes working in the UK.

In Stage 1, one-to-one interviews took place with representatives from three different orthodontic companies, the interview participants comprised one female and two males.

Recruitment for Stage 2 is summarised in Figure 8. Of the 50 people emailed from the contact list of a previous study, eight responded willing to take part and three ended up taking part in one of the focus groups. In total, 1398 BOS members were sent the recruitment email and seven replied willing to take part, and five actually ended up taking part. Another eight participants got in touch via email after hearing about the study through a colleague or friend, of the eight people recruited via snowball sampling, five took part in focus groups.

The results from Stage 1 and Stage 2 of this project are combined throughout the results section. This is done to avoid duplication of results, the themes that developed from the interviews and focus groups were similar and therefore it was felt that they could be combined in reporting. Where opinions from interviews and focus groups differed, this is explained in the reporting of results. Quotes are identified throughout as either from interview representative (IR) or focus group respondent (FGR) to clarify whether they came from stage 1 or stage 2 of the project. Quotes are also identified by which focus group or interview and which individual within the focus group was speaking, e.g. FG2 R4 = focus group 2, respondent 4. This is done to allow the reader to identify whether one individual held specific opinions over topics raised and to represent the variety in respondents who have been quoted.

Figure 9: Recruitment process for Stage 2



In Stage 2, three focus groups took place with a total of 13 participants (FG1 = 3, FG2 = 5 and FG3 = 5 participants) whose characteristics are summarised in Table 8. Focus group participants comprised eight females and five males. Over half (n = 7) of the participants worked in hospital settings, two worked in practice and four in a mixture of hospital and practice. Over half (n = 7) worked for the NHS, one person carried out solely private work and five worked in a mixture of private and NHS settings. Ten of the participants worked in England and three in Scotland.

Table 8: Focus group participant demographics

	FG1	FG2	FG3
Male : Female	1 : 2	1 : 4	3 : 2
Hospital : Practice : Mixed	2 : 0 : 1	3 : 1 : 1	2 : 1 : 2
NHS : Private : Mixed	2 : 0 : 1	3 : 1 : 1	2 : 0 : 3
England : Scotland	2 : 1	4 :1	4 : 1

6.2 Reported use of SUP in orthodontic practice in the UK

Single use plastics are commonplace within the orthodontic industry. Participants in this study included representatives from orthodontic industry as well as members of clinical teams working in private, NHS and mixed funding settings who were based in either in primary or tertiary care centres, across England and Scotland. All participants were able to list a wide range of examples in which SUP are ingrained into their everyday working lives (Table 9).

6.2.1 Use of SUP in the delivery of orthodontic treatment

Table 9: SUP examples given by respondents

Orthodontic-specific items	Dental items
Appliances and auxiliaries: • Aligners • Elastomerics (modules, elastic chain, Class II/III elastics) *Equipment:* • Rulers	*Equipment:* • Exam kits (mirror, probe, tweezers) • Impression trays • Cheek retractors • Cups • Aspirator tips/saliva ejectors • 3-in-1 tips • Micro brushes • Dappens pots • Self-etch lollipops *Cross-infection measures:* • Barrier protection • PPE: gloves, visors, aprons • Packaging

Both interview and focus group participants reported that the utilisation of SUP in orthodontic clinical practice is driven by several factors that include ensuring operational efficiency, patient safety and compliance with regulatory standards. One of the foremost reasons is the necessity for stringent infection prevention and control (IPC) measures. SUP provide a reliable means of maintaining sterility and hygiene, as they are designed to be disposed of after contact with patients, thereby mitigating the risk of cross-contamination.

In addition to IPC considerations, the practicality and convenience of single-use items are significant contributors to their prevalence. These items eliminate the need for labour-intensive cleaning and sterilisation processes, offering a time-efficient solution in fast-paced clinical environments. One focus group participant addressed this issue:

"I mean I accept that in something like dentistry you really have got to have single use items. It's not possible to make everything to be sterilised. It's too convenient, you know.." (FG2 R1)

Their widespread use is often dictated by regulatory requirements, particularly within hospital settings, where such materials are mandated to meet sterility standards:

"We have regular visits from CQC…and they do go through things with a fine-tooth comb. It's the cross-infection control that they're particularly interested in." (FG3 R3)

Cost dynamics further influence reliance on SUP within orthodontics with a focus group participant explaining that:

"Even though it costs more to dispose of them, overall it's still unfortunately cheaper to use the single-use mirror and probe." (FG1 R3)

When discussing people who are responsible for procurement in one orthodontic department, a participant explained that:

"They understand the environmental impact, but they've got to balance the books." (FG1 R3)

Institutional procurement policies frequently prioritise single-use products due to established supply chain frameworks and IPC mandates. There was agreement from one focus group that:

"We're hugely restricted by our procurement, and in the hospital as well, we're limited to who we can buy from." (FG1 R3)

Focus group respondents felt that patients perceive SUP as a safer choice, offering reassurance that such items have not been previously utilised or inadequately sterilised. The respondent here felt that there is a consumer perspective to be considered:

"The patient comes into the surgery, sits down…we take out all the brand-new stuff that's never been used before and is never going to be used again, and just some patients, from a consumer perspective, I think they find that reassuring." (FG3 R3)

This view was also echoed in the Stage 1 interviews, however the interview participants felt that patients are unaware of how much plastic waste is produced per appointment:

