Consensus on Environmentally Sustainable Oral Healthcare:

A Joint Stakeholder Statement

Nicolas Martin, Steven Mulligan, Ian J Shellard, Paul V Hatton

FDI World Dental Federation

The University Of Sheffield.

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Preface

This document is divided into sections, which enables the reader to readily access areas of interest.

Contributors to the Stakeholder Statement are acknowledged at the outset together with a **glossary of the terms and definitions** used throughout.

A **Joint Stakeholder Statement** for Environmentally Sustainable Oral Healthcare is established. This sets the tone and construct for a detailed and comprehensive operational **Strategic Action Framework** (Section V) for all stakeholders in the supply chain.

The **Strategic Action Framework** is an operational framework that provides a series of principles and action points that have been reached through consensual agreement. This forms the basis for proactive engagement in worldwide environmentally sustainable oral healthcare. A synopsis concludes this section.

The Strategic Action Framework is founded on a comprehensively developed **Frame of Reference** (Section IV) for the concept of sustainability in oral healthcare. In doing so, it highlights the levels of awareness, the challenges, the drivers and the opportunities involved in achieving this goal. It also identifies and considers the various routes to sustainability identified in the literature.

The whole process has been developed through a robust and detailed **Research Framework** (Section III) that identifies the background to the study, the main aim and objectives and the actual methodology that has been used to reach the Strategic Action Framework.

The document concludes with the relevant **Bibliography** and the **Appendix** for the mapping exercise that matches the United Nations' Sustainability Development Goals to those reached in this oral healthcare sustainability statement.

This stakeholder statement was ratified in March 2022 by the contributors as identified.

Contributors and acknowledgements

This publication, *Consensus on Environmentally Sustainable Oral Healthcare: A Joint Stakeholder Statement*, was made possible through the passion, hard work and dedication of many people and organisations. Their individual and collective contributions are duly recognised under the following headings.

- **Authorship** – Biographical context for the authors of this publication.
- **FDI Sustainability Task Team** – Individuals with responsibility for the inception, management and timely delivery of this project.
- **Founding Partners** of the **FDI 'Sustainability in Dentistry Project'** – Key global industry-leading companies that have committed as founding partners, to lead and work together in the development of this project, on behalf of the wider industry. Through their collective knowledge, expertise and non-partisan collaborative engagement, they have made an invaluable contribution to the content of this publication.
- **Participants** – Individuals and organisations that have willingly shared their expertise and contributed in a powerful and insightful manner to the content of this publication, *Consensus on Environmentally Sustainable Oral Healthcare: A Joint Stakeholder Statement*.

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Glossary and definitions

Acronyms and abbreviations

ASTM	American Society for Testing and Materials
CEU/CPD	Continuing education units (CEU credits) or continuing professional development (CPD). Quantifiable units, used to provide accreditation of professional development and enable revalidation, if appropriate
CGF	Consumer Goods Forum [1]
CO_2e	Carbon dioxide equivalent. The number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas
COP26	'Conference of the Parties #26'. United Nations Climate Change Conference, Glasgow, 2021
DHCP	Dental healthcare professional
EHS	Environment, health and safety: management system. Codifies the organisation's environment, health and safety strategy and then streamlines its implementation and management
EMF	Ellen MacArthur Foundation (Global Commitment)
EPR	Extended producer responsibility (for packaging) [2]
ESG	Environmental, social and governance (business operational framework)
FDI	Federation Dentaire Internationale (World Dental Federation)
KPI	Key performance indicators
ISO	International Organization for Standardization
ISOTC106	International Organization for Standardization Technical Committee Dentistry 106
IDM	International Dental Manufacturers Association
LCA	Life cycle analysis
LMIC	Low- to medium-income countries
MHIC	Medium- to high-income countries
NGO	Non-governmental organisation

PPE	Personal protective equipment
WHO	World Health Organization
RSB	Roundtable on Sustainable Biomaterials. A global, multi-stakeholder, independent organisation that drives the development of a bio-based and circular economy on a global scale through sustainability solutions, certification, and collaborative partnerships
SUP	Single-use plastic
SWOT	Strengths, weaknesses, opportunities and threats (business analysis tool)
UNEP	United Nations Environment Programme
4Rs	Reduce, reuse, recycle, rethink
UN SDGs	United Nations Sustainable Development Goals
WRI	World Resources Institute [3]

Terminology and definitions

Circular economy	An economic system that tackles global challenges like climate change, biodiversity loss, waste and pollution. We keep resources in use for as long as possible, extract the maximum value from them while in use, then recover and regenerate products and materials at the end of each service life.
CGF Plastic Waste Coalition	Consumer Goods Forum [4], Plastic Waste Coalition. Organisation that brings consumer goods retailers and manufacturers together globally.
Companies	The various stakeholders in the oral healthcare supply chain that operate as commercial businesses. This includes manufacturing, distribution and oral healthcare providers and corporates.
Dental industry	A generic term used in this work to describe the whole of the oral healthcare supply chain that includes any and every stakeholder-associated provision of raw materials, goods and services and management of waste.
Materiality assessment	Tool used to identify and prioritise ESG issues that are the most critical to the organisation.
Carbon negative	The reduction of an entity's carbon footprint to less than neutral, so that the entity has a net effect of *removing* carbon dioxide from the atmosphere rather than adding it.
Sustainability in Dentistry Task Team	The group charged by the FDI with planning managing and delivering the Sustainability in Dentistry Project on behalf of the stakeholders.
Carbon zero	Causing or resulting in no net release of carbon dioxide into the atmosphere.

SECTION 1

A Joint Stakeholder Statement

Through this statement, we recognise that the oral healthcare sector – as a whole supply chain – has a responsibility to undertake its activities in a manner that seeks to improve the sustainability of oral healthcare products and interventions.

Through our collective ambition to reduce the environmental impact of oral healthcare, we recognise that there is a substantial opportunity and desire to work collaboratively across the sector, to engage in sustainable practices with all stakeholders for the benefit of society. We recognise the need to establish a strategy to achieve meaningful and measurable environmental outcomes throughout the oral healthcare supply chain.

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SECTION II

Executive Summary

Climate change and environmental pollution are among the greatest health threats affecting the planet, humanity and biodiversity. This is recognised in the 2030 United Nations Agenda for Sustainable Development, which includes an urgent call for action from all sectors. The entire oral healthcare community, including clinical professionals and industry, recognises that we have a responsibility to deliver products and interventions that improve oral health in a sustainable manner. We also recognise the need to address this environmental challenge within the context of huge oral health inequalities across the world. The actions taken to address sustainability goals need to be balanced with the need to manage these avoidable inequalities and the associated preventable diseases.

Towards this objective, the FDI World Dental Federation convened an expert group to produce this *Consensus Statement on Environmentally Sustainable Oral Healthcare*. This brings together a coalition of stakeholders that includes leading figures from industry, health professionals, academic experts, legislative authorities and dental associations, with the clear intent to identify an impactful and robust strategic action framework that crosses boundaries and takes a truly collaborative, evidence-based approach. In doing so, the work of this panel represents an important continuum of the pioneering statement adopted by the FDI General Assembly (August 2017, Madrid, Spain) [5].

Through this document, we identify the collective views across the whole supply chain, where all are equally committed to further improving sustainability without compromising healthcare benefits. This work is in close alignment with the UN Sustainable Development Goals, and recognises that both excellent oral healthcare and the development of a circular economy are two key pillars in delivering sustainability. We further recognise that there are opportunities to collaborate across the sector and throughout supply chains, to develop and promote sustainable practices that achieve meaningful and measurable environmental benefits.

This joint stakeholder statement recognises the major challenges facing oral healthcare, the complex drivers that underpin current behaviours and practices, and the best opportunities to improve and deliver sustainable oral healthcare for people and the planet. The statement further emphasises the routes to sustainability in oral healthcare, drawing on evidence from the published literature [6, 7]: reduce, reuse, recycle and rethink; legislation, policy and guidelines; waste management (including SUPs); procurement and logistics; research and education; and materials for clinical use.

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Each of these routes is considered in a three-step process that sequentially informs future strategy, including positive actions that should be implemented across the sector:

- **Awareness and challenges.** This step recognises the current degree of awareness of the environmental impacts from oral healthcare products, services and consumer behaviours. It also identifies the challenges that all stakeholders face to improve better understanding of these impacts, behaviours and the dissemination of this knowledge.
- **Drivers and opportunities.** There are numerous drivers now operating that promote the development of – and engagement with – sustainable practice. This presents a major opportunity to make improvements across the sector.
- **Strategic action framework.** This consensus statement makes specific recommendations and identifies potential best practices to deliver environmental benefits with a focus on the improvement of global oral health.

Knowledge of the impact of oral healthcare on the environment is not uniform, with significant awareness among manufacturers but relatively little insight from end-users including oral healthcare professionals, patients and consumers. CO_2 emissions and plastic waste, packaging and end-user single-use plastics (SUP) are recognised to be among the main contributors to unsustainable practice. Companies across the supply chain have identified that impactful solutions will only come about through unbiased and open inter- and intra-stakeholder collaboration and communication within the supply chain. Companies recognise that they will have to work differently and often together to address key issues. The dental industry seeks to do this through engagement with policymakers, healthcare professionals, manufacturers, distributors and the public as a major stakeholder and end-user of these services. There is a further opportunity for all stakeholders to identify and embrace every element of sustainable practice and in this way, through multiple individual activities, achieve significant cumulative positive benefits.

This consensus statement recognises the importance of legislation to ensure products are fit for purpose while driving sustainable practice. Designing and working with the duality of this legislation is challenging at all levels, but especially so for end-user/oral healthcare providers that have to work within the constraints of stringent regulations that promote patient and workforce safety. There are undoubtedly opportunities to work with legislative authorities at all levels to seek effective remediation strategies.

The greatest opportunities for sustainable practice are through reduction, reuse and recycling:

- **Reduction** – by the patient and consumer end-user, through the promotion of preventive care and provision of good oral healthcare, in this way reducing the demand for restorative products and associated plastic packaging [8].
- **Reuse** – throughout the supply chain, with a focus on clinical end-users when safe to do so. Reuse is more environmentally favourable to the use of disposable single-use items (e.g. single-use wipes).
- **Recycling** – at the manufacturer and distribution level, with a focus on energy-efficient manufacturing, the design of recyclable end-user products, reducing unnecessary packaging and optimising distribution logistics.

There is broad agreement that stakeholders in the dental sector could potentially make significant reductions in the volume of waste generated, most notably from manufacturing processes, packaging, and the high prevalence of single-use products (mostly plastic). Most of the contaminated biomedical waste impact lies downstream of the supply chain, with the oral healthcare professionals, patients and end-user consumers. This waste problem is further compounded by the increased use of personal protective equipment (PPE).

Recycling remains a challenge at the patient end-user level, but less so with packaging and uncontaminated SUPs. For both scenarios, there is an opportunity to engage in robust research that will drive the required know-how and supporting technologies.

Education is considered the fundamental component of any action strategy, with a focus on increasing awareness and identifying solutions for each sector and for the supply chain as a whole. Any strategic educational framework should be based on strong and robust research that provides an objective and unbiased representation of the facts that contribute to environmental sustainability in the oral healthcare industry. The oral healthcare industry has a responsibility to promote innovation and high-quality research and to harness best operational models to identify and support sustainable activities within the supply chain.

In conclusion, this statement establishes a consensus opinion on the most promising approaches to reduce the environmental impact of oral healthcare without compromising patient welfare. This is in response to a recognition of the value of implementing sustainable practices, in alignment with the United Nations agenda. While recognising that our sector makes a significant contribution to oral health, which improves the quality of life for millions of people worldwide, this statement also acknowledges that there is an opportunity to further improve sustainability. Specifically, this consensus statement demonstrates clearly the potential for far greater future impact as a direct result of improved coordination and collaboration between diverse stakeholders. Implementation of the approaches presented here will deliver the twin benefits of a sustainable, circular economy with improved global oral health.

SECTION III

Research Framework

Introduction

The 2030 Agenda for Sustainable Development, 'adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future'.

> At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries – developed and developing – in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests [9].

In keeping with this 'urgent call for action', the oral healthcare industry has come together and joined forces, under the continued leadership of the FDI World Dental Federation, to collaborate with a strong and genuine ambition to engage with this UN Agenda for Sustainable Development.

The FDI has assumed the responsibility of this leadership role, in its capacity as the World Dental Federation, which serves as the principal representative body for more than one million dentists worldwide, some 200 national dental associations and specialist groups in over 130 countries [10]. The FDI has convened the development of a joint stakeholder Consensus Statement on Environmentally Sustainable Oral Healthcare. This has been achieved through a unique working partnership between the FDI Sustainability in Dentistry task team, five project founding partners and the wide participation of stakeholders in the oral healthcare supply chain (see *Contributors*).

This consensus statement seeks to identify, understand and establish an improvement strategy that will address our responsibilities, both as individual stakeholders and as part of a global supply chain to address the goals identified.

The WHO has established that oral health 'is a key indicator of overall health, well-being and quality of life' [11]. This sentiment is echoed by the FDI World Dental Federation in its definition of oral health,

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Figure 1: Prevention and maintenance as a key route to environmental sustainability. "SewCream/Shutterstock.com" 2022.

highlighting that it is 'vital to general health and well-being' [12]. The hard and unavoidable reality is that the world population is far from achieving oral health, with oral diseases affecting nearly 3.5 billion people worldwide (approximately 50% of the world population) [13]. This situation poses 'a major health burden for many countries and affects people throughout their lifetime, causing pain, discomfort, disfigurement and even death' [14]. Oral diseases are most commonly expressed in the form of caries (the most common health condition) [15], severe periodontal disease (affecting almost 10% of the world population) [11] and oral cancer (among the most common forms of cancer worldwide [16]). The WHO further states that 'Most oral health conditions are largely preventable and can be treated in their early stages' [11].

It is in this context that **we need to focus the efforts of the oral healthcare professions and the associated oral health industry to reverse this undesirable situation with the provision of good oral health for all**, largely through effective prevention and maintenance regimes that minimise the need for interventions and operative treatment (*Figure 1*). In the last decades, the combined efforts of the oral healthcare profession and the oral health industry have been extraordinarily successful in the delivery of a sophisticated understanding and knowledge of diseases, treatment strategies and modalities, including the innovation and development of excellent technologies, materials and products to provide this care. These combined efforts have, to date, been largely focused on the end goal: preventing and managing oral diseases.

Today, we have a further understanding that these laudable intentions and efforts are having the unintentional consequence of contributing to the global net rise in CO_2e emissions and pollution. The recently published draft COP26 special report on climate change and health highlights the impact of healthcare on the environment [17], with evidence of how 'health professionals worldwide are already responding to the health harms caused by this unfolding crisis' [18]. Significant progress in this field has been made by the American Society for Testing and Materials, with the important recent publications *Standard Practice for Managing Sustainability in Dentistry* (2015, 2021), written in response for 'a consensus-based practical guidance document in support of the cost-efficient integration of generally recognized sustainable development principles into day-to-day management of dental practices both for individual dental professionals as well as dental service organizations' [19, 20].

Healthcare systems are responsible for around 5% of global greenhouse gas emissions, of which oral health is an important contributor [21, 22]. The delivery of general healthcare is currently not environmentally, socially or financially sustainable owing to high amounts of CO_2e and waste generation [23]. It is paradoxical that healthcare, with the central tenet of supporting and protecting health and life, contributes to climate change through unsustainable practices and, in doing so, to negative health impacts and inequalities.