"They probably don't know about, I guess, the amount of waste we produce just running a day-to-day practice" (IR1)

The lack of practical, readily available alternatives also perpetuates the reliance on SUP, especially in hospital settings where procurement may be limited to certain providers, even when looking for simple alternatives such as moving from plastic to paper cups they are not always available to buy:

"I did look through quite a few of the catalogues, and there's just not paper cups out there." (FG1 R3)

When industry representatives were asked about alternatives to SUPs, they felt that although the products were available and that manufacturers were aware of the move to be more sustainable, there was a lack of uptake from customers due to increased prices:

"Unfortunately those products are most expensive to produce, and so they're more expensive to buy. So although there is a demand - the difference between a plastic cup and a paper cup is quite a lot, and then obviously you're going through a large number of it a day, per practice, so it does make quite a difference unfortunately." (IR1)

6.2.2 Aligners

One major influence for SUP use in orthodontic practice is that that aligners are now an incredibly popular appliance system. Focus group participants agreed there were a number of issues associated with aligner treatment, beginning with where the aligner is manufactured and how many miles they have had to travel before reaching the patient:

"I think what people need to be aware of as well is where their aligners are being manufactured and the carbon footprint of that as well. It's a huge part of it." (FG1 R3)

Other focus group participants felt that the counter argument may be used in cases where orthodontic services procurement has meant that patients have to travel long distances for treatment:

"I think one of the problems there, is that when we had a procurement exercise they made a complete hash of it, we've got people… travelling …because the providers just aren't here [locally]. That's potentially what people would say about Invisalign, which I think is far more limited in its scope of activity, but people will say, "Well you can have Invisalign and then you don't need to come back, once every six months is sufficient because as long as you're tracking them, we'll look at you through Dental Monitoring." (FG3 R2)

Other issues raised in the focus groups included the scale at which they are produced and the associated model printing:

“We’re now on the 20 millionth Invisalign case that’s been done, and if you think all of those 20 million cases probably had between 30 and 50 aligners, and all of those aligners had a plastic model made on which the aligner was constructed, so that’s the biggest scandal of all for single-use plastic.” (FG3 R1)

The industry representatives interviewed in Stage 1 did not manufacture or distribute aligners and therefore they could only speculate on the amount of plastic waste produced by aligner systems. The feeling from industry representatives interviewed was that consideration should be given to the impacts of the growing amount of plastic waste produced by the aligner industry.

6.3 Perceptions of use of SUP in the clinical environment

The participants discussed their perceptions of SUP in terms of their feelings and beliefs about the responsibility of different stakeholders.

6.3.1 Feelings

The feelings surrounding environmental sustainability within orthodontics, particularly regarding the use of SUP, encompass a range of complex emotions reflecting both challenges and aspirations. Reported emotions include frustration, hope, anxiety and disappointment.

Frustration emerges as a common sentiment among clinical teams, stemming primarily from regulatory constraints. Strict IPC policies, while essential for patient safety, often limit the adoption of more sustainable practices, creating a significant barrier to change. Many participants voiced views agreeing with this participant:

"I don’t feel like we have a lot of control at all, because of IPC. We’re pretty much told that we have to put it in the certain bin bags, and I understand that, but certainly at my trust there’s no scope for recycling.” (FG2 R2)

A lack of autonomy linked to making sustainable choices at work also caused frustration, whether that be due to working within a large Trust where waste management decisions are removed from clinicians or limited procurement options for sustainable alternatives:

"We're limited to…what the suppliers are giving us." (FG1 R3)

There was some frustration surrounding the standards applied to orthodontics, with focus group participants feeling that standards were too high considering that the vast majority of orthodontic procedures are non-invasive:

"I work in a really big Trust, it just all comes down to, well this is what we're doing on the wards, this is what we're doing in out-patients across the board, and you can't change that. I really struggle to see how those barriers are going to come down" (FG2 R2)

Another participant agreed:

"I think it's absolute overkill that orthodontics is held to the same standards of sterility as colorectal surgery, because it's a completely different game." (FG3 R1)

Compounding this frustration is the perceived lack of external support, with participants noting the absence of clear regulations or tangible incentives to drive environmentally conscious initiatives. When asked whether the focus group participants felt any pressure to work more sustainably at work, the answers were almost unanimously *"no"* or *"none at all".*

Despite these challenges, there is a sense of hope and optimism among many within the field. Participants expressed positivity about the potential for small changes, such as reducing reliance on SUP or incorporating recycled/recyclable materials, to collectively make a meaningful impact. This optimism is further fuelled by the promise of innovation, with hopes for the development of biodegradable alternatives and other cost-effective sustainable solutions seen as a beacon for future progress:

"What they need is biodegradable aligners." (FG3 R1)

For some, the drive toward sustainability is deeply personal. Motivation was frequently linked to a sense of personal responsibility, with participants from orthodontic industry viewing sustainable practices as a moral or ethical duty:

“Look, you know, if we don’t have children, we know children, and we all need to take a degree of responsibility, whether that’s individually, collectively, corporately, around what we’re doing to the planet, so yeah, it absolutely matters to me.” (IR2)

Efforts by motivated team members have proven to be a catalyst for change, as their enthusiasm inspires colleagues and fosters a culture of environmental consciousness within clinics, demonstrated by one participant:

“Certainly in my department, everybody’s on board with it, from nursing, from trainee level, consultant level – we all want the same thing.” (FG2 R2)

There was a sense of disappointment regarding the slow pace of progress:

"I think slowly people – not as much as I’d like to see, but people are becoming aware of [sustainability issues]” (IR1)

Many participants voiced frustration over the inertia within both their organisations and the broader orthodontic industry.