The oral healthcare industry is keen to address this challenge and ensure that, through the actions of both individual stakeholders (companies, associations and other entities) and the entire supply chain acting in unison, we reduce and limit our environmental impact to ensure sustainable planetary health. The whole oral healthcare supply chain (inclusive of the manufacturing industry, distribution, care professions and waste management) has a vital role to play in climate change mitigation efforts through a comprehensive engagement in sustainable practice. Not only would sustainable oral healthcare potentially result in substantial CO_2e reductions but it could lead to enhanced patient care, staff satisfaction, cost savings and improved quality of life [24, 25, 26].

To improve the sustainability of oral healthcare services, all stakeholders have identified and recognise the urgent need to work together synergistically, collaboratively and in a non-partisan manner to build knowledge, identify remediation opportunities and share good practice. The dental industry seeks to do this through engagement with policymakers, healthcare professionals, manufacturers, distributors and the public as a major stakeholder and end-user of these services.

Sustainability in relation to oral healthcare is comprehensively defined by the American Society for Testing and Materials (ASTM) in the document *Standard Practice for Managing Sustainability in Dentistry E3014–15* as:

> Sustainable development is about integrating the goals of a high quality of life, health, and prosperity with social justice and maintaining the earth's capacity to support life in all its diversity. These social, economic, and environmental goals are interdependent and mutually reinforcing. Sustainable development can be treated as a way of expressing the broader expectations of society as a whole [19, 20, 27].

The FDI World Dental Federation, in its *Sustainability in Dentistry Statement* (2017), has also adopted a series of relevant definitions for sustainable development, green economy and sustainability [5].

For the purpose of writing this consensus statement and providing a practical operational framework, the partner and participant stakeholders have agreed a **definition for sustainability in oral healthcare** that establishes **why** we need to engage, **what** we are trying to achieve and **how** best to accomplish this work.

Sustainable oral healthcare is the provision of equitable, ethical, high-quality, inclusive and safe care with appropriate, effective and efficient use of resources. Through this, the healthcare opportunities of current and future generations are respected and protected by actively minimising negative environmental impacts.

Aim

To respond to the United Nations' 'urgent call for action by all countries – developed and developing – in a global partnership' through the establishment of a global, unified and recognised working consensus opinion that is representative of participating key stakeholders in the provision of oral healthcare and which will reduce and minimise our environmental footprint.

Objectives

1. Raising awareness and outline the opportunities relative to decreasing carbon emissions, improved choice and use of materials, improving waste generation and management, and other environmental impacts relating to oral healthcare.
2. Promoting impactful research and educating all sectors of the supply chain, to ensure broad consensus around sustainable oral health practice and sustainable lifestyle habits.
3. Acknowledging individual and joint responsibilities to understanding and seeking to minimise the environmental impact of our activities while improving the quality of products and healthcare provision.
4. Seeking to work jointly and proactively, to achieve environmentally sustainable solutions for the good of our profession, the population we serve and the environment we share globally.

Methodology

The FDI World Dental Federation Sustainability in Dentistry Task Team has led this research process [28]. The process was based on an iterative series of drafts informed by a comprehensive three-wave Delphi inquiry [29, 30], undertaken with the key stakeholder focus group (partner companies) from May to October 2021 and supported with appropriate published literature. A series of workshops (November 2021) with the multidisciplinary worldwide participation of key stakeholders followed, to add further perspectives from other key supply chain stakeholders (see *Appendix*). The additional participant workshop data was categorised thematically and included in the relevant sections of the document with further revisions from the partner companies. The final approved joint stakeholder statement was released at the FDI Sustainability in Dentistry Summit (March 2022).

The consensus statement sought to identify common ground between all the key stakeholders, with all the findings and inclusions agreed in a consensual and non-partisan manner. The statement is set out in the

manner of a *concept journey*, commencing with an awareness of the problem, exploring the challenges, drivers and opportunities to solutions, and concluding with an action plan in the form of a remediation strategy.

1. Awareness and challenges
   - *Awareness* among all stakeholders of the impact of oral health professional activities on the environment.
   - *Challenges* to develop and engage with sustainable practice.
2. Drivers and opportunities
   - *Drivers* to develop and engage with sustainable practice.
   - *Opportunities* to develop and engage with sustainable practice.
3. Strategic Action Framework
   - *Recommendations and best practice* for effective sustainable dental practice.

In this consensus statement, the agreements detailed are representative of the oral healthcare supply chain as individual stakeholders and acting as a single entity. As such, we have sought to include representation from each stakeholder group, acting as an individual organisation (within their internal environmental, social and governance – ESG – framework) and also beyond their internal boundaries to engage and influence other stakeholders in the supply chain.

A recent and comprehensive scoping review identifies the range of themes that capture all the broad topics for consideration [6, 7]. These are: environmental impacts, CO_2e, air and water; reduce, reuse, recycle and rethink; policy and guidelines; waste management (SUPs); procurement; research and education; and materials for clinical use. The consensus statement considers the literature included in this scoping review and additional relevant literature as appropriate. Accordingly, statements of fact that are not cited are attributable to the findings from the scoping review.

The process was financially sponsored by the five partner companies (Colgate, Dentsply Sirona, Haleon, Procter & Gamble and TePe), each providing equal financial contributions and operating within a framework of antitrust procedures as a fundamental part of the methodology. The overall participant engagement is representative of all sectors of the oral healthcare supply chain with global representation (see *Contributors*).

SECTION IV

Frame of Reference

Sustainability in oral healthcare

This consensus statement recognises the need to align the combined efforts of the oral healthcare industry to the Sustainable Development Goals stipulated in the UN 2030 Agenda for Sustainable Development [9] (*Figure 2*).

Figure 2: Sustainable Development Goals stipulated in the UN 2030 Agenda for Sustainable Development. Artvictory/Shutterstock.com, 2022.

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We have identified that our activities have a strong alignment with eight of the goals, presenting a real opportunity for positive sustainability action (see *Appendix*):

- Goal 3 (Good health and well-being)
- Goal 4 (Quality education)
- Goal 6 (Clean water and sanitation)
- Goal 8 (Decent work and economic growth)
- Goal 9 (Industry, innovation and infrastructure)
- Goal 12 (Responsible consumption and production)
- Goal 13 (Climate action)
- Goal 17 (Partnership for the goals)

The ability to engage with these UN SDGs is founded on a comprehensive understanding of the background levels of awareness of these issues, the challenges to changes, the drivers to engage with change and the opportunities to do so in an effective way. The following broad exploration of the levels of *awareness*, *challenges*, *drivers* and *opportunities* makes reference to the evidence identified in the scoping review by Martin et al. (2021) [6, 7].

1 – Awareness

The environmental impacts (carbon emissions, air and water pollution) associated with the entire oral healthcare supply chain have not been comprehensively determined and, as such, are largely unknown. The only assessments that have been made for CO_2 emissions are those directly associated with commuting travel and transport centred around the direct provision of clinical care (i.e. patient and staff travel). In the UK, this alone accounts for approximately two-thirds of all emissions from the oral healthcare sector and about 8% of the total UK NHS air pollution attributable to travel [31]. Energy use from all sectors in the supply chain is high and much of this is indirectly attributable to the individual patients and users of the products. Again, most of the published evidence for energy use focuses on activities in the dental practice, with little in the public domain for organisations and other stakeholders in the supply chain.

Specific contributions to **CO_2 emissions** from the healthcare industry are increasingly being understood. This accounts for a significant percentage of national emissions (e.g. accounting for approximately 5% of emissions in the UK), with significant effects on the health of the human population and planetary biodiversity. Petrol and diesel vehicles are a major contributor to air pollution, from travel and commuting of staff and patients but also from distribution/procurement.

In oral healthcare, the major contributions to air pollution arise from the incineration of waste, anaesthetic gases and CO_2 emissions associated with travel and transport at the point of patient care. Oral healthcare presents with higher levels of patient and staff transport than other medical specialisations. This is partly due to the need for regular oral health maintenance, where other specialisations tend only to treat illness, and partly due to the more dispersed nature of secondary care in dentistry, e.g. dental hospitals.

Water is an invaluable resource and its supply is, at best, becoming unpredictable and, at worst, it has completely disappeared in areas of the world through human activities and desertification. There is an awareness of the need to conserve this and there is also a realisation that, by virtue of the large and rapidly increasing global human population (nearly eight billion as of March 2022), the practice of dentistry and personal oral healthcare is a significant consumer. If we estimate that half the world population cleans their teeth once per day and uses 600ml each time [66] the daily global water usage from cleaning our teeth equates to 2.4 billion litres or 480 Olympic swimming pools per day (*Figure 3*). This figure is in addition to the consumption of water up and down the supply chain, all of which is undocumented.

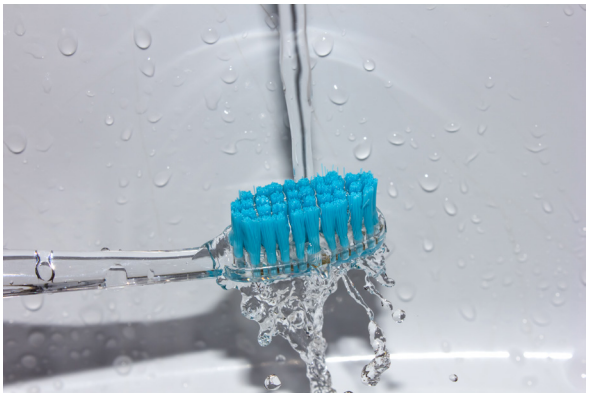

Figure 3: Need to conserve water during toothbrushing. Sergey Polishchuk/Shutterstock.com, 2022.

Beyond actual environmental impacts, we should also consider the demographics of our population, at a global and regional level. Ageing populations in medium- to high-income countries (MHICs) are increasingly dentate and in need of complex oral healthcare, which requires multiple (often of increased complexity) interventions and associated travel. There is a lack of awareness of the impact of this in terms of workforce requirements and the associated environmental impact of this. Equally, inadequate or disjointed care provision, cumbersome logistics and inadequate waste disposal services in low- to middle-income countries (LMICs) adds a further environmental burden to the existing baseline sustainability problem of oral healthcare.

Sustainability affects everybody in the supply chain, including the patient as a co-creator of their own oral health, through the choices and actions they make that influence their treatment needs and therefore environmental impacts. In this way, the public in a patient capacity has a role to play in reducing the impact of the oral healthcare on the environment.

Solutions arise from a deep and conceptual understanding of the levels of awareness and the challenges that present at two levels: for each stakeholder as an individual enterprise and as part of the larger supply chain, of which they are a key element.

The provision of oral healthcare is a joint effort that involves every stakeholder in the whole supply chain, from manufacturers to end-users, including professionals and patients.

As a supply chain, we are presented with the choice of operating in the manner of a linear economy that is wasteful of resources with an accompanying high pollution cost (*Figure 4*) or as a circular economy that seeks to recover and recycle waste products that are created along the whole process, with a consequential reduced burden on virgin resources and reduced pollution (*Figure 5*). The current, mostly linear supply chain economy presents a barrier to reducing the impact of the industry on the environment.

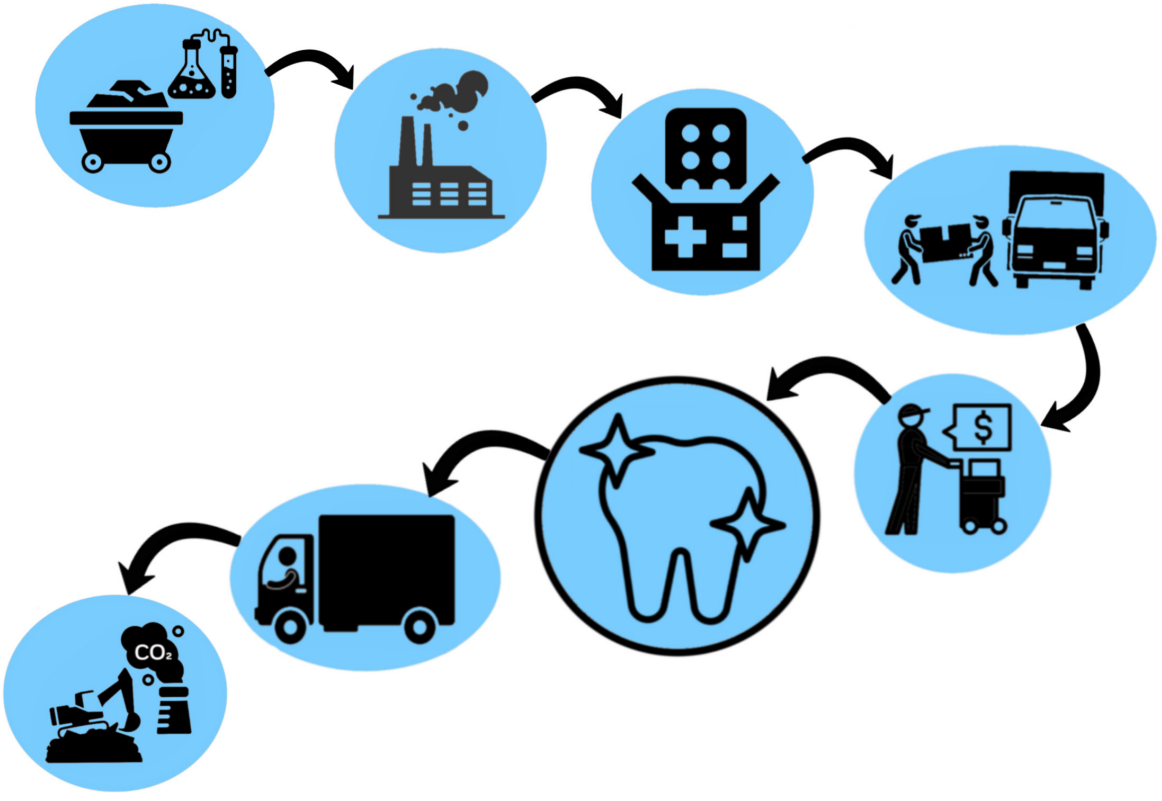

Figure 4: Linear economy in oral healthcare. A point-to-point journey for products with all resulting waste with zero-value: mineral extraction, production and synthesis of raw materials >>> manufacture of equipment, materials and sundries >>> packaging >>> product distribution and logistics >>> product procurement >>> clinical and consumer healthcare >>> waste collection with different levels of contamination >>> waste disposal through landfill and incineration. Copyright Hannah Martin, Sheffield, UK, 2022 Sheffield, UK, 2022, CC BY 4.0.

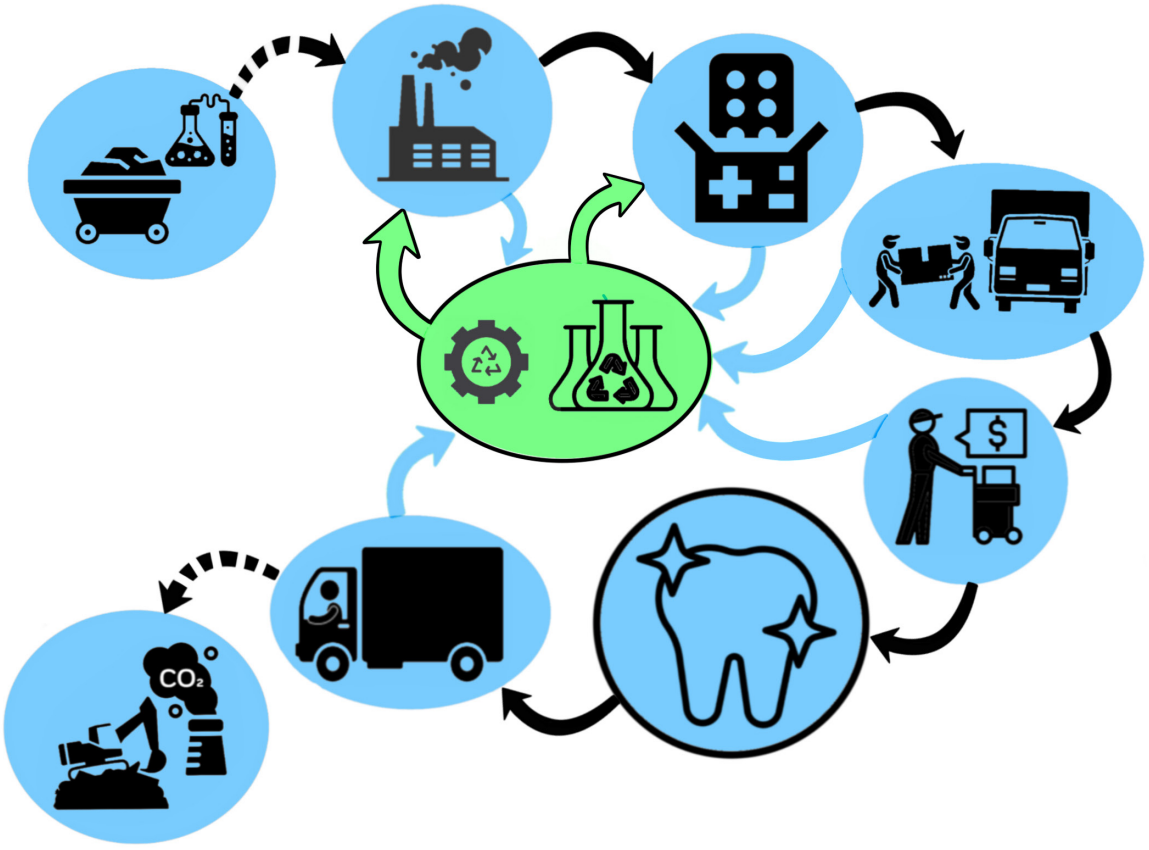

Figure 5: Circular economy in oral healthcare. Reduced reliance on the extraction and synthesis of raw materials and disposal in landfill or incineration. Waste from materials and packaging is diverted back into the supply chain through mechanical and chemical recycling. Copyright Hannah Martin, Sheffield, UK, 2022, CC BY 4.0.

Stakeholders

Companies are increasingly aware of the need to include the impact of CO2e, air and water, SUPs (including packaging), distribution and procurement, and waste management into their ESG frameworks. This generally extends to include suppliers that are either already committed to sustainable operations or showing increasing awareness of this need. Nevertheless, there is a widely held view, based on qualitative observation, that the level of awareness of the impact of oral health on the environment and the need for sustainable practices is much lower downstream of the supply chain, i.e. the end-user community (dental professionals, patients and consumers).

Within companies, sustainable practice has to date been driven by clear internal company strategy and effective communication. Corporate responsibility has a distinct inclusion of environmental responsibilities through internal structures, corporate ESG frameworks (*Figure 6*) or through the alignment with the UN Sustainable Development Goals [9]. The strength of this movement is such that it is increasingly framing and providing a context for the business models of the companies. Much of this alignment is focused on the activities that are directly attributable to the manufacturing of products. Good practice in the dental industry points to the delivery of high-quality products that maintain the correct balance between product performance and sustainable positive impacts. Reputable (large and small) companies are actively engaged in sustainable practices, with a strong and clear ambition to integrate sustainability into the fabric of the business, at all levels. This is clearly expressed in the internal 'modus operandi' of the companies, establishing a high level of awareness with the activities that are directly attributable to the manufacturing of products and through internal communications and active employee participation.

Figure 6: Environment, social and governance framework used by industrial companies and organisations. Superstar/Shutterstock.com, 2022.

Companies mostly recognise the benefit and need to characterise and understand environmental impacts arising from the core business. This is derived from various sources, which include: leverage insights from life cycle analysis (LCA) studies, published studies and research work with internal and external experts, NGOs and research organisations; third-party verification of footprint by category; studies completed on all major product formats; and reviews and data collected from manufacturing energy use, processing and waste management. There is a recognition, though, that many companies and industrial stakeholders have a limited understanding and ability to effectively implement LCA studies.

There is a notable lower, but improving, level of awareness of impacts outside the companies, up- and downstream of the supply chain, with the important inclusion of end-users (the dental profession or the consumer). End-users are generally considered to be poorly engaged in sustainable practices, but this is not quantified. There is a need to change behaviour at home and at the workplace [8, 32]. Within this low level of awareness in the oral healthcare sector, there is a wide range between different challenges in different world regions, each with its own specific challenges. Anecdotal evidence indicates that this is a particular problem in LMICs, with high levels of product packaging, associated high shipping and transport needs, and limited recycling infrastructure.

There is a recognition of a need to engage with regulatory bodies, such as the International Organization for Standardization Technical Committee 106 Dentistry (TC106 Dentistry) [33] and the International Dental Manufacturers Association (IDM) [34], to ensure an alignment of manufacturing and sustainability.

There is a perceived lack of awareness among the whole of the industry that the single most effective route to sustainable care is through the provision of good-quality care, which includes prevention at its core. Essentially, good oral healthcare, through prevention or delivery, results in fewer interventions and a reduced environmental impact [8, 28].

2 – Challenges

The greatest barrier to the implementation of sustainability is 'set behaviours and attitudes' within the profession, and other major barriers are a lack of economic feasibility and knowledge base. Most countries and autonomous authorities have strong guidance or statutory requirements set by local or governmental legislative authorities to manage the toxic or directly polluting environmental impact of their activities. This, however, does not fully extend to the impact of the goods provided, associated with the high volume produced and/or the impact associated from energy and water use, or the use of non-recyclable materials downstream of the supply chain.

Industry recognises that a significant challenge to developing impactful measures is the **lack of a 'joined-up' engagement of the supply chain with other stakeholders up- and downstream on any focused and single aspect**, whether it be energy use, SUPs, packaging, distribution, policy and legislation or waste management. This has a notable impact on the ability to develop and create a circular economy. The development of a circular economy remains a major 'conceptual' challenge for stakeholders across the whole supply chain (*Figure 5*). Underpinning this challenge is a lack of 'understanding' for how any individual stakeholder can engage with the supply chain to create a circular economy and how these impact on a business model. These challenges are, thus, common and inherent to the whole supply chain and also specific to the development of a circular economy in oral healthcare.

Companies recognise the difficulty to ensure business models are both profitable and environmentally sustainable. The challenge is balancing sustainability attitudes with practical implementation. Setting and achieving bold commitments and targets is not easy work and, while balancing costs and priorities is a challenge, if done correctly it enhances the company's trust and value. Nevertheless, it is acknowledged that, despite the challenges, sustainability is increasingly one of the biggest priorities for corporate businesses.

Communication and collaboration are recognised to be both a challenge within the wider supply chain and an opportunity to drive change and find sustainable solutions and work towards a circular economy. The main recognised difficulties in this area are:

- The need to establish a sound educational baseline across the board that covers awareness, challenges and opportunities.
- The need to establish a clear focus and mission that all can unite behind.
- To date, most companies have focused on their own supply chain and are now at the beginning of the journey to engage suppliers; these can be very numerous and diverse, so the process requires time, infrastructure and data analytics to embed.
- A further challenge arises from the diverse understanding of sustainability, priorities and challenges held by the different stakeholders.
- Vertical and horizontal collaboration in the industry might have antitrust risks.
- Commercial sensitivity and risk of collusion limits collaboration as objectives, priorities and timings are not always aligned.

Challenges to 'a sustainable oral healthcare supply chain'

- There is a lack of recognition of the supply chain as a single entity, with each stakeholder working in a disjointed manner with little impact beyond the core business model.
- There is conflict between business models and sustainable practice. Some performance imperatives can sometimes be seen as conflicting with the need for improved environmental performance (e.g. investment and operational cost of reducing emissions and waste, minimising hygiene risks versus minimising waste – disposable versus reusable).
- The is an absence of collaborative work between stakeholders to manage waste generated upstream and downstream.
- The current lack of communication and collaboration between front-line services, suppliers and patients means that issues (e.g. waste management) are often viewed locally rather than across the whole spectrum.
- Stakeholders are working solely within the structure of their internal corporate responsibility or ESG frameworks and, in doing so, failing to engage more widely with the supply chain.
- The legislative frameworks for manufacturing, packaging, distribution and safe clinical care inadvertently hamper or challenge sustainability.
- It is a challenge to design and develop a product that is fit for purpose and at the same time environmentally sustainable. The concern focuses on the perceived higher costs and the possible need for consumers to pay a premium.
- Companies in the supply chain identify with the need for unbiased and open inter- and intra-stakeholder communication within the supply chain for effective collaboration on sustainability. This apparently simple premise is a challenge due to:
  - A perceived 'silo mentality' of some stakeholders with different maturity levels of understanding of key sustainability issues.
  - Short-term commercial interests make information sharing sensitive; the need to engage in transparency around common issues.
  - Lack of accurate and timely data that prevents agreement of KPIs and priority targets.
  - The need to establish networks and ways to collaborate that include the whole supply chain.
  - The need for a legislative framework relating to antitrust or other potentially anti-competitive or collusive behaviour.

Challenges to 'operating in a circular economy'

- Identification and implementation of a framework that engages the whole supply chain is difficult. This framework should be based on the creation of socially equitable funding models, infrastructure, culture and a sustainability mindset that will promote and permit practical recovery and recycling schemes.
- The environmental sustainability of products (and associated transport and packaging) entering and leaving the company within the supply chain is difficult to manage.
- There is a need to understand that neither providers nor customers wish to compromise performance for more sustainable options.
- It is important to engage all stakeholders, and in particular end-users (private citizens and professionals) with a sustainable culture with respect to healthcare provision. Healthcare is considered 'exempt' (by the general public) from sustainable practices under the perceived assumption that the pollution footprint from healthcare is an unavoidable consequence.
- There is a need to manage resources at every level of the supply chain (especially energy and water), and in particular the waste management of disposed waste products.
- There is a requirement for manufacturers to make products and associated packaging more recyclable, while ensuring appropriate recovery of these products for subsequent recycling.
- We need to understand and work with existing stringent legislation and healthcare laws that require medical products to be safe for the end-user: a factor closely associated with a litigation-averse culture. External legislation and internal ESG frameworks can sometimes be seen as a constraint rather than as an enabler, because they focus attention on compliance with specific 'legislated' issues only.

3 – Drivers

It is important to recognise the specific drivers that will encourage and enable individual stakeholders to make changes. Drivers are an enabling force for change and, like awareness, these can operate at the level of individual stakeholders and spread out to the broader supply chain. These are classified as generic, affecting the whole supply chain, or stakeholder-specific.

Generic drivers for a more sustainable supply chain

- Strongly established social ethical responsibilities within companies and the dental practices, which are also promoted at an individual level.
- Promotion of a positive image of the dental profession and supply chain in a world where environmental sustainability performance is a big contributor to a positive image.
- The need to establish strategic alliances with actively pro-environmental stakeholders up and down the supply chain and work to achieve significant benefits from full and comprehensive engagement.
- The status of the company on the world platform of commerce is very important to drive good practice through leadership and example. For example, one stakeholder stated:

  Our global reach, our understanding of the billions of consumers we serve, and our innovation capabilities give us a unique ability to make a positive difference promoting conversations, influencing attitudes, inspiring behaviour change and driving positive impact on society and the environment.
- The status of the company as a sector leader in sustainability is critically important to drive sustainability more widely, through education, knowledge and education, and a focus of inspiration.
- Stakeholder sustainable practice is key to maintaining staff morale, demonstrating that the company goes beyond being a commercial business enterprise and has a social consciousness that is real and impactful.
- Within the context of oral healthcare providers, there is a business driver for further engagement – 'Sustainability makes business sense for dentistry' [35].
- Company employees see the status of their company within the industry as an important opportunity to promote sustainability in the sector.

Drivers focused on the stakeholder

1. **Company employees see the drive to sustainability as a positive endeavour** rather than 'a box-ticking task'. This positivity is a strong internal driver that can be harnessed and used to good effect by the following actions:

- Promoting company sustainability leadership and the idea that both external as well as internal recognition are important to them.
- Reinforcing the perception that sustainability is a growth driver and that doing good (or being sustainable) is good for business.
- Empowering employees to be part of the change; helping them contribute and feel meaningful.
- Promoting behaviour change through education, supporting/praising engagement and recognising success.
- Engaging with employees to create a feeling of ownership.
- Proactively influencing and making a difference in everyday work.

2. **The strong local, regional, national and international pressures on all industries to improve sustainable practice.** Environmental sustainability is embedded in the operational ethos of companies, at a corporate and individual employee level. These are aligned with internal structures, corporate responsibility strategy or the UN SDGs [9]. This strong pervasive level of engagement is a major driving force for sustainable practice in companies, as part of the corporate 'mission' for companies.

3. **The increased levels of legislation aimed at protecting the environment, sustainability targets and awareness of a need to engage in sustainable practice or risk losing public confidence.**

4. **The 'lead' set by stakeholder companies that have implemented a series of key measures or interventions for improved sustainability within the company.** There is uniform agreement on the need to have a clearly defined and well-formed sustainability strategy that is considered essential, and should have the following characteristics:

- Being based upon sound data with specific targets. Targets should be achievable that are both generic and core to the company operation and the supply chain.
- Being designed to raise awareness (through education) and embed a sustainability culture across all functions of the company.
- Being designed to drive the quality of the engagement across the business.
- Promoting individual responsibility.
- Integrating sustainability throughout the company business with identification of areas of strongest impact.
- Building sustainability into the business growth strategic plan.
- Working in line with the UN Sustainable Development Goals [9].

5. **Improvement of oral health is a recognised key driver for environmental sustainability.** The provision of high-quality care with prevention at its core will deliver immediate and impactful environmentally sustainability outcomes. This will have an impact on end-users and across the supply chain, with notable reduction in CO_2 emissions and waste generation [8, 28].

4 – Opportunities

Based on the levels of awareness, a number of opportunities have been identified for engagement in sustainable practice. These are considered generically in this section and subsequently within each specific theme.

Environmental impacts – CO_2e, air and water

Companies have an opportunity to develop a carbon-positive supply chain by **identifying and engaging with opportunities that promote and implement a circular economy**, working with stakeholders and expertise to provide guidance, and seeking opportunities at both individual stakeholder level and as a 'joined-up supply chain – from mineral extraction to waste management', promoting, inspiring, helping and engaging upstream

and downstream with environmental sustainability, for example focusing on strategic decisions that have a clear ambition, product and materials expertise.

Opportunities for communication and collaborative engagement

All stakeholders identify the importance of effective communication, dissemination and participation, as key to keeping staff engaged and equipped with the sustainability ethos of the organisation (*Figure 7*). Reaching out to the whole workforce through sustainability champions, employee surveys and education programmes is considered an effective and motivational action for this objective.