There is a perceived lack of awareness or demand from patients for greener options. When focus group respondents were asked whether they felt pressure from patients, the response was that no-one felt any pressure. This perceived lack of awareness from patients leads to a feeling that sustainability efforts are undervalued or unnoticed. Participants felt that they were not appropriately equipped to speak to patients regarding sustainability, that they did not have the time or that it was not the correct setting in which to bring up the topic.

Industry representatives felt positive about the increasing awareness surrounding environmental issues and agreed that it was good for customers to have high expectations of companies’ environmental commitment. They voiced frustration that the main barrier to becoming more environmentally sustainable was cost.

6.3.2 Responsibility of different stakeholders

When the representatives from orthodontic industry were questioned on who the responsibility lay with, for becoming more environmentally sustainable and reducing SUP, the response was that for making improvements within their industry, the responsibility lies with each department within an organisation collectively:

"*We have got staff onboard but ideally we'd need someone from every department to work together." (IR3)*

The respondents felt they had a sense of corporate responsibility to be more sustainable at work, but also to provide more sustainable options and products to clients:

"Corporately, it lies with us and only us. We have to take responsibility for our own commitment to reducing plastic." (IR2)

When asked about improving environmental sustainability and reducing SUP in clinical environments, the representatives from industry felt that manufacturers play a pivotal role**:**

"I think there are some manufacturers out there…that are trying to make things out of recyclable materials." (IR1)

There was a sense of shared responsibility between individuals and corporations but that corporate leadership was expected to act**.** Overall the industry representative and focus group respondents agreed that there should be shared responsibility across stakeholders**:**

"It's everybody's responsibility; the patients, the dentists, the trusts, everybody, the regulators." (FG2 R4)

The focus group participants identified different stakeholders to hold responsibility for becoming more environmentally sustainable and reducing SUP in orthodontics. Focus group participants felt that the responsibility was shared between all stakeholders:

"I really think it's everybody's responsibility at the end of the day. We're on the frontline dealing with it. But if there's a demand for greener products or for challenging who we're buying from, that's the only real way to make change. It starts from the clinic floor up." (FG1 R3)

Some focus group respondents felt that although there was shared responsibility, most of the change must come from the orthodontic industry:

"I'd say everyone, but the manufacturers are more likely to actually have an influence." (FG2 R4)

Industry representatives agreed that there was a big responsibility on manufacturers to play their part, but that overall efforts needed to be made by all stakeholders:

“So I think corporately it lies with us and only us. We have to take responsibility for our own commitment to reducing plastic, but I think the more people that get involved and raise awareness of it, the more attention it gets, then maybe things could potentially move quicker” (IR2)

A high onus was placed at management level for responsibility of making improvements:

"I think working in a hospital, it definitely comes from our service or management level. It’s very difficult for a clinician to make a change without getting it signed off at the very top, despite best efforts." (FG2 R5)

Regulators and policy makers were also recognised as stakeholders who could have a significant impact on reducing SUP, especially highlighting profitable companies who have the resources to bring about change:

"If regulators are able to help – so that could come from the GDC, CQC, or the BDA – then that would make a big difference. Ultimately, it’s the companies making the big bucks that can create systemic change more easily than we can." (FG2 R4)

There was a strong feeling that the focus group respondents felt an individual responsibility towards making environmentally sustainable improvements in their home lives as well as at work, even with other priorities such as providing high standards of clinical care within time pressures:

"When we’re outside work, I’m conscious of trying not to use [plastics] where possible. Work-wise, I’m concentrating on patients and work, and material aspects aren’t always a high priority, but individuals can still make small changes." (FG1 R1)

Sustainability champions, individuals within an orthodontic department who are allocated time to work on sustainability issues, were seen as a driver for making environmentally sustainable improvements:

"I think the more voices that you have, and if you have a way of channelling the feedback up [to management], making them think and be aware of and start thinking about is like a good first step." (FG1 R1)

6.4 Barriers and facilitators to behaviour change surrounding SUP

To meet the objectives of examining UK orthodontic community's perception of use of SUP in the clinical environment and to explore perceived barriers and facilitators surrounding a change in SUP use in orthodontic practice, the data from interviews and focus groups was thematically analysed and barriers and facilitators to behaviour change were identified. The barriers and facilitators to behaviour change were mapped to the COM-B model for behaviour change. This behaviour change framework proposes that there are three components required to bring about behaviour change (B): capability (C), opportunity (O) and motivation (M). This model allows identification of potential barriers to behaviour change. A mapped final list of themes into COM-B framework is found in Table 10.

Not all themes identified from the data were able to be mapped into the COM-B framework as the initial data coding was not done according to COM-B. Themes that did not fit into the framework include: aligners, impacts and unknown potential.