Manufacturing companies (with competing business interests) recognise that they **can operate in an unbiased and non-partisan manner to promote open inter- and intra-stakeholder communication within the supply chain**. This is considered **essential for effective collaboration** that seeks to share knowledge, good practice and influence behaviour change. This can be achieved through:

- The leverage of the global footprint of commercial companies and partnerships to drive healthier habits for the planet. Especially related to promoting more responsible consumption of resources such as water and electricity and encourage sorting and recycling in the bathroom.
- A focus on specific areas that identify opportunities or a responsibility to act on brands with purpose, embedding sustainable business practices and improving healthcare and wellness outcomes as a company and through commercial brands. For example, harness the voice of commercial brands and via partnership with dental professionals and organisations.

Collaboration is a key opportunity to work towards a circular economy and have a true impact on sustainability. A key and acknowledged driver for positive societal and environmental change is the promotion of communication and being a positive influential role model to inspire behaviour change. Nevertheless, such a collaboration requires:

- Active and strategic collaboration and clear procurement policies with clear key performance indicators (KPIs) and matched expectations.
- A collaborative approach to distribution and use of products that focuses on energy, water efficiency and reduction.
- Building the mastery, incentives and the means to adopt more sustainable practices with regard to materials, renewable electricity in operations, diversity and ethical practices across sourcing and manufacturing, etc.
- Analysis of need through a materiality assessment and SWOT or similar analysis.
- A clear, focused effort on reducing the carbon footprint.
- Transportation, end-of-life and choices of material alongside ensuring safe and fair working conditions.

Companies should contribute resources to collaborative partnerships to drive sustainability; these may be:

- Knowledge, expertise and research.
- Expert resources: human; communication, materials, consumer behaviour; logistical learning/scale.
- Funding (to the extent that it is feasible and makes sense for the business).
- Partnership and ideas. Companies understand their challenges and can work with other stakeholders to provide new points of view and solutions.
- Education, communication, engagement, support.

Figure 7: Collaboration with effective communication, dissemination and participation is essential to promote environmental sustainability. ASDF_MEDIA/ Shutterstock.com, 2022.

Leadership in good practice

Acknowledge that established and reputable companies are well placed to provide strategic sustainability leadership. Companies have the capability to engage with the end-to-end supply chain, to identify and improve sustainable operations with impactful outcomes. For example, the promotion of awareness and activities through comprehensive and targeted education programmes; the establishment of partnerships to drive change and find sustainable solutions; and working towards a circular economy.

The manufacturing industry can promote wider engagement with all stakeholders, so that, for example, end-users can influence product design choices or for legislators to design better regulations. For this, the manufacturing industry needs to lead in a proactive manner and convene discussion and events to raise its profile and drive decision-making. The aim of this is to gain a common understanding of how the whole loop needs to be closed in order to reach sustainability and that everyone has a role to play.

Upstream suppliers can share innovations across the whole supply chain. Companies and their suppliers can share ideas and improvements across the whole supply chain in a more effective manner in some of the following ways:

- Through trusted partners and trade associations, for example CGF, EMF, EPR, RSB and WRI (see *Glossary*).
- Helping suppliers understand and define goals for themselves.
- Engaging, discussing and finding mutual positive feasible business value.
- Establishing closer dialogue and networking.

Opportunity for engagement across all sectors with practical and impactful solutions.

- Obtaining baseline measurement of individual stakeholder carbon impact, to identify opportunities and to enable activities that will reduce this.
- Rewarding engagement and impact through awards.
- Establishing 'supply innovation centres' to serve as a hub for collaboration with networks of local suppliers, technology companies, R&D institutions and high-ranking universities to develop solutions to decarbonise our global supply chain.
- Establishment of internal sustainability 'road maps' towards net zero carbon that will indicate a practical, prioritised, challenging and impactful route.
- Reducing the impact of patient travel through (i) the promotion of prevention that results in improved oral health and a reduced need for complex procedures; and (ii) improved patient care logistics at the point of care delivery [28].
- Leverage of end-users (dental professionals, patients and consumers) as part of the solution to drive positive change.

Ethical responsibility

Each stakeholder organisation and individual person should realise that every sustainable practice, however small, will have a net positive environmental impact. This is the concept of *cumulative incremental gains*. Each action is multiplied by the millions of oral healthcare providers around the world and across a population of nearly eight billion people as end-user consumers of oral health products. Nevertheless, there is a recognition that, owing to global inequalities, not every person is a direct consumer and the true figure will probably be lower, but still significant. Each sustainable practice undertaken at individual levels will act as a seed and catalyst for engagement with further more impactful practices in a snowball fashion.

Routes to sustainability in oral healthcare

Sustainability in oral healthcare can be through different routes, ideally considered in a collective and synergistic manner. Any potential action strategy needs to be based on a sound understanding of the existing levels of awareness among the various stakeholders and the inherent challenges that exist, both in the systems they

represent and in the supply chain as a whole. Equally, there is a need to understand the factors that drive any change and the opportunities that exist, to enact positive sustainability actions.

This section presents the various routes to sustainability, as identified in a recently published two-part comprehensive scoping review [6, 7]. Each route considers (i) factors and levels of *awareness*, together with the *challenges* that we need to overcome; and (ii) the *drivers* and motivators to make the required changes together with the *opportunities* that exist to make such changes, even if these are not overtly evident.

Routes to sustainability in oral healthcare:

- Route 1 – Reduce, reuse, recycle and rethink
- Route 2 – Legislation, policy and guidelines
- Route 3 – Waste management
- Route 4 – Procurement and logistics
- Route 5 – Research and education
- Route 6 – Materials for clinical use

Route 1 – Reduce, reuse, recycle and rethink

Awareness and challenges

Reduce, reuse and recycle are the central sustainability tenets that enable a circular economy (*Figure 8*). The fourth R, 'rethink', enables us to consider alternative opportunities to engage in a reduction of our environmental impacts.

There is a need to engage with these concepts at each point of the supply chain, from manufacturing to waste management. In this context, **the greatest areas of conflict are manufacturing, packaging and end-users (clinical or consumer)**. Additionally, engagement is not consistent across the industry, with varying levels of commitment.

Manufacturers have a key role in the design of products with reduced manufacturing waste, promoting high-quality and durable products that are fit for purpose with built-in end-of-life management strategies.

Packaging is the single largest contributor to plastics in the dental industry as the product travels down the supply chain to the dental surgery and end-user, with the majority (>90%) disposed of as waste for incineration or landfill [36]. The dental industry is a net contributor to this problem and has a duty of responsibility to act with global and national movements to reduce this (e.g. the UK Plastics Pact has set targets for 2025 with the headline of 100% of plastic packaging to be reused, recycled or compostable [37]).

There is a recognition that the **established strategies of reuse, reduce and recycle cannot be readily applied to the end-user** (either as a clinician or consumer), **creating an opportunity for 'rethink'**. The contaminated nature of used products and the complex shape and construction of many devices makes it impossible or very costly and difficult to clean, disinfect and sterilise, or recover for recycling. Plastic devices, for example, are often assembled from multiple polymers in multi-layer constructs and combined (glued/welded) in complex shapes, making them difficult or impossible to disassemble. There is a need to raise awareness of the actual number of SUPs that is generated at the point of clinical provision. A recent study conducted in the UK has identified a mean of twenty-one (n=21) SUP items utilised in every routine adult primary care dental procedure, with a mean mass of 354g per procedure. This figure can be extrapolated to a conservative estimate of approximately two billion dental SUP items per year (14.4 tonnes) [38]. The additional PPE required during the COVID–19 pandemic increased this figure to approximately 2.4 billion SUP items (27 tonnes) in the UK. Further studies of this type are required in alternative settings to obtain a clear baseline and to help inform remediation strategies [32, 38, 45].

Figure 8: Reduce, reuse and recycle are central tenets of an environmentally sustainable circular economy. Superstar/Shutterstock.com, 2022.

Recycling as a basis for a business model is a significant challenge that needs resolving. There is a (real or perceived) conflict or lack of understanding of the value of using recycled materials and alternative distribution practices that are considered to be more costly or challenging to implement than virgin raw materials.

Most oral health companies have an established or an emerging strategy for recycling and for the use of recycled materials. This is considered a core measure of a company's overall sustainability strategy. Measures include:

- Creating a roadmap with fixed targets in the use of recyclable, reusable or compostable plastic packaging.
- A reduction of the use of virgin plastic in products, packaging and marketing material (where safety and quality allow).
- Actively exploring use of recycled materials and circularity.
- Establish external alliances etc. to find solutions that improve effective recycling at scale.
- Develop corporate-level EHS management systems that will help define, implement and drive strategic improvement.
- Support and commit to the principles of organisations and alliances that seek a reduction of plastic use (e.g. the Ellen MacArthur global commitment [39]).

A 'reduction approach' focuses on **a reduction of demand, which can be achieved through a promotion of better oral health focused on disease prevention and the provision of high-quality interventions** that do not require revising [28]. This model is an excellent fit for oral healthcare, which has a number of validated prevention protocols that can be successfully delivered as a public health initiative, professionally within the dental practice setting or by the individual at a patient-centred level. Alongside this, the use of high-quality, effective and durable oral healthcare products should be promoted as a more sustainable option, especially if recovery and recycling of waste are built into the product as part of a circular economy.

From a clinical perspective, there is a clear realisation and agreement that **sustainable practices can have a positive effect in developing and delivering successful business models**; a strong, pro-sustainability company image and sustainability strategy influence a strong positive customer response as consumers/patients increasingly consider and prioritise environmental sustainability.

Consumers also play an important role in both the effective and safe use and the disposal of products in a responsible manner. This requires grass roots educational programmes that emphasise citizen responsibility and the inherent value of a used product and its associated packaging.

Drivers and opportunities

As per the United Nations' waste management inverted pyramid [40], **source reduction and recycling are the most preferable options**. In this context, the main drivers for the oral health supply chain are through engagement with reduction combined with recycling (pre- and post-clinical contamination) (*Figure 9*). Reuse is not considered a viable option for SUPs that arise from primary packaging or clinical waste.

The concept of 'rethink' encourages us to consider how we can embrace reduction and recycle to overcome the inherent challenges that this presents in the oral healthcare industry.

There is a need to critically consider and implement a reduction approach combined with innovative recycling approaches for every pre- and post-clinical setting (manufacturing, distribution, end-user and waste management).

Opportunities for companies

Engage fully with recycling opportunities with other stakeholders in the supply chain. This must be done as a partnership and is considered an essential component of finding sustainable solutions. A materiality assessment and SWOT or similar analysis will help manufacturing companies understand where this type of activity fits within the overall strategy.

Focus on reducing plastic waste, mainly single-use but also non-recyclable longer-life items. It is essential to establish, through strong research, a powerful knowledge baseline of data at industry level that will enable impactful solutions.

Undertake a systemic analysis of packaging needs and the elimination of unnecessary wasteful packaging that works its way downstream.

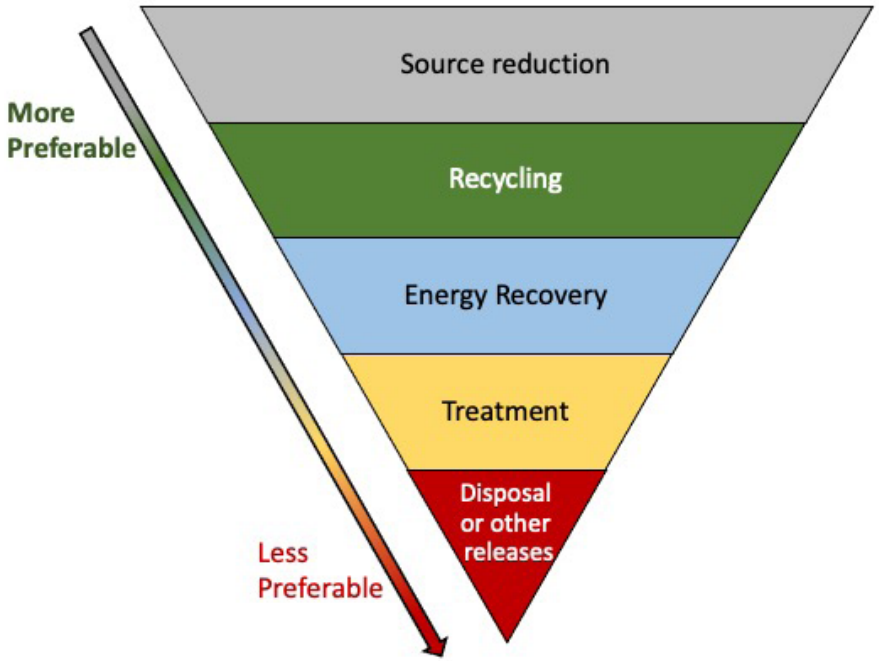

Figure 9: Inverted pyramid for waste management (adapted from the original publication – UNEP, 2013). Copyright Nicolas Martin, Sheffield, UK, 2022, Sheffield, UK, 2022, CC BY 4.0.

Increase our knowledge base, with a specific focus on:

- Identification of the biggest contributors, within companies or supply chain, to plastic waste and encourage new technology to reduce this.
- Understanding the consequences of replacing a material with another and the impact that this will have. In this context, understanding the complexity of plastic and the difference between, for example, bioplastic, biodegradable plastic and fossil-based plastic from an LCA perspective and comparing this to the alternative replacements.
- Understanding how plastic products and/or associated containers/packaging are used today. Identification of essential versus superfluous plastic that can be eliminated.
- Identification of the benefits of recycling for specific items in terms of net carbon footprint.
- With a focus on 'essential' plastics, identification of the resources that need to be put in place to drive an improvement of the sustainability profile.
- The need for funded schemes that collect and process 'hard to recycle' materials. In this context, collaborate with the recyclers to make it scalable and financially viable.
- Consideration of alternative materials to replace current ones, such that they can be produced at scale and have a genuine sustainability benefit versus current ones.
- Working with the supply chain to develop and impact recycling of plastics from packaging and clinical use.
- Education to inform about waste management and take plastic waste to a circular economy to prevent it from ending up in landfill or incineration.

Understand that the different supply chain stakeholders (e.g. manufacturer, distributor and end-user) **have a shared and equal responsibility to collaborate in recycling strategies for a circular economy.** This should be achieved through:

- Engagement with stakeholders in the supply chain to add value to waste plastic packaging.
- Full cooperation across the supply chain to improve recycling/recyclability. All stakeholders must take responsibility and collaborate to find sustainable solutions, e.g. the design and development of plastic items made from single plastics that can be readily recycled.

- Engagement with end-user consumers and waste management companies to segregate, collect and recycle clinical SUPS as a valuable commodity.
- The establishment of shared rules/specifications are key for all to participate.
- The establishment of a 'supply chain lead' in this process.
- The provision of sufficient resources and funding to manage and maintain the model.
- The establishment of a baseline knowledge analysis, through LCA, with the engagement of suppliers, distributors and end-users.

Opportunities for end-users: clinicians, patients and consumers

Reduction is best achieved through the delivery (by clinicians) and maintenance of good oral health, focused on prevention and high-quality interventions [8]. This approach focuses on a reduction in the need for restorative consumables and interventive care appointments at the patient end-user level. This reduced demand can be achieved through a promotion of better health focused on disease prevention coupled with the provision of high-quality interventions that last longer and do not require revising. It is important to note that effective preventive care clearly has an environmental burden, but this is lower than that of failing dentition requiring continuous rehabilitation and supportive maintenance. The whole supply chain, including the end-user patient, benefits through this with a direct personal and environmental benefit.