Table 10: COM-B facilitators and barriers to behaviour change

	Facilitator	**Barrier**
Capability Can this behaviour be achieved in principle? "I know I can do this"	Knowledge and skills: • Staff awareness of issues within orthodontics • Leadership • Team engagement	Knowledge and skills: • Confusion surrounding sustainable practices
Opportunity Is there sufficient opportunity for the behaviour to occur? "I have what I need to be able to do this"	Costs: • Green alternatives associated with cost-saving Clinical environment: • Processes for separating waste • Recycling available • Digital scanning Social influences: • ES champions	Costs: • Greener alternatives more expensive • Wider financial constraints Clinical environment: • Recycling not encouraged or available Social influences: • Lack of institutional support
Motivation Is there sufficient motivation for the behaviour to occur? "I want to do this"	Intentions • Personal/organisational motivation Goals: • Industry environmental regulations	Attitudes/beliefs: • Cultural and habitual resistance Feelings: • Worry over workflow disruption Goals: • Cross-infection standards

6.4.1 Capability

Awareness of environmental sustainability and SUP was high amongst the industry representatives and clinical teams that took part in the research. Industry representatives felt that both manufacturers and distributors were aware of environmental problems and acting on them:

“What I would say is that I think awareness is increasing really, which is good.” (IR1)

Participants from the focus groups felt that awareness of environmental issues was high in their home lives and that was also filtering into their clinical work:

“I think it’s something I've become more conscious of with time, where I've noticed in my outside of work life that I’m switching to using more reusable things.” (FG1 R2)

There was not felt to be any pressure from either patients or external bodies, with one focus group respondent remarking that:

“The British Orthodontic Society should be active and take a lead on this” (FG3 R1)
“Is it a big thing for our customers? No. And I don’t know why it’s not.” (IR2)

The lack of patient-driven pressure for environmentally sustainable practices reduces the perceived urgency to adopt greener options. As one focus group participant observed:

“I don’t feel the pressure in the workplace, in the hospital it’s more about making money savings.” (FG3 R2)

Focus group participants identified several factors that encourage the adoption of sustainable practices and the reduction of SUP. Leadership emerged as a driving force for change, with motivated individuals, including sustainability champions, leading by example. These individuals play a critical role in fostering new practices and encouraging teams to adopt sustainable approaches. One participant noted how:

“In our unit we have two ladies that are involved with the BOS and their sustainability project, so they’ve done quite a lot in the ortho department, but also the hospital in general.” (FG2 R5) Another participant felt that *“if I want to see change, I’ll do something about it when it’s something I’m quite passionate about.” (FG1 R3)*

Team engagement further supports change, governance meetings provide a platform for discussing and planning sustainable practices. Collective accountability and open discussions help build momentum for change:

"When it comes to department governance meeting, if people are willing to have a discussion about it, then I think that would offer an opportunity to bring up [environmental sustainability]." (FG1 R1)

Although other participants felt that they would not be able to bring up sustainability issues within governance meetings. Education plays a pivotal role, quality improvement (QI) projects and training programs for students and trainees embed sustainability into clinical practice, fostering awareness and innovation. A participant remarked:

"So we're ensuring any of our QI projects are including sustainability going forward, and we're making that a policy across the hospital, that any audits and things have to take sustainability into consideration." (FG1 R3)

However other respondents noted the lack of sustainability training:

"I don't think it's even in the mandatory training." (FG1 R1)

There was a notable sense of confusion surrounding sustainable practices, causing a lack of clarity on green issues, which was felt to hinder progress. Participants expressed frustration over unclear recycling guidelines and the ambiguity of what can be reused or disposed of sustainably:

"Again, it's this confusion. I don't know whether they can put them in their recycling. I would suspect absolutely not. But I don't know where you get that information. Invisalign don't give you that information." (FG2 R1)

6.4.2 Opportunity

Cost considerations play a crucial role in facilitating or hindering behaviour change toward environmental sustainability in orthodontics. Aligning sustainability with cost-saving measures has proven effective. Initiatives that reduce material use or streamline supply chains not only benefit the environment but also offer financial incentives. For example, switching to more efficient products or reducing unnecessary disposables can lower overall expenses. As one participant noted:

"So you have to kind of target it to different people. If you can target it – some people like the environmental side of it. Other people, if you think about it's saving the NHS money, that encourages them. So it's trying to, across the board, engage people." (FG1 R3)

Within the orthodontic industry, investments in renewable energy sources, like solar panels, were described as having a positive return on investment. Aligning sustainability efforts with broader organisational goals, such as cost savings or operational efficiency, can act as a facilitator for change. Connecting environmental practices to financial incentives was thought to increase engagement.

Financial constraints pose a significant barrier, particularly when greener alternatives are more expensive. Participants shared concerns about the affordability of sustainable options, with one remarking:

"We've tried to launch a green range, so that being more eco environmentally friendly, but they didn't sell as much as the normal ones, and I think that's simply just down to the cost, which is yeah, it's unfortunate." (IR1)

This discrepancy was a recurring theme, with one participant explaining:

"Unfortunately, finances trump green issues sometimes." (FG3 R3)

This is exacerbated by the absence of external subsidies or incentives to offset the expense of eco-friendly products. Participants expressed frustration that the financial responsibility of sustainability often falls disproportionately on individual clinics or departments. This imbalance discourages wider adoption of sustainable practices, despite their long-term benefits. Financial concerns loom large, with worries about the cost implications of adopting greener alternatives in an already budget-constrained environment:

"Even though it costs more to dispose of them, overall it's still unfortunately cheaper to use the single-use mirror and probe." (FG1 R2)

Updating workflows can facilitate orthodontic teams to reduce SUP, many participants noting the move towards digital scanning:

"*Our Trust has started the shift towards intra-oral scanning in one of the units, so that hopefully will reduce the amount of [plastic] usage." (FG1 R1)*

However, some participants felt that even with updated workflows there are other issues:

"We do a lot of scanning, but the scanning tips don't last very long, and of course you get back all the 3D models from the lab that have been printed in plastic." (FG3 R3)

In contrast, having outdated workflows that do not support sustainable practices will act to hinder behaviour change, one participant explained that simply:

“There are no plastic recycling containers that I can put that into to be recycled. It has to go into domestic waste.” (FG2 R2)

A lack of alternatives to SUP also means that orthodontic teams are forced to rely upon them.

Having staff members, such as sustainability champions or environmental sustainability groups (ESG) who are dedicated to promoting green issues can help to bring about change. Support from clinical leads or management was another driver that was mentioned in interviews and focus groups:

“Our clinical leads have been so supportive with the sustainability work that we've been doing.” (FG1 R3)

Incorporating sustainability into induction of new staff was also mentioned as a useful tool, along with audit and QI projects. A lack of institutional support acts as a barrier to behaviour change. Without strong backing from management, individuals often struggle to implement change.

6.4.3 Motivation

Respondents felt a strong ethical responsibility to address environmental concerns, driven by a desire to create a positive impact for future generations:

" It’s just important for us that we know exactly what it is that we’re doing, and we’re making a difference not just now but for future generations in terms of climate change." (IR1)

Environmental groups within the orthodontic industry and sustainability champions in clinics/departments help to drive systemic changes. When representatives from the orthodontic industry were interviewed, there was a strong sense of wanting to make a positive impact as a company:

“I think it’s especially something…we’re very passionate about, being more environmentally friendly.” (IR1)

However, other industry representatives felt that their company should only address environmental issues, if it was what their customers wanted.

“As business we absolutely should get there if it’s what our customers want” (IR2)

Despite this sense of responsibility, significant barriers to behaviour change remain. Cultural and habitual resistance were among the commonly cited obstacles. Many staff members find it challenging to alter established workflows:

“Breaking people’s usual habits and asking them not to put those [SUP] out feels daunting.” (FG1 R3)

Anxiety about potential workflow disruption further contributes to hesitation. Focus group respondents worried that adopting new sustainable practices might complicate routines or slow down operations.

Resistance to change, often rooted in fears of workflow disruption, plays a role in slowing the adoption of sustainable practices. This has been overcome in some places with the implementation of incremental changes making sustainability goals more manageable. Small shifts in practice, like avoiding routine use of SUP, can reduce waste without overwhelming staff.

“We don’t put out three-in-ones unless they’re going to be needed, and that alone has reduced waste” (FG1 R2)

“*I think we really need to be moving towards the mindset of challenging of what we’re being given.” (FG2 R4)*

Participants expressed uncertainty about whether their sustainability efforts would yield tangible environmental benefits, leading to hesitancy about committing fully to new practices:

"If they are either recycled or if they're incinerated, is that better than just putting them into landfill?” (FG2 R1)

Regulatory standards are increasingly incorporating sustainability goals, providing incentives and frameworks for eco-friendly practices. Targets for reducing emissions and waste encourage organisations to adopt greener alternatives. Industry representatives noted that regulatory pressures, such as compliance with sustainability certifications like ISO14001,

drive efforts to align operations with environmental standards. Initiatives like net-zero commitments also push institutions to examine their use of SUP and implement more sustainable systems. One participant highlighted the potential of regulatory bodies like the CQC to take a proactive approach, stating:

"I think that the CQC could take a lead on this in a perhaps positive and proactive way, and give people recognition for improving what they're doing within their practices, within hospitals if they do, and that would then open the door to thinking more about that approach." (FG2 R4)

Many regulations, however, were perceived to act as significant barriers to change. Strict IPC standards often require the use of SUP to maintain sterility, even in cases where their necessity is questioned. As one participant remarked:

"I think it's both with the regulators and the hospitals, that the powers that be in the hospital just won't listen to a rational argument about the level of sterility we have and need in orthodontics." (FG3 R1)

These stringent requirements limit opportunities to transition to reusable or biodegradable materials, especially when dealing with mixed-material packaging or contaminated plastics that are difficult to recycle. Healthcare-specific exemptions from broader environmental policies, such as bans on certain SUP, perpetuate reliance on them within clinical settings.

Participants felt that there was inconsistent application of regulations across regions and institutions, noting discrepancies in recycling policies and the lack of clear definitions or guidelines on what constitutes sustainable practices. This inconsistency creates confusion and hampers the adoption of standardised, environmentally friendly approaches. Some practitioners felt that the UK's regulatory environment imposes excessive burdens compared to other countries, describing it as unnecessarily rigid and counterproductive to innovation.

Chapter 7: Discussion

Aligners were listed by participants as a commonly used SUP specific to orthodontics. The first pillars of the waste management hierarchy (Figure 5) are to prevent and reduce waste. Orthodontists have a variety of appliance systems that are available for use when treating patients however the final decision of appliance type may be determined by patient choice. Patient preference for an aesthetic appliance drives uptake of aligner treatment. A societal shift towards aesthetic treatments means that reduction of aligner use becomes an unlikely aim. Therefore, SUP aligner waste is unlikely to be prevented or reduced significantly.