There is a requirement to understand the need to contextualise challenges and opportunities for plastic use and recycling, according to the local geographical and societal framework. Focus should be made on plastic across the whole supply chain and not only simply oral hygiene products that use plastic. A local assessment on what is achievable is required to identify what will have the biggest impact in the different world regions or countries [27, 41]. A global code of good practice should make adjustments for global regional variations to ensure that it is practical and achievable.

There is a need to create socially equitable funding models that will promote and permit practical recovery and recycling schemes. The social aspect of managing plastic waste is key to achieving a circular economy. The recent Flexible Plastics Consortium activity is a good example of progress in this respect [42]. Nevertheless, there is also an acknowledgement that it goes beyond funding to include other elements such as infrastructure, culture and a sustainability mindset.

The 'supply and demand' nature of the supply chain provides consumers and end-users (dental professionals and consumers) **with an opportunity to influence and demand products and services** that encourage more environmentally positive solutions.

Route 2 – Legislation, policy and guidelines

Awareness and challenges

There is a clear recognition of the **requirement for all stakeholders to operate within the boundaries of legislative regulation for the safe conduct of operations and the goods produced or services provided**. These frameworks vary in their remit and across governmental authorities, from guidelines to legally enforceable laws. This legislation principally focuses on the avoidance of hazardous practices and products. The requirements to manage pollution arising from energy consumption or product waste (packaging at all levels and the item itself) is mostly not considered.

Current regulations governing products and services may be perceived to be a barrier to the implementation of sustainable practices. There is a recognition that this needs further scrutiny and direct engagement between the industry and the legislative bodies at global and local level.

Products are heavily regulated at a national and international level, to ensure their safety at the consumer endpoint, with little regard to the environmental impact of this type of policy. There is an increased recognition of the need to adapt legislation to find common ground between these conflicting priorities.

Stakeholder companies have a real or perceived lack of control over legislation and regulations. Specific identified issues are:

- A lack of a forum that enables discussions and engagement with policy regulatory bodies, end-users and other stakeholders up- and downstream.
- Conflicting regulation for the promotion and enforcement of different aims – this is a recurring issue and also identified as a challenge to the creation of circular economies.
- Lack of coherent legislation for:
  - The sourcing of materials and failure to place sufficient pressure and resources on the procurement and use of sustainable and responsible sourcing of biomaterials and fuels.
  - The management of waste in the clinical sector; this discourages the environmentally conscious management of clinical waste.

New legislation/regulation represents both a challenge and an opportunity for the industry. For example, the European Commission is working on 'A European Green Deal' [43], a set of policy initiatives with the overarching aim of making Europe climate neutral in 2050. Industry needs to embrace this type of legislation and consider how it can optimise the required resource investment to maximise sustainability outputs in other company-specific sectors within its own product supply chain.

Legislation is considered a driver and a barrier. Some organisations use legislation as a protective blanket that justifies and excuses their inability to engage with sustainable practices. For others, stringent legislation with polarised frameworks (e.g. extreme, often illogical, patient safety measures at the expense of sustainability) is a source of frustration that serves as a deterrent to engaging with sustainable goals.

There is an agreed position among industrial companies that **legislation and/or regulation may be effective to incentivise sustainability and catalyse organisations to move in a positive direction.** In this context, legislation or regulation can work to level the playing field across the industry to ensure that all stakeholders operate to an accepted minimum common standard. Nevertheless, there is a need to be mindful of setting artificial boundaries or incentives relating to a relatively small number of sustainability aspects that could possibly hinder sustainable development in some areas of the supply chain.

Regulatory and legislative decisions should be based on knowledge ascertained through the development of a standardised robust methodology of lifecycle analysis that considers the broad array of variables and their interaction to improve sustainability. In this way, a robust and standardised LCA methodology should provide a more quantitative way to understand the sustainability of a component, product or company.

Drivers and opportunities

Policymakers and legislative powers need to clarify new regulations and legislation to remove or reduce apparently conflicting drivers. There is a conflict of interest between legislation that drives safety and the need to achieve sustainable targets. There is a recognition of the need for legislation to drive change, as profit remains the priority for businesses.

Legislation should act as an advocacy tool, to support sustainable practice by incentivisation, rather than limit it through regulation. In this context, legislation should seek to drive compliance and public advocacy through trade associations, rewarding best practice and informing public policies, but with care not to stifle innovation and other forms of sustainable development. As stakeholders, operating in different world platforms and settings, we need to be mindful of the different regulatory frameworks across countries and seek opportunities to translate good practice from other arenas, to influence and raise standards as appropriate.

The provision of incentives in the form of financial impact toward compliance of more sustainable practices would be a desirable framework that can be both carrot (preferred) and stick in nature. This would drive supply chains to comply with sustainable practices and rewarding those that take leadership in this space. Legislators will also play a role in convening public and private sector to define standards of compliance.

Effective partnerships in the industry can promote research and harness best practice research models (e.g. standardised and robust LCA methodology). This will inform legislation to improve industry sustainability profile without compromising on oral health outcomes. In this context, the implementation of common policy is considered an opportunity to guide businesses and professionals to understand the value and benefit of sustainability.

There is an opportunity to work with legislative authorities to **promote and drive a requirement for the procurement and use of sustainable and responsibly sourced of biomaterials and fuels**. Forging alliances with expert organisations, such as the Roundtable on Sustainable Biomaterials (RSB) [44], would catalyse this.

Legislation can help drive progress across companies, industries and countries and also across the supply chain. Having a common (and clear) legislative framework across world regions/continents for example (instead of different regulations per country) could be very helpful for the industry.

Driving policy advocacy through trade associations can play an important role in promoting best practice, informing public policies and regulations and developing industry standards.

Route 3 – Waste management

Awareness and challenges

Waste is generated at all points of the supply chain: during mineral extraction and chemical synthesis, product manufacture, packaging at all levels (primary, secondary and tertiary) and end-user consumption. The high prevalence of single-use products (mainly plastics) and the increased use of PPE adds a huge burden to this [38].

Biomedical (contaminated) waste originates downstream with the oral healthcare professionals, patients and end-user consumers. **An increase in the prevalence of infectious diseases coupled with much greater patient safety awareness, infection control measures and associated regulation results in a significant increase in the quantity of SUP solid waste generated** (e.g. plastic barriers, gloves and masks) in the oral healthcare industry. This is a widely recognised problem that is poorly addressed.

Each stakeholder in the supply chain has a dual responsibility: to manage their own waste and the waste that is 'passed on' downstream of the supply chain. There needs to be a recognition of this duality of responsibility, which currently does not exist as waste that is passed downstream becomes the responsibility of the end-user. There is a recognised complexity associated with the governance of clinical waste management, which varies between jurisdictions.

Plastic packaging and single-use plastics (SUPs)

Single-use plastic forms an essential and indispensable part of current healthcare provision at all levels and in all clinical environments (*Figure 10*). Plastic provides a very safe and cost-effective material for packaging and products that can be combined with other materials to create complex bespoke devices or medicinal delivery vehicles. In doing so, SUPs provide the required clinical and public confidence of using a new clean and/or sterile device every time without risk of cross-infection. Thus, SUPs fulfil all the major requirements of a risk-averse industry that operates within very tight budgetary constraints and tight regulatory frameworks. The inherent versatility, safety and low cost of SUPs is also its downfall as it is a major contributor to a highly wasteful linear economy resulting from their end-of-life fate [32, 45].

Figure 10: Plastics are essential for the provision of safe oral healthcare in clinical environments. Superstar/Shutterstock.com, 2022.

There is a recognition that the **reliance on SUPs creates a wasteful linear economy**, with a need to reduce their use and reliance on fossil-based constituents. **There is a need to transfer healthcare plastic from its current status of a low-value commodity in a wasteful linear life cycle to a circular life cycle as recycled, valuable feedstock for the synthesis of new plastics.** Thus, there is a need to plan for circularity as the bigger goal with full stakeholder engagement and to understand that recycling is a component of this, but not the end point.

Plastic packaging in the healthcare sector is considered a difficult challenge to address, primarily because it is a highly regulated sector to ensure that medical products arrive fit for purpose (protected from damage or degradation, and frequently sterile).

Plastic packaging (at all levels) is considered a zero-value waste product at the point of manufacturing and throughout the supply chain, rather than a valued commodity that can be recovered and recycled as feedstock for new devices. Moreover, the sustainability of the packaging is not challenged as the product moves downstream until disposal. The result is a linear business model, disconnected with respect to reducing plastic waste, hindering disruptive innovation and limiting the potential to deliver a circular economy model to reduce environmental impact.

Stakeholder companies recognise the need to drive a reduction in the use of single-use plastic materials (packaging and consumer products). They identify the following specific challenges to achieving a circular economy.

Challenges to achieving a circular economy through recycling and the use of recycled materials

- End-user SUPs are assembled in multi-layer constructs from multiple polymers and combined (glued/welded) in complex shapes that are very difficult/impossible to disassemble. Thus, reusing and recycling are not currently considered viable options for the management of this clinical waste stream in healthcare.
- There is a lack of collaboration among supply chain stakeholders for the development of plastic items that can be easily recovered and recycled.
- There is an overall lack of effective and efficient collection infrastructure globally. This is especially so for different recycling streams that selectively target specific materials (e.g. tubes).
- Different regulations exist in different markets for handling of waste, adding complexity.
- The economics of recycling needs to fit into the companies' business models.
- The need to ensure that constituent chemical components from primary containers/packaging do not interact or affect the product.
- Safety requirements on medical devices – there is a need for food-grade recycled materials, which are not available at scale and are in competition with other, larger industries, such as the food industry.
- The need to promote positive end-user (private citizen) consumer habits and overcome current low engagement with sorting and separating bathroom waste products (i.e. toiletries and personal healthcare products).
- There is a lack of global recycling capability that will provide recycled high-quality plastics in the required volume.
- Maintaining patient services and safety during the COVID–19 pandemic has moved the focus from the environment, which may have long-term impacts.
- Regulation and legislation are focused (at the exclusion of many other considerations, including sustainability) on high safety standards for the end-user.
- There is a need to consider the environmental impact of single-use metallic instruments that could potentially safely be reprocessed/sterilised. This needs to be considered from the perspective of manufacturing quality, safety profile and regulation.
- Inadequate knowledge and lack of motivation towards the management, generation and disposal of biomedical waste across the world, and in particular in LMICs.
- Downstream users need to understand 'materiality' as it is necessary to ensure clarity of focus and effort on the most important aspects that require action to achieve impactful sustainable goals. Materiality assessments help to avoid wasted resources, time and effort on non-material aspects. In essence, an effective assessment may show varying materiality between aspects in different areas of the supply chain, suggesting that an assessment of each individual area that identifies the most common key aspects may be a good approach.

Drivers and opportunities

There is a need to set plastics use in a broader perspective. **The solution is not just about eliminating plastic but understanding the use and ability to recycle the different kinds of plastic in use and their possible replacements.**

There is a need to educate the public and the profession about the merits, usefulness and indispensability of plastic in the healthcare sector.

Oral healthcare manufacturers can work with the plastic synthesis suppliers in the design of feedstocks and materials that meet safety, quality and durability requirements and can be accepted by recyclers.

Oral healthcare manufacturers should seek to work with end-users to identify ways of reducing the generation of medical waste and subsequently with recyclers on technologies that enable drive effective recycling.

There is an opportunity to reduce (unnecessary and excessive) packaging waste, ensuring that this is recyclable with appropriate drop-off downstream facilities.

The most effective way of reducing SUP waste is through the **promotion of good oral healthcare through preventive regimes and high-quality interventions**.

Recycling pre-clinical plastic waste (products and packaging) that arises from manufacturing and distribution **prior to being contaminated by end-users**.

The supply chain, acting as a single entity, can help to manage the waste generated by end-users (the general public or the oral healthcare profession), with a focus on materials reduction, optimised transport and distribution logistics and recycling packaging materials. Also, assuming safety requirements can be met, a reverse supply chain would enable used products and packaging to travel back to manufacturers for processing into new products.

Opportunities for management of SUPs should focus on overcoming the challenges listed. Further opportunities include:

- Unlocking the barriers that exist at each point of the supply chain, changing systems and behaviours at a local and systemic level, and coupling waste management to innovative solutions for reprocessing.
- Following a more desirable SUP circular economy that focuses on a reduced consumption of finite resources (such as oil-derived plastics) that designs 'plastic waste' out of the systems.
- Defining plastic waste as a resource that is part of a circular economy rather than waste.
- Including core knowledge on plastic, its forms and recycling opportunities to enable stakeholders to make more sustainable choices when using it (for example, if it is fossil-based or bio-based, or a combination of the two).
- Accepting joint and shared responsibility for the management of this waste with all sectors of the supply chain, including the recycling industry.
- Establishing collaborative partnerships and communicate effectively with peers, NGOs and other stakeholders that will drive and enable innovation and new designs, build infrastructure and secure quality recycled plastics.
- Influencing consumers' mindsets, but with the required infrastructure in place that enables the consumer to act in a responsible way.
- Developing a fully circular supply chain that can handle small-format items at commercial scale.

Route 4 – Procurement and logistics

Awareness and challenges

Each stakeholder of the supply chain has a significant impact on the environment through the process of procurement of raw materials, manufacture, transport and distribution.

Procurement is considered a major environmental 'hotspot', with the use of plastic packaging central to this. The complex distribution and logistical requirements required to access locations with poor or limited civic infrastructure compounds this problem significantly, as is evident in LMICs.

Companies are actively engaged and provide environmental leadership across supply chains. Historically, this engagement has been downstream, but increasingly companies are extending their reach across the value chain, upstream to suppliers and downstream to consumers.

Sustainable manufacturing and distribution of goods is generally considered less associated than conventional (less sustainable) practices with higher overheads. The rationale for this is that the sustainable option may have high upfront costs for implementation but more sustainable processes tend to have lower ongoing costs (and this is likely to be more the case in the future). Also, once the investment is made and assuming availability of more sustainable materials, manufacturing and distribution processes should be pretty similar to the existing ones including economies of scale. In the future, the cost of being less sustainable could be much greater (when considering the impact of producer responsibility liabilities).

Efficient procurement and distribution present a particular problem for the dental profession. With the exception of large multi-practice corporates, most dental practices around the world operate as small discrete entities to meet the needs of their local population. They have very limited storage facilities, relying on daily deliveries and collections. This results in increased distribution costs involving many journeys, contributing further to CO_2 emissions. There is need to consider whether the existing model of dental care is effective or whether larger centres with optimised distribution logistics, storage and dedicated transport links is a more efficient concept from a patient care, financial and sustainable perspective.

Environmentally sustainable procurement is not understood well at the level of dental practices. There is a need to provide educational programmes to enable smart purchasing/procurement. For example, the benefits of bulk buying would include less packaging, shared distribution costs and lower emissions from distribution.

Distribution logistics to the end-user is disjointed and wasteful of resources. There is an opportunity for companies to collaborate in optimisation of distribution logistics.

Drivers and opportunities

Each stakeholder needs to engage through proactive intervention in environmentally sustainable practices to disrupt the linearity of the supply chain and achieve a circular economy.

There is a need for **the supply chain to come together as an entity to develop less cumbersome systems and processes with improved logistics capacity that has sustainability as a key driver**, which will result in an improved circular economy. Examples of this are:

- Including sustainability as a factor for the selection of vendors.
- The use of efficient distribution and procurement logistics with shared facilities.
- Collaboration on logistics between competitors with more unification on warehousing and transport of products to save journeys and transport.