Moving down the waste management hierarchy, recycling of aligners is the next feasible option. As discussed earlier there are challenges associated with recycling of plastics (Bucknall, 2020) including: guidance dictating medical waste management, limitations on how many times plastics can be recycled (Domenech et al. 2020) and the focus groups highlighted that there is confusion regarding recycling of plastics.

Most other examples of SUP listed by participants were not specific to the orthodontic specialty but are also used in general dentistry and routine dental treatment. This highlights that solutions from research into environmental sustainability within general dentistry may also be relevant to orthodontics. SUP are not just an orthodontic problem, they are much more pervasive and problematic in general dentistry and wider healthcare settings.

This research highlighted how much emotion is attached to environmental issues. Topics that stimulate complex human emotions are challenging to address. As is the case when trying to bring about any behaviour change, education plays a major role. Awareness of environmental sustainability and SUP issues were high amongst the industry representatives and clinical teams, although this could be due to the participants being a self-selecting group who were all environmentally-minded. This level of awareness is in line with previous research that found dental students and professionals' awareness of environmental sustainability to be high, although knowledge levels of environmental issues in dental students were low (Jamal et al., 2023, Gershberg et al., 2022 and Joury et al., 2021).

No patients were involved in this study but it was felt by both the industry representatives and clinical teams that patients' awareness of environmental issues was low and not a priority for patients when they attend for treatment. This is in contrast to research looking into dental patients' perceptions of environmental sustainability (Baird et al., 2022) which found that patients would be willing to compromise on time, convenience and pay more to

reduce the environmental impact of their treatment. This could be due to participants in research feeling pressured into saying that they care about environmental issues then failing to put those words into action.

This study has highlighted the difficulties in changing habits and that costs and processes are vitally important. Any solution to SUP must be one that has wider benefits such as improving patient care or streamlining workflows. If the alternative to SUP is more expensive and does not improve the outcome, then it will understandably not be adopted. Where changes are equivocal in one sense, such as two products that have equal cost, other factors of comparison may be brought in such as efficiency or environmental impact. This concept of the triple bottom line is an important one and is a tool that can be used to make sustainable improvements in orthodontics.

Techniques such as targeting ‘low-hanging fruit’ or making small incremental changes can be employed so that incorporating sustainability does not seem like an overwhelming burden. This is a concept that was mentioned in the focus groups by staff who have introduced environmental improvements in their departments. Clinicians and staff should be encouraged to challenge habitual behaviours, such as the automatic use of SUP, and adopt a ‘minimal waste’ mindset.

To effectively reduce the use of SUP in the delivery of orthodontic care, systemic organisational and cultural changes would need to be implemented. These changes span across regulatory updates, material innovations, education, and incentives to ensure both environmental sustainability and the maintenance of clinical standards.

7.1 Promoting facilitators

Focus group participants recommended courses to help educate clinicians such as those provided by the Centre for Sustainable Healthcare, on sustainable dentistry. It is important for awareness to be raised among patients about the environmental impact of orthodontic care, although currently there is no evidence regarding the best way to do this. Life cycle assessment of orthodontic treatment options would equip clinicians to inform patients about making sustainable choices and is one area that further research is required.

Strong leadership was identified as an important factor in bringing about change. Locally that may be seen in the form of ‘Sustainability Champions’, staff members who are assigned protected time to work on environmental sustainability. Establishment of dedicated

sustainability leads or committees to oversee the reduction of SUP and promote green initiatives will help drive change. Integration of sustainability into governance discussions to align organisational goals with environmental responsibility will ensure that this topic is routinely addressed.

Participants felt that high level leadership is currently lacking. Organisations such as the British Dental Association, Care Quality Commission or British Orthodontic Society could take more of an active role in promoting sustainability and reducing SUP within the profession. Development of comprehensive guidelines that are tailored to orthodontics and outlining acceptable alternatives to SUP, may provide the guidance that clinicians feel is needed. These guidelines should balance safety with environmental goals. Within the guidelines there should be an attempt to simplify the definition of what constitutes sustainable and recyclable materials, to reduce confusion among practitioners.

This study highlighted issues surrounding recycling of SUP and other waste. There was confusion from both interview and focus group respondents about which items can be recycled. Manufacturers of plastic products should work to clarify this confusion, highlighting clearly the components which can or cannot be recycled.

Team engagement was another key factor in bringing about change, it is not the responsibility of just one or a few team members, but the actions of a whole team that will ensure meaningful change.

7.2 Overcoming barriers

Participants of this study felt that industry regulations hindered efforts to reduce SUP. Regulation surrounding sterilisation of instruments provoked strong feelings of frustration with the participants of this study. IPC regulations should be reviewed and updated to allow for the safe use of reusable alternatives in non-critical areas of care, such as orthodontics, while maintaining sterility in necessary contexts. This should be done in collaboration with regulatory bodies, such as the CQC or GDC, to create sustainability-focused protocols.

Participants noted a lack of sustainable alternatives to SUP. Where alternatives are available, they were thought to be prohibitively expensive, forcing teams to resort to purchase of SUP. Investment in the development of biodegradable materials that meet

orthodontic clinical requirements is key, so that manufacturers can produce and supply more sustainable products that have all the benefits of SUP.

Where cost was listed as a barrier to reducing SUP and becoming more environmentally sustainable, financial support could be given to ease the transition to becoming greener. This could be in the form of subsidies or grants for orthodontic teams investing in reusable systems or greener alternatives to SUP. The costs of eco-friendly products could be reduced through tax incentives for sustainable working although this kind of change would need to come from government level.

7.3 What future research is needed?

Future research should focus on three distinct areas in order to have a meaningful environmental impact: reviewing IPC regulations, life cycle analyses and alternative sustainable materials.

Regulators of the orthodontic industry should focus their efforts on the feasibility of adaptable regulations. It would be beneficial to explore how IPC regulations can accommodate sustainable practices without compromising patient safety. IPC standards could be modified to support sustainable practices in orthodontics.

Innovation from outside of the orthodontic industry may provide solutions to the SUP problem by research and development of new materials. Development of biodegradable plastics or compostable materials which can be used for aligners, models and packaging may reduce the environmental impact of orthodontics in the future. Biodegradable aligners that match the clinical effectiveness and sterility of traditional SUP would almost completely solve the current issues surrounding aligner waste.

There is wide scope to carry out LCA on orthodontic products and treatments. We still do not know the complete environmental impact of orthodontic treatment modalities across their life cycles. This information would help clinicians to determine the most sustainable options and could be communicated to patients to make informed decisions. Knowing which treatments offer the lowest carbon footprint while maintaining clinical standards would equip clinicians and patients with knowledge to make informed decisions.

7.4 Strengths and limitations

The strengths of this project are that it explored an area that had previously not been researched. The findings of this project will allow others to conduct further projects surrounding SUP, environmental sustainability and orthodontics.

Conducting one-to-one interviews with representatives from the orthodontic industry meant that an important stakeholder viewpoint was considered. The orthodontic industry plays a vital role in improving the environmental impact of orthodontics and other research had not previously considered including industry. The method of one-to-one interviews meant that representatives could speak freely without the worry of having open conversations with competitors.

The focus group dynamics worked well with discussion flowing freely. Each group included participants working in different roles, locations of work and with varying levels of experience. This provided a diversity within the conversations. There were no obvious influences from participants of different levels of superiority talking with each other.

There are limitations to this study including the self-selecting method of recruitment for focus groups. This may have led to the results showing bias of respondents being more interested in environmental issues than the wider population. Nevertheless, this does not lessen the validity of the study.

The study was led by an inexperienced researcher which could be interpreted as a limitation, however three experienced supervisors were involved who all contributed their advice and time generously throughout.

Chapter 8: Conclusions

Environmental sustainability is a vital consideration in the provision of healthcare, including orthodontics. Previous research indicated that more work should be done to look into SUP waste from dental treatment, involving multiple stakeholders to better understand their perspectives. This study conducted qualitative research using document review, interviews and focus groups to explore how orthodontic teams and the orthodontic industry use and perceive SUP. This exploratory study has identified facilitators and barriers to orthodontic teams reducing their SUP use and becoming more environmentally sustainable.

The level of impact that SUP have on the environment may be small in comparison to other aspects of orthodontic treatment, such as travel. However, the absolute impact of SUP is significant and therefore this study was felt to be worthwhile. One strength of the study includes the applicability of the results to other dental and wider healthcare settings.

This study was the first to look into the problem of SUP within orthodontics. Recommendations are made for future research to focus on reviewing the IPC regulations that governs orthodontics in the UK, looking into alternative sustainable materials to work with and carrying out LCA of orthodontic products and treatments.

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Chapter 10: Appendices

10.1 Ethical approval

DREC ref: 230124-CS-003

DREC ref: 230124-CS-003 - Environmental sustainability and single-use plastics within orthodontics

Julie McDermott <J.K.McDermott@leeds.ac.uk>
Fri 5/10/2024 12:41 PM

To:Cara Sandler <dncs@leeds.ac.uk>
Cc:Paula Lancaster <P.E.Lancaster@leeds.ac.uk>;Karen Vinall-Collier <K.A.Vinall@leeds.ac.uk>

Dear Cara

DREC ref: 230124-CS-003
Study title: Environmental sustainability and single-use plastics within orthodontics

I am pleased to inform you that your research ethics application has been reviewed by the Dental Research Ethics Committee (DREC) and confirm that the application has been given ethical approval based on the documentation reviewed as per below. Please retain this email as evidence of ethical approval in your study file.

Documents reviewed

Document	Version number/date
Research ethics application form	Version 3 10.04.2024
Protocol	Version 1 08.01.2024
Participant information sheet (focus groups)	Version 3 10.03.2024
Participant information sheet (industry)	Version 3 10.03.2024
Consent form	Version 2 14.02.2024
Recruitment email direct to participants	Version 2 14.02.2024
Recruitment email to be sent by BOS	Version 2 14.02.2024
Recruitment email to industry	Version 2 14.02.2024
Participant demographics form	Version 1 08.01.2024

Please notify DREC if you intend to make any amendments to the research as submitted and approved to date. This includes recruitment methodology; all changes must receive ethical approval prior to implementation. Please see https://ris.leeds.ac.uk/research-ethics-and-integrity/applying-for-an-amendment/ or contact Julie McDermott for further information if required.

Ethical approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two-week notice period if your project is to be audited.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety, Data Protection and any other legal and/or professional guidelines there may be.