Sustainable operations are a business opportunity for companies, with the following potential benefits.

- Sustainable operational sustainable practices with increased efficiency require less energy, water and distance travelled, and produce fewer CO_2 emissions and waste, which results in cost savings.
- The production of better, more sustainable products and highlighting this through increased consumer engagement produces product loyalty.
- Sustainably marketed products have grown much faster than traditionally marketed products (e.g. car manufacturers offering hybrid technologies).
- Investing in sustainable solutions can/should result in smarter production and eventually lower energy consumption.

Sector leadership, stakeholder collaboration, sharing best practice and engagement in 'procurement summits' that are led by major product manufacturers. These provide an opportunity for supplier engagement, identifying an opportunity to work with suppliers and improve their awareness, understanding and improving levels of engagement. Such summits should work in both directions and consider not only the 'transmit from the buyer' perspective but also the 'receive from the supplier' viewpoint.

More efficient oral healthcare service models must be considered that meet the needs of the population, through the provision of effective patient-centred care with environmentally sustainable gains. This service should aim for the provision improved logistics with less transport of goods, reduced commuting for the professional workforce, reduced patient travel journeys and less packaging. Thus, implementation should focus on:

- Effective workforce planning.
- The nature of the target population (e.g. schools, care homes, population hubs…).
- The provision of core care principles (prevention and screening).
- Travel for providers and patients.
- The structure of the facilities.
- Collaborative engagement with industry for logistical support.
- Reduced packaging.
- Effective waste recovery/recycling.

Need for greater levels of information on the sustainability credentials of a product. This will provide the buyer with information on the environmental sourcing, ethical manufacturing, supply chain distribution and procurement.

Route 5 – Research and education

Awareness and challenges

Research

There is a clear need for primary research into all aspects of our industry, which should seek to provide efficient, high-quality durable products and services that are both fit for purpose and environmentally sustainable. Sustainability research is required to include the manufacturing of dental materials, distribution and procurement logistics, and provision of clinical services, with a focus on prevention and reduced patient-centred activity, patient care pathways, remote consultations and waste management options. For example, the last edition of the WHO–UNEP report *Future Use of Materials for Dental Restoration* (2009) highlighted the paucity of science around the toxicology and ecotoxicology of materials for dental restoration and that dental materials research is not a priority [46].

There is an increasing **awareness that the ability to combine effective oral healthcare, disease prevention and sustainable practices can only take place through strong and impactful research** that considers the various challenges and strategies [6, 7].

Education

There is a growing recognition across the sector of the **need for educational programmes at all levels, both within each stakeholder organisation and across the supply chain**.

There currently exists **very good practice of industrial manufacturing and distribution companies collaborating with educational providers** for the benefit of the profession and the public.

Higher education providers (universities, colleges, dental societies) **have a responsibility and an opportunity to integrate sustainable practices into their educational models.** There is a growing recognition of the need to urgently raise awareness of sustainability at the formative stage of individual's professional education. This requires the integration of concepts and remediation strategies in the undergraduate curricula of dental education, with current important pioneering work highlighting academic progress and student representation [47, 48, 49].

There is a recognition of the **need to balance the drivers for engagement as being both economic and health outcomes**. In essence, sustainability awareness and engagement should be taught as key aspects of running future dental practices. Tied into this, alternative care models with a focus on prevention and screening should be core to the future activities of the profession.

The same WHO–UNEP report, *Future Use of Materials for Dental Restoration* (2009), also highlighted that the study of environmental and occupational health is not a requirement in dental professional undergraduate

education and training and continuing professional development. As a consequence, **dental professionals lack the knowledge and training to provide science-based information to support and engage with environmentally sustainable practices**. This needs to be addressed and changed.

There is a low level of understanding of the value of recycling at all levels of the supply chain, principally associated with packaging and end-user clinical waste. This low-level knowledge base is counterbalanced by a **strong recognition of a need for education at a corporate level to achieve more cooperation and collaboration at all levels within the company and with other supply chain sectors**.

The challenges lie with 'educating' each supply chain stakeholder as an individual entity and as part of the whole chain problem. Specifically, there is a need for:

- The development of educational syllabi (or educational guidance) that can be used and targeted for specific stakeholder groups at all levels.
- The integration of sustainability into educational (awareness and knowledge) curriculum for dental practitioners.
- An increase in consumer empowerment to drive green oral healthcare products. Greater recycling rates of consumer end-users (e.g. promote better management of bathroom waste plastics).
- The use of educational programmes to overcome human factors and attitudes that remain a strong barrier to changes in sustainable practice.
- Stakeholders to understand the benefits of sustainability for themselves. This is a hugely marketable commodity for practices through increased efficiency and clinical success through alternative workflows.

Drivers and opportunities

Sustainability works hand in hand and synergistically with the core principles of good-quality oral healthcare. Thus, the central pillars **for sustainable patient-centred oral healthcare are one and the same: prevention and the provision of high-quality care** [8]. It is important that these umbrella principles are not used as a tool to discriminate against elements of society that suffer from non-preventable diseases or are unable to engage with effective prevention practices. Not all diseases are preventable in nature and high-quality care is not available universally, especially in LMICs. Appropriate care should be provided for the management of all oral diseases, even if considered unsustainable. The key messages should focus on disease prevention regimes and sustainable oral hygiene practices at home.

Educational programmes need to raise awareness of the connection between oral health and overall health, promoting better education and access. Hence, there is an **opportunity to raise awareness of highly impactful sustainability gains through the promotion of healthy oral healthcare for preventable diseases**. Consideration should be given and improvements made to how oral health preventive regimes are remunerated in the healthcare system, akin to a medical appointment where payment is made for a consultation and advice or medication. In this context, stakeholders should be aware that **there is a series of 'low hanging fruits'** (measures that are important and easy to achieve) **that can drive and act as precursors for greater engagement** (e.g. FDI sustainability infographics) [28].

Within the context of oral healthcare providers, there is recognition that **sustainability is a strong driver for successful clinical practice business models** [35] – 'Sustainability makes business sense for dentistry.' An effective business model can be a powerful driver for sustainability with the added financial incentives. This model requires an appreciation for:

- Stakeholders to understand the benefits for themselves. Sustainability is a hugely marketable commodity for practices.
- There being scope for increased efficiency and clinical success through alternative workflows.
- The need to align outcome measurements to prevention.
- The requirement to shift from a focus on current clinical pathways, with the adoption of new servicing models that avoids inequality. A focus on prevention is needed.

Company stakeholders

There is an acknowledgement that **the dental industry is an influential driver and provider of professional education, which needs to include sustainability**.

Within companies, there is a **need to increase awareness, understanding brand/company loyalty and motivation of the workforce**. In this way, it is important to **foster an employee community that cares deeply about the impact of their work on the environment**.

Engage with all supply chain stakeholders through the voice of commercial brands and via partnerships with dental professionals and organisations. In this way the education and advocacy for the adoption of healthy oral care habits can be facilitated on a global scale.

More broadly, there is an opportunity to **engage in open and active discussion forums in all work environments that will encourage the translation of behaviours** (as private citizens) to established well-rooted attitudes in the workplace – there is a need to *normalise* conversations around sustainability in the workplace. This requires stakeholders to support activities that seek a change of mindset and behaviour, creating increased awareness, knowledge and engagement.

Supply chain stakeholders have a responsibility to find and leverage more sustainable alternatives in their area of influence. In this context, manufacturing companies should design and manufacture products that are more sustainable (recyclable, without excess and unnecessary packaging and the use of alternative sourcing for materials, seek ethical sourcing etc.) and work with others to develop solutions to make new products more sustainable.

Companies have an opportunity and responsibility to engage, promote and resource impactful research activities in the field of environmental sustainability. These could include the need to:

1 identify research gaps through scoping or mapping exercises;
2 identify and leverage more sustainable alternatives in their area of influence;
3 generate actionable data for industry;
4 enable innovation and progress;
5 identify and support feasible sustainable business practices.

Companies see an opportunity to **support knowledge transfer** from sound research and innovation in structured programmes delivered to other stakeholders, including end-users.

There is agreement across the supply chain over the **need for a science-based approach to sustainability interventions, adoption of best-in-class and sharing of best practice across the sector**, which may be based on experience as well as research.

The inverted pyramid for waste management, with reduction and recycling as key priorities, should act as a point of discussion and engagement at all levels, in research, knowledge transfer and core educational programmes.

End-users: clinicians, patients and consumers

Within the supply chain, healthcare providers are a key 'end-user', considered to be a major driver that can influence other stakeholders. In this respect, there is a strong awareness of the **need to influence business models on the economic value of sustainable practices and as an increasing requisite for positive and profitable business**.

There is a need for education of the entire dental practice, including reception staff, nurses, assistants, clinicians and patients as active co-participants in their care. Proactive patient engagement with preventive regimes is essential that will result in healthy oral health with low environmental impacts (low use of resources, low carbon footprint and low waste).

Patients are often the forgotten stakeholder in the supply chain – **patient participation is essential and this can only be achieved through effective education as part of the core oral healthcare education programmes**. The key messages about sustainability and patient care are: (i) sustainability affects the patient, even if indirectly; (ii) sustainability is not a separate and optional aspect of care quality or a luxury element of dentistry; and (iii) patient-centred care has an impact on the environment and most individuals have control over the magnitude of the impact. Patient information and guidelines should be provided as an intrinsic component of patient oral health education in an easy way to understand.

There is a **need to raise the profile of oral healthcare within medicine and ensure that sustainable lessons are learnt and shared**. Oral healthcare (dentistry) and general healthcare (medicine) should be considered intrinsically linked, with shared sustainable practices that translate between the two.

We need to **understand, harness and promote the value of small actions of individual clinical professionals**, and how these multiply as they are implemented across the world by millions of professionals and by billions of citizens. Small actions act as a catalyst for greater engagement. The high number of oral healthcare professionals globally presents an invaluable opportunity to disseminate influential and impactful messages. Examples of this are:

- Driving awareness with patients on the importance of preventive dentistry and at-home habits.
- Educating on responsible consumption (e.g. the disposal of products or packaging or not wasting tap water during oral care routines).
- Reducing their own impact by adopting responsible consumption habits at the clinic or at home (e.g. the disposal of packaging and products, reduced use of electricity or water, purchase of more sustainable products etc.).

A similar opportunity presents itself by **harnessing the power of patients and individual patients and consumers** (especially when considering the current circa eight billion world population). The end-user consumer group can be engaged in sustainable practice by raising awareness and designing products and services that enable them to reduce their oral health carbon footprint, principally through the avoidance of preventable diseases, following validated oral healthcare messages.

Oral health professional education

In the oral healthcare undergraduate curricula, there is a need to increase awareness and sustainable impactful actions through carefully channelled educational programmes, a process that is currently underway that considers how sustainability can be included in the undergraduate dental curriculum [47, 48, 49]. This needs to be provided from an early point in the curriculum with an opportunity to share best practice with other dental schools. Key concepts to include in an undergraduate curriculum are:

- Integration and co-existence of the principles of sustainability and prevention within a paid-for healthcare system.
- Promotion of disease prevention as a core pillar and continuous strand for environmental sustainability throughout the undergraduate and professional development curricula.
- Sustainability as a key aspect of running future dental practice.
- Sustainable and effective use of materials and alternatives.
- Education for smart procurement– e.g. bulk buying uses less packaging and making smarter choices.
- Education of policymakers for appropriate governance and legislation.
- Inclusion of patient education as an entity – patient education goes beyond prevention and should consider personal choices that may have a detrimental impact so that informed decisions can be made.
- The promotion of sustainable 'green' travel, highlighting public transport routes or providing an area to allow patients/employees to secure their bicycles outside of dental practices/workplace.

The promotion and integration of sustainable practice into continued professional development programmes, such as the programme run by the Green Impact Initiative [50]. Education of patients regarding sustainability would follow with simple and non-demanding messages that focus on reduction through good oral healthcare as a key driver focusing on the message [8]. Maintenance of good oral health delivers huge personal benefits and as an unintended consequence it achieves important environmental gains that are enormously impactful as they are multiplied throughout the population. In this context, it is important to engage with the profession and patients as promotion of public health is key to achieving this goal.

There is also an **opportunity to reduce the carbon footprint of specialist practices through alternative modalities, such as tele-dentistry and remote clinical consultations** [45, 51]. Remote clinical services and tele-dentistry present an opportunity, requiring further professional engagement and associated legislation to ensure its effectiveness.

Nevertheless, it is an acknowledged fact that oral healthcare professionals look up to national associations and governments or legislatures for guidance on behaviour changes. Consequently, **national dental associations and governments need to be engaged and actively influence and support oral healthcare professionals with achievable and practical solutions.**

Route 6 – Materials for clinical use

Awareness and challenges

Dental materials have an environmental impact that arises from all stages of the supply chain: extraction of minerals, synthesis of raw materials, manufacturing, distribution, procurement, clinical use and ultimately waste management. There is an associated acknowledgement of the diversity of materials, complexity of manufacturing and distribution logistics (*Figures 4 and 5*).

The environmental impact from dental materials is not uniformly qualified or quantified. **There is recognition that an effective and meaningful data set can only be obtained through a sophisticated and standardised LCA** (cradle to gate or cradle to grave).

There is **an emerging understanding of the impact of dental materials as they find their way back to the environment through recognised pollution pathways** [52]:

- disposal to landfill of expired materials;
- incineration of waste materials;
- microparticulate waste from use of dental materials [53, 54];
- elution and excretion from restorations into sewerage and water systems;
- interment and/or cremation at end of life.

The most effective way of limiting the impact of materials on the environment is by reducing their use and making them last longer. Reduction is achieved through:

- preventive programmes;
- the implementation of good-quality practice, with good materials, used appropriately in accordance with the manufacturer's instructions;
- effective maintenance programmes.

There is an existing high level of awareness associated with the environmental impact of dental amalgam [55, 56, 57, 58]. The Minamata Convention on Mercury has stipulated a reduction or cessation of dental amalgam [59]. Alternative materials should be used with due consideration to their environmental impact.

The environmental impact of other restorative materials is not well understood, despite extensive emerging research in this field [6, 7, 60, 61].

There is a **need for continued R&D for a material that will provide effective tooth reconstruction with low operative technique sensitivity and predictable durable outcomes, and which reduces or obviates the need for replacement**. Current resin-based direct-placement alternatives are very effective when used well but their associated technique sensitivity with a need for auxiliary items and processes can negatively impact predictability of placement and therefore durability.

The introduction of new end-user products or restorative materials with a lower environmental impact presents a series of challenges:

- The cost of materials and acceptance by consumers to drive behaviour change.
- The availability of new materials.
- Product safety considerations.
- High testing requirements to meet quality standards (including stability and consumer acceptance for example) and the time to undertake these.
- Availability at scale while maintaining a low environmental impact profile.
- Understanding the complexity of sustainability and its actual impact (the product or material).

- Accurate characterisation and understanding trade-offs/compromises, which must be evaluated and understood in order to determine the best options from an overall sustainability perspective.
- Understanding that durability is key to sustainability, so that replacements are reduced or obviated during the lifetime of the patient.