With best wishes for the success of your study.

For and on behalf of
Dr Paula Lancaster
Deputy DREC Chair

10.2 Appendix I

Search strategy as used in database for document review

Database	Search criteria	Results
Pub Med	11 #7 and #10 579 10 #8 or #9 1,988,663 9 sustainab*[Title/Abstract] OR waste[Title/Abstract] OR pollution[Title/Abstract] 362,770 8 (((environmental pollutants[MeSH Terms]) OR (sustainable development[MeSH Terms])) OR (environmental[MeSH Terms])) OR (environmental monitoring[MeSH Terms]) 1,772,533 7 #3 and #6 9,171 6 #4 or #5 596,978 5 (PPE[Title/Abstract] OR glove*[Title/Abstract] OR gown*[Title/Abstract] OR (face adj1 shield*[Title/Abstract]) OR mirror*[Title/Abstract] OR ruler*[Title/Abstract] OR aligner*[Title/Abstract] OR intraoral[Title/Abstract] OR (impression adj1 tray*[Title/Abstract]) OR (exam* adj1 kit*[Title/Abstract]) OR tips[Title/Abstract] OR packaging[Title/Abstract]) OR (plastic*[Title/Abstract]) 425,264 4 (plastics[MeSH Terms]) OR (disposable equipment[MeSH Terms]) 199,255 3 #1 or #2 75,765 2 orthodontic*[Title/Abstract] OR orthodontist*[Title/Abstract] 48,153 1 (orthodontics[MeSH Terms]) OR (orthodontists[MeSH Terms]) 57,018	579
Embase	orthodontics/ or orthodontic procedure/ or orthodontist/ 37259 2 (orthodontic* or orthodontist*).ti,ab. 45040 3 1 or 2 58891 4 plastic/ 28748 5 disposable equipment/ 11297 6 plastic*.ti,ab. 283790 7 (PPE or glove* or gown* or (face adj1 shield*) or mirror* or ruler* or aligner* or intraoral or (impression adj1 tray*) or (exam* adj1 kit*) or tips or packaging).ti,ab. 202398	235

	8 4 or 5 or 6 or 7 495128 9 3 and 8 3090 10 environmental sustainability/ or environmental impact/ or environmental management/ 57260 11 (sustainab* or waste or pollution).ti,ab. 408297 12 plastic waste/ 2395 13 plastic pollution/ 1583 14 10 or 11 or 12 or 13 446067 15 9 and 14 8 16 (dentist or dentistry or dental or oral).ti,ab. 1232403 17 8 and 14 and 16 235	
Emcare	1 exp orthodontics/ or orthodontist/ or exp orthodontic procedure/ 20875 2 (orthodontic* or orthodontist*).ti,ab. 23684 3 1 or 2 27103 4 plastic/ 6882 5 disposable equipment/ 1977 6 (PPE or glove* or gown* or (face adj1 shield*) or mirror* or ruler* or aligner* or intraoral or (impression adj1 tray*) or (exam* adj1 kit*) or tips or packaging).ti,ab. 49621 7 plastic.ti,ab. 21065 8 4 or 5 or 6 or 7 72937 9 3 and 8 1613 10 environmental impact/ or environmental management/ or environmental sustainability/ 5574 11 (sustainab* or waste or pollution).ti,ab. 68055 12 10 or 11 72195 13 9 and 12 2	2
Medline	1 exp Orthodontics/ or Orthodontists/ 56873 2 (orthodontic* or orthodontist*).ti,ab. 46364 3 1 or 2 74780 4 Plastics/ 27185 5 Disposable Equipment/ 5304	246

	6 (PPE or glove* or gown* or (face adj1 shield*) or mirror* or ruler* or aligner* or intraoral or (impression adj1 tray*) or (exam* adj1 kit*) or tips or packaging).ti,ab. 172971 7 plastic*.ti,ab. 238088 8 4 or 5 or 6 or 7 420706 9 3 and 8 3609 10 Environmental Pollutants/ or Sustainable Development/ or Environment/ or Environmental Monitoring/ 252058 11 (sustainab* or waste or pollution).ti,ab. 337842 12 10 or 11 540776 13 9 and 12 10 14 (dentist or dentistry or dental or oral).ti,ab. 962934 15 8 and 12 and 14 252 16 limit 15 to english language 246	
Hand search	Orthodontics, dental, single-use plastics, waste, waste-management, decontamination	4

10.3 Appendix II

Document review excluded studies with reasons (n = 18)

Study		**Reason for exclusion**
1	Aukett, J. 2018	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
2	Batra, P. 2014	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
3	Bertolino, G. 2023	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics

4	Bichu, Y. M. 2023	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
5	Byrne, D. 2022	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
6	Cannata, S. 1997	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
7	Cleveland, J. *et al.* 1993	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
8	Duane, B. 2022	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
9	Farmer, G.M. 1997	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
10	Gali, S. 2021	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
11	Halton, C. 2022	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
12	Henn, S. A. 2015	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
13	Lyne, A. 2020	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
14	Martin, N. 2021	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
15	Martin, N. 2022	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics

16	Martin, N. 2024	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
17	Peter, E. 2022	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics
18	Wilson, N. H. 1998	Not a guideline or policy affecting the use of single-use plastics, decontamination or waste within orthodontics