There is an increasing desire for 'cosmetic dentistry' with potential consequences for oral health, as stated in the joint statement by UK specialist dental societies [62] 'that elective invasive cosmetic dental treatments can result in great benefit to patients but that these can also produce significant morbidities in teeth which were previously considered healthy'. It should be noted that **these elective cosmetic treatments also have an environmental impact that is potentially avoidable**.

Drivers and opportunities

The recognition of the critical need for increased effort to reduce human environmental impact has grown rapidly in recent years. Consumers, including patients, increasingly look for evidence that suppliers are making serious efforts to improve their performance.

This consensus statement provides a unique **opportunity to set a benchmark and encourage all dental materials manufacturers to work together as a unit, cross-company, along the whole supply chain, including traditional competitors**. The aim is to share knowledge and best practice on the performance indicators for successful and durable restoratives.

Good materials that are fit for purpose are an essential element of sustainable practice. Restorative materials should perform in a predictable manner to an accepted clinical standard, enabling effective placement and maintenance. A durable restoration will have a lower carbon footprint and associated waste by virtue of not requiring replacement. If sustainability can be built into the product, as part of a circular economy in the manufacturing, packaging and distribution, this is a further desirable goal.

Governments across the world have made national and international environmentally sustainable commitments. They will pressure public services, including the health services, to take a leading position to achieve environmental outcomes in their sectors.

Some companies or services in the dental supply chain have made commitments of their own, and will bring pressure to bear on supply chain partners to support and enable these improvements.

Effective research into sustainable materials requires **effective and meaningful life cycle analyses. LCAs need to follow robust and standardised methodologies to enable meaningful comparisons to be made.** This will enable more effective development of materials with sustainable goals. The environmental impact from dental materials is not uniformly qualified or quantified, and this can be achieved through well-designed LCAs and research.

There is an opportunity to increase awareness and engage in proactive action through the **legislation of dental materials standards, with incorporation of sustainability into the ISO dental standards**. In particular, ISO-TC106 can be used as a vehicle to incorporate sustainability into all the dental standards [33]. It might be a motherhood-type statement that applies to all current and future standards. A further option is to strive to use only the most sustainable raw materials to manufacture equipment and materials and products that use the least energy and water to function.

The International Medical Device Regulators Forum (IMFDR), through its global reach and infrastructure, is well placed to engage in the production of a global agreement on packaging requirements between countries. 'We strategically accelerate international medical device regulatory convergence to promote an efficient and effective regulatory model for medical devices that is responsive to emerging challenges while protecting and maximizing public health and safety' [63].

Specific opportunities for the manufacturing industry:

- Reviewing and challenging the shelf life of materials – e.g. replacing with a concept of functional versus optimal performance of materials.
- Fit-for-purpose materials that are very durable and do not require multiple replacements will have a net lower environmental impact.
- Reviewing the value of glass ionomer and improvements in longevity for treating elderly patients.

- Undertaking standardised LCAs of materials will help to identify opportunities and acceptable trade-offs/compromises.
- Reviewing the expiry and shelf life of materials versus packaging style (compules).
- Reviewing and considering the current suitability of shelf life testing protocols.
- Due consideration should be given to the material and the associated packaging.
- Sharing of knowledge and experience of outcomes between parties.

SECTION V

Strategic Action Framework

A broad strategic action framework has been developed on the basis of the previous elements of this report, which reviews and identifies:

- our level of **awareness** of the nature and magnitude of the environmental pollution caused through our activities;
- the **challenges** that we need to overcome that will enable real and impactful solutions;
- the **drivers** that may facilitate and promote the required changes; and finally
- the **opportunities** that exist or that can be created through this collaborative working partnership.

The impact and effectiveness of this action framework arises from the strength of each of its components and statements, taken individually and as a whole in a truly synergistic manner, with the potential for real and effective outcomes. It should be noted that the strategy presented does not intend to provide detailed granular detail for specific approaches or projects.

There is an acknowledged level of health inequalities across the world, between countries and within countries. This is also particularly pertinent to oral health that presents the challenge of balancing preventive oral healthcare with sustainability goals. This challenge needs to be addressed with ingenuity and use of multiple fit-for-purpose approaches. The strategic action points that are promoted in this document **must be considered in the cultural and socio-economic contextual framework of the region in which it they are to be implemented**. Essentially, stakeholders must take note that the appropriateness of recommendations, solutions and level of impact will vary significantly according to the country and the ability to effect change within it. A local assessment is essential to consider what is achievable and what will have biggest impact.

Thus, **this collaborative and non-partisan strategy** needs to operate within a code of practice, embodied by the following principles:

- a desire to engage in a collaborative and non-partisan manner;
- real commitment with engagement, actions and funding;
- consideration of cultural and socio-economic operational frameworks;
- focusing on impactful solutions;
- sharing best practice;
- supporting other stakeholders;
- reviewing outcomes;
- establishing a code of good practice;

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- learning best practice from other sectors and reciprocating with translation to other sectors;
- demonstrating leadership in healthcare.

This stakeholder action framework complements the **strategic objectives identified in the Executive Board Report by the Director-General of the WHO (January 2022)** [64]:

- **Strategic objective 1: Oral health governance** – improve political and resource commitment to oral health, strengthen leadership and create win–win partnerships within and outside the health sector.
- **Strategic objective 2: Oral health promotion and oral disease prevention** – enable all people to achieve the best possible oral health and address the social and commercial determinants and risk factors of oral diseases and conditions.
- **Strategic objective 3: Health workforce** – develop innovative workforce models and revise and expand competency-based education to respond to population oral health needs.
- **Strategic objective 4: Oral healthcare** – integrate essential oral healthcare and ensure related financial protection and essential supplies in public healthcare.
- **Strategic objective 5: Oral health information systems** – enhance surveillance and information systems to provide timely and relevant feedback on oral health to decision makers for evidence-based policymaking.
- **Strategic objective 6: Oral health research agendas** – create and continuously update context- and needs-specific research that is focused on the public health aspects of oral health.

The strategic action framework that follows is considered in two complementary parts:

- **Enabling success** – identification of the role of the different stakeholders in the supply chain and suggestions for optimum operational success.
- **Action through routes to sustainability** – specific actions that can be achieved that are specifically focused on the different routes as described.

Enabling success

The strategy is considered in the context of the three key principles that have been identified as core to its effectiveness:

- Collaboration and leadership.
- Person-centred oral healthcare.
- The role of enabling agencies.

1. Collaboration and leadership

Companies to lead the promotion of ethical and sustainable behaviours and practices (attitudes) throughout the whole sector. This is based on a recognition of the strongly embedded social and ethical environmental responsibilities that already exist within a company. The leadership and promotion of these attitudes should be directed initially to the direct sphere of influence working through brands, within the supply chain and also through corporate leadership in the industry sector.

Sustainability in the oral healthcare industry must be addressed as a 'supply chain' challenge with *all stakeholders working collaboratively*. The aim of such individual and combined stakeholder actions is to develop a *circular economy*.

Companies to provide leadership in the drive for sustainability, working collaboratively across the whole supply chain. Uniting around a mission or target, the oral healthcare industry needs to be able to speak with 'one voice' and have a much greater impact, principally **via the strong image of competing companies coming together in this purposeful way**.

Company leadership can be achieved through the promotion of the following domains:

a) Education

(i) Engage in dialogue, education and the use of proactive activities to promote wider engagement with stakeholders.

(ii) Promote behaviour change through the company workforce and drive engagement through focused training, such as workshops, in order to bring the outside in and make the workforce more aware of the challenges and opportunities.
(iii) Promote behaviour change among oral healthcare professionals, making it easy for people to act, and commit to sustained communication over time.
(iv) Collaboration with dental professionals in the development of educational materials (both on sustainability and on healthy oral care habits) for patients, the general public and the profession at large.
(v) Use of CEU and CPD credits, engagement incentives and business benefits for sustainable partnerships.
(vi) The translation of complex knowledge into multiformat, strategic and international communication actions.

b) Showcase good practice
(i) Work with healthcare providers and the public end-user through brands and an obviously explicit sustainability corporate responsibility.
(ii) Collaborative partnerships between private sector oral care product providers and dental practices to develop a collection system to drive circularity.
(iii) Share internal good practice from companies (manufacturing, distribution and oral healthcare providers) more widely to educate and promote a ripple effect throughout the supply chain.
(iv) Design and promotion of sustainable products and habits through these products.
(v) Tackle the challenges and barriers that exists between the provision and attainment of everyday health and environmental and societal sustainability.

c) Lead industry change
(i) Establish collaborative partnerships with cross-value chain consortiums that work with government. It is important to identify where the largest gain for collaboration is and how the chain is interconnected.
(ii) Work with all the stakeholders and the supply chain as a single entity, end to end.
(iii) Be a role model with suppliers to set new standards and expectations within the supply chain and with consumers.

There is clear recognition that **companies can bring significant resources to collaborative partnerships** to drive sustainability; these include:

- Knowledge, expertise and research.
- Expert resources, such as human, communication, materials, consumer behaviour; logistical learning/scale.
- Funding that is appropriate and effective.
- Partnership and ideas. Companies understand their challenges and can work with other stakeholders to provide new points of view and solutions.
- Education, communication, engagement, support.
- Focus on tangible, easy-to-understand messages, such as the preservation of water usage.
- Establishing centralised, non-partisan, platforms for sharing examples of good practice and data.

2. Person-centred oral healthcare

The pursuit and achievement of **oral health, through preventive programmes, good-quality care and effective maintenance, is the mainstay of sustainability**.

There is a need to raise awareness and normalise a sustainability culture that sits comfortably alongside the promotion of oral healthcare as a whole 'provider–recipient' team effort.

Within the context of dental practices, there is a **need to promote the positive financial business model that underpin the provision of sustainable clinical dental practice**. There is an opportunity for the development of a multi-faceted, collaborative practical business model for the care provision stakeholders.

Promote a greater use of digital technologies with the manufacturing and distribution industry, which will reduce the need for personal contact and engagement should be sought to reduce unnecessary travel. At the point of clinical patient-centred care, **consider and engage with tele-dentistry and remote clinical consultations**. The adoption of these technologies needs to be carefully assessed, as they can be very resource intensive in terms of equipment, technical support and energy.

3. Enabling agencies

External organisations (e.g. government, professional institutes, legislative authorities) **should support the development of environmental sustainability in the oral health industry.** Consider alignment to the action plan of leading organisations such as those identified by *Health Care Without Harm – HCWH* [25]. Key to this is a need to engage in a mutual, consensual dialogue that seeks to understand the challenges and identify solutions.

Examples of such actions are:

- Revision and drafting of new and 'fit for purpose' legislation and regulations with sustainability as a major driving consideration will be key.
- Creating policies that are flexible to allow companies to take actions in their own specific areas (e.g. producers responsibility payments could be offset by investment into alternative proven sustainable initiatives).
- Working with trusted non-partisan leaders to continue to support good practices and drive action, for example RSB, WRI, EMF and others (see *Glossary*).
- Creating incentives for responsible sourcing, manufacturing and consumption (e.g. returning specific products creates a discount in future purchase/oral health insurance plans).
- Education and transparent communication to (oral healthcare) consumers that combines performance, constituent/material transparency and sustainability profile.
- National dental associations to raise awareness, through the integration of sustainability into national conferences and the promotion of adapted national guidance.

Agencies (e.g. local/national governments) and legislators should work collaboratively to enable sustainable practices at all levels.

- Make it easier to be sustainable than not to do so, e.g. easy, practical and effective waste recovery and recycling schemes and financial penalties (taxes) for non-recycled waste.
- All stakeholders should benefit from the process, e.g. waste recycling with the benefit of financial benefits and social/patient recognition.

Action through the routes to sustainability

Route 1 – Reduce, reuse, recycle and rethink

Reduce and *recycle* should be the focus of remediation, being the most practical and readily implementable approaches.

***Reduction* is best achieved through the delivery and maintenance of good oral health**, focused on prevention and with the provision of durable interventions, using high-quality products materials and that will last longer and/or require fewer revisions. Every stakeholder in the supply chain, from manufacturing to the clinician and end-user, has a role to play to optimise this reductionist approach, the emphasis being on ensuring high quality, fitness for purpose and durability that is more important than perceived 'greener' options of questionable effectiveness and durability.

At the point of delivery of care, *reduction* is achieved through the provision of good oral healthcare by engaging with good practice, as detailed in the four domains [8]: *preventive care*, *operative care*, *integrated care* and *ownership of care*.

- **Preventive care** – the assessment and management of systemic and local risk factors with a practical and patient-centred preventive regime.

- **Operative care** – the combination of core knowledge, skill sets, experiential learning and team work acting synergistically. The provision of high-quality operative interventions results in durable treatment that will require fewer repairs and replacements.
- **Integrated care** – the integration of services, patient-centred structured treatments and patient participation as co-creators and co-managers of their care.
- **Ownership of care** – active participation in core and complementary activities that leads to professional development, a passion to excel and the satisfaction of achievement.

The outcome of this integrated approach for the delivery of oral care is twofold: (i) fewer appointments, with fewer patient journeys and reduced need for professional interventions, resulting in an overall reduction in CO_2 emissions; and (ii) increased longevity of restorations and a reduced need for procurement, which results in an overall reduction in waste generated.

Reduction of packaging should be sought at all levels: primary/container/delivery vehicle; secondary and tertiary packaging.

Recycling opportunities arise from:

- **Engagement with stakeholders** in the supply chain to add value to waste plastic packaging.
- The **design and development** of plastic items made **from single plastics** that can be readily recycled.
- **Engagement with end-user consumers and waste management companies** to segregate, collect and recycle clinical SUPS as a valuable commodity.

Companies should fully engage with recycling opportunities with other stakeholders in the supply chain. This must be done in a partnership and is an essential component of finding sustainable solutions. A materiality assessment and SWOT or similar analysis will help manufacturing companies understand where this type of activity fits within the overall strategy.

There is need to create socially equitable funding models and appropriate infrastructure that will promote and permit practical recovery and recycling schemes. The social aspect of managing plastic waste is key to achieving a circular economy. The activity from the Flexible Plastics Consortium is a good example of progress in this respect [42].

Stakeholders in the supply chain should use their influence to increase the application of reuse or recycling, through:

- Education in manufacturing companies – encourage sustainable product design and environmentally conscious changes in consumer behaviour, the latter with a focus on the use of at-home oral care prevention products.
- Simple, clear communication and marketing to retailers and consumers, supported and enhanced by the oral care professionals.
- The establishment of partnerships, collaboration and communicating examples of good practice.
- Speaking with one voice to drive change.
- Innovation and setting expectations with suppliers and other third parties.
- Dental professionals, by implementing sustainable practices in the dental practices.

Route 2 – Legislation, policy and guidelines

Policies and public health guidance should promote oral healthcare as the most important and impactful route to environmental sustainability:

- Public awareness about the triple benefits of preventive regimes:
  (i) individual disease reduction
  (ii) public health cost savings
  (iii) environmental sustainability gains.
- Screening and health promotion campaigns
- Water fluoridation
- Incorporation of environmental considerations into all clinical intervention guidance.

Supply chain stakeholders should seek to engage with legislation at two levels:

- **Legislation** (lawfully enforceable) **to drive sustainability** and in this way catalyse organisations to move in a positive direction. Legislation or regulation can work to level the playing field across the industry to ensure that all stakeholders operate to an accepted minimum common standard.
- **Legislation using incentivisation and as an advocacy tool**, to support sustainable practice, rather than limiting it through regulation. Legislation should seek to drive compliance and public advocacy through trade associations, rewarding best practice and informing public policies, but with care not to stifle innovation and other forms of sustainable development. As stakeholders, operating in different world platforms and settings, we need to be mindful of the different regulatory frameworks across countries and seek opportunities to translate good practice, from other arenas, to influence and raise standards as appropriate.

Legislation should be derived from a fact-based decision-making process. Based on knowledge ascertained through the development of a standardised robust LCA that considers the broad array of variables and their interaction to improve sustainability.

Stakeholders in the oral healthcare supply chain should work with legislators to influence and improve the manner in which laws and rules assist sustainable practice, through:

- Better stakeholder engagement with legislators/policy regulators, through forums that enable discussions and engagement with policy regulatory bodies, end-users and other stakeholders up- and downstream.
- Active and regular input into the sustainability debate, to ensure consistent and contemporaneous messages across the industry.
- Working together and identifying challenges and potential solutions that would be good for the environment but without compromising patients' and consumers' oral health.
- Incentives and support for sustainable business practices that demonstrate sustainable outcomes, rather than limiting it through regulation.
- Collaboration and sharing good examples and speaking with one voice to drive change.

Route 3 – Waste management

Educate the profession and the public about the merits, usefulness and indispensability of plastic in the healthcare sector. Improve knowledge and attitudes towards the generation and management of biomedical waste across the world and in particular in developing economies.

Promote and support research into recovery and recycling of all forms of plastics used by the industry. Do so in collaboration with supply chain stakeholders up and down the supply chain to achieve a coordinated and impactful solution to the challenge. This should include effective communication and education of end-users about the ability to recycle waste plastic so that it can be repurposed as valuable feedstock in a circular economy.

Focus research on a life cycle perspective of products/materials that considers the whole picture of the environmental impact in the context of the intended purpose of the device, its durability and its management as eventual waste.

Unlock the barriers that exist at each point of the supply chain, changing systems and behaviours at a local and systemic level, and coupling waste management to innovative solutions for reprocessing. The supply chain, acting as a single entity, can help to manage the waste generated by end-users (general public or the oral healthcare profession), with a focus on materials reduction, optimised transport and distribution logistics and recycling packaging materials.

Promote and support research into recovery and recycling of all plastics used by the industry. Do so in collaboration with supply chain stakeholders up and down the supply chain to achieve a coordinated and impactful solution to the challenge. Need to view plastic waste as a resource that can be recycled as part of a circular economy.

R&D collaboration between the oral healthcare manufacturing industry and the plastic synthesis suppliers to design feedstocks (from sustainable sources) and materials that meet safety, quality and durability requirements and can be accepted by recyclers. Further down the supply chain, the oral healthcare manufacturers should work with recyclers on technologies that enable and drive effective recycling.

Management of plastic (SUPs) by means of:

- **Establishment of partnerships and effective communication channels** with peers, NGOs and other stakeholders that will drive and enable innovation, new designs, build infrastructure and secure quality recycled feedstock plastic.
- **Pursuit of a more desirable SUP circular economy** that focuses on a reduced consumption of finite resources (such as oil-derived plastics) and that designs 'plastic waste' out of the systems.
- **Identification of strategies that address single-use plastics at three key stages**: (i) packaging, (ii) pre-clinical or pre-use and (iii) clinical or end-user products.
- **Identification of practical and pragmatic approaches** that are appropriate for the setting.

Pre-clinical and pre-consumer SUPs (e.g. packaging)

Work towards a circular economy through a reduction of packaging waste by ensuring that this is both recyclable and that there are systems in place to provide recovery and recycling opportunities further down the supply chain.

Establish a business culture that identifies the value of all plastic packaging (including product delivery sundries, e.g. materials compules)**, setting it as a valued commodity/resource that can be recovered and recycled**, rather than the current status of a zero-value waste product at the point of manufacturing and throughout the supply chain.

Focus on the use of recycled plastic waste arising from manufacturing and distribution as feedstock for new products, devices and packaging. This is considered a less challenging route to circularity than the use of clinical or consumer contaminated plastic and end-user contamination, through a combination of established mechanical (shredding) and innovative chemical (polymer breakdown) recovery methods. In this context, **all supply chain stakeholders to collaborate with equal responsibility in recycling schemes**:

- All stakeholders must take responsibility and collaborate to find sustainable solutions.
- Shared rules/specifications are key for all to participate.
- Requirement for a 'supply chain lead' in this process with sufficient resources and funding to manage and maintain the model.
- Requirement to gain core knowledge on plastic, its forms and recycling opportunities. To enable stakeholders to make more sustainable choices when using it (e.g. to select bio-based over fossil-based).
- Need to create a level of baseline knowledge through the conduct of robust life cycle analysis, with the engagement of suppliers, distributors and end-users.

Biomedical SUP waste (clinical and consumer)

Undertake an effective assessment to show varying materiality between aspects in different areas of the supply chain. Focus the assessment on each individual area that identifies the most common key aspects.

Stakeholders (manufacturers, legislative authorities, end-users and waste handlers) **need to review opportunities for effective recovery and recycling of clinical and consumer plastic items.** Some plastic items (e.g. packaging) used in the oral healthcare sector, do not need to be considered medical waste if they not in direct contact with clinical environments. In addition, other plastics such as dental sundries, primary containers (e.g. composite compules, micro-brushes and dispensing pots), waste sterilised autoclave pouches and even uncontaminated gloves present further opportunities for recovery and recycling, if safely and effectively placed in the correct waste stream.

Route 4 – Procurement and logistics

The supply chain should unite to work as a single entity to develop less cumbersome systems and processes with improved logistics capacity with sustainability as a key driver, which will result in an improved circular economy.

All stakeholders should engage in effective and shared auditing practice of sustainability processes and outcomes, within their own sphere of activity and across the whole supply chain to establish a clear baseline and progression toward a gold standard.

Companies should continue to engage and provide environmental leadership across supply chains, extending reach across the value chain, upstream to suppliers and downstream to consumers.

Establish more efficient logistics within the supply chain at manufacturer/distribution and end-user levels: the creation of efficient manufacturing, distribution and procurement logistics with shared facilities. At the point of care delivery, patient-centred clinical care plans need to be managed in an effective manner.

Procurement summits are an opportunity for sector leadership, stakeholder collaboration and sharing best practice. This creates an opportunity for supplier engagement: identifying an opportunity to work with suppliers and improve their awareness, understanding and level of engagement.

Consider the opportunity to include a 'sustainability index' as a means to inform purchasers on the sustainability credentials of a product. To include information on environmental sourcing, ethical manufacturing, supply chain distribution and procurement.

Identify mechanisms for the redistribution of equipment and materials to LMICs and educational institutions: products nearing their use-by date and equipment that is nearing the end of its 'legislation-driven' useful life in a particular market.

Route 5 – Research and education

Research

Establish research and innovation partnerships, in the manner of formal alliances, to jointly tackle sustainability projects: effective recycling; the development of sustainable practices across industries; new material introduction (development of more sustainable ethically sourced alternatives to currently used materials); shared logistics; working with dental professionals to develop educational materials for patients; and sponsoring relevant and impactful scientific studies [65].

Undertake effective scoping and mapping studies to identify fundamental research gaps. This needs to be a continuous and live project that can respond and adapt to new emerging challenges.

Obtain reliable and independent research data to enable prioritisation and collective action. Circularity is viewed as a key priority area with comparative industrywide LCAs in healthcare to help identify or exclude options that will engage significant opportunities.

Conduct combined health–economic–sustainability impact analyses as a priority in oral healthcare. It is important to consider the intended purpose and effect of the material or product on the end-user and how this may impact on the overall sustainability impact of that individual over the course of their life.

Engagement of national dental associations and governments to support and actively influence oral healthcare professionals with achievable and practical solutions.

Explore, through quality research, the effectiveness of existing and alternative service delivery models that focus on effective and equitable (understanding the challenges of different settings) oral healthcare and sustainability as core aims.

Education

Promote behaviour change **by raising awareness** among **all stakeholders with a focus on end-users (clinical and consumers)** and undergraduate dental students as the future clinicians.

Promotion of effective oral healthcare as the most important route to sustainability, with primary positive outcomes on individual health, public health resources and the environment – achieved through a reduced need for interventions.

Drive sustainable practice throughout the supply chain through education, the promotion of sustainability conversations and leading by example.

Educational messages should focus on:

- **Disease prevention and maintenance regimes** with sustainable oral hygiene practices at home.
- **A requirement for accountability in the clinical environment.**
- **Alternative, more clinically cost-effective service models that can deliver optimum and sustainable oral healthcare.** Consideration should be given to implementing impactful prevention and screening services in population hotspots, such as schools, care homes and shopping precincts.

Design of products and services that enable consumers to reduce their oral health carbon footprint, principally through the avoidance of preventable diseases, following validated oral healthcare messages.

Promote sustainability policies and support behaviour change…

- **within companies.** This is vital to embedding sustainability across all business and a key building block in business growth strategies. This education and embedding of practices/policies extends beyond supply chains to all functions within company business, helping all to build this mindset into their objectives.
- **among the entire dental practice team**, to include reception, nurses, clinicians and patients – the latter as active co-participants of their care. Focus on preventive regimes that will deliver healthy oral health with low environmental impacts (low use of resources, low carbon footprint and low waste). Sustainability becomes a welcome unintended consequence of good-quality oral healthcare.
- **among oral healthcare professionals and the worldwide consumer public.** Do so with a focus on prevention, delivery of high-quality optimised operative care, integrated patient-centred care logistics and joint collaborative ownership of care [8].
- **among national dental associations**, which have a unique opportunity and responsibility to raise awareness and proactively engage with the oral healthcare profession and allied industries.

Integrate sustainability in the undergraduate oral healthcare curricula. This should make use of the expertise and resources of the oral healthcare industry (e.g. communication, educational programmes and good practice), educational providers and the students themselves as co-participants of their education.

Route 6 – Materials for clinical use

Products and materials (e.g. oral hygiene aids and dental restorative materials) **need to be 'fit for purpose', with sustainability as a core driver** (i.e. during manufacturing, distribution, use and disposal). Labelling materials and products as 'sustainable' if they are made from sustainably sourced constituents +/– recycled, is overly simplistic. **Products and materials need to be: (i) fit for purpose (effectively and predictably achieve their intended purpose), (ii) built from sustainably sourced materials, and (iii) durable, so that they can perform for a very long time and require reduced revisions and/or replacements.** In the context of restorative materials, for example, these should provide a lifetime service for the patient. A product or material that is not durable will require replacement, with the consequent environmental impacts associated with the iterative repetition of the greenhouse emissions (throughout the supply chain, including patient commutes) and pollution associated with the manufacturing, supply and provision of restorative materials or other products.

Research focus on a simple, effective, comparable LCA process that can be used cross-industry to support effective R&D strategies and material choice.

Requirement for a direct partnership with waste management companies to encourage collection, sorting and recycling of waste materials.

Integrate environmental sustainability as an intrinsic element of the ISO standards. To include detail of the process that a manufacturer undertakes to choose the most sustainable raw materials, to create the product,

and to produce products that will use minimum amounts of energy and water to function, under the auspices of ISO TC (Technical Committee) 106 Dentistry.

Strategic action – Synopsis

Climate change and environmental pollution represent two of the greatest problems facing humanity and the planet. The whole oral healthcare sector recognises the value and positive impact of further improving environmental sustainability throughout the supply chain. To address these challenges, the FDI World Dental Federation assembled a coalition that included leading manufacturers, health professionals, academic experts, and legislative authorities to reach a consensus and prepare this *Joint Stakeholder Statement for the Provision of Environmentally Sustainable Oral Healthcare*. This endeavour was driven by a collective ambition to reduce the environmental impact that arises from the wide range of activities associated with the global delivery of improved oral health.

This statement identifies the state of awareness of the impact of oral health activities on the environment: the major challenges facing oral healthcare; the complex drivers that underpin current behaviours and practices; and the opportunities to improve and deliver sustainable oral healthcare for people and the planet. As a result of this collaborative programme, a strategic action framework has been identified that is based on defined opportunities to improve sustainability. This framework is based on the evidential and experiential knowledge alongside insights and expert opinions from the diverse stakeholder community engaged by the FDI. Furthermore, actions need to be implemented with due regard to the cultural and socio-economic contextual framework of the regions where they will be deployed. A code of practice for the implementation of these strategies has therefore also been defined, and this is considered core to effective, collaborative action.

It was concluded that sustainability in the oral healthcare industry must be addressed as a 'supply chain' challenge, with all stakeholders working collaboratively wherever possible. The primary objective of these individual and combined stakeholder actions should be to develop a circular economy. Industry recognises that, by providing leadership, the potential for positive impact will be substantially enhanced throughout the whole supply chain. This partnership is also committed to sharing best practice to maximise benefits throughout the sector. This consensus statement acknowledges the need to work with the supply chain to fix the supply chain, and in time the goal must be to more closely coordinate our actions in order to further optimise efficient systems and processes alongside logistics capacity. *Reduce* and *recycle* should be the main focus of an improvement strategy as being the most practical and readily implementable approach, that is, a reduction of packaging, preclinical, and clinical/end-user plastic products and engagement with recycling as the next best strategy of waste management. Reduction of treatment needs represents a significant opportunity to improve sustainability, and can be achieved with a combination of effective preventive programmes and the provision of high-quality consumer health products with effective/durable clinical interventions when needed.

External organisations (including national governments, professional bodies and legislative authorities, including regulators) are strongly encouraged to support this development of even greater environmental sustainability across the oral health sector. This recognition and active support need to be extended to the provision of sustainable clinical dental practice. End-user consumer stakeholders should also be engaged in sustainable practice by raising their awareness and engaging in the design of products and services that enable them to reduce their personal oral health-related carbon footprint.

This consensus statement recognises the value of promoting research into the recovery and recycling of all plastics used across the sector, including in packaging. The reduction generation of associated waste streams requires 'sustainability' to be embedded in the earliest stages of product design. Reduction may also be improved through adoption of the best technological solutions (including in distribution, logistics, teledentistry and remote clinical consultations). Related to this, research programmes that have the potential to provide innovations in recycling or waste reduction should be given a high priority by governments and their agencies. High-quality and impactful research are a fundamental enabler of any effective sustainability action in the sector. There is a need to obtain reliable and independent research data to enable prioritisation and collective action at all levels. This should include a combined health–economic–sustainability impact analysis. Clinical materials and products require robust life cycle analysis research, to enable effective comparisons to be made. Sustainability through improved recycling requires that companies engage with other stakeholders in

the supply chain. There may be specific benefits in creating socially equitable funding models and appropriate infrastructure, which will promote and permit practical recovery and recycling schemes. Stakeholders in the supply chain should use their position to increase the application of reuse or recycling.

There is distinct requirement to engage with legislation to drive sustainability and use incentivisation as an advocacy tool. Legislation should be derived from a fact-based decision-making process. Stakeholders in the oral healthcare supply chain should work with legislators to influence and improve the manner in which laws and rules assist sustainable practice. This statement also recognises the benefits of improving education within the professions at all levels and more widely among the public. Behaviour changes at individual and organisation level, through targeted educational programmes, are key to increasing awareness and driving sustainable practices throughout the supply chain. This should include development of sustainability polices and education of company workforces, oral healthcare professionals, whole dental practice teams, and the global public. A particular focus for educational programmes is the oral healthcare profession, which represents a key link between the dental industry and patient education. This can be enhanced through the integration of sustainability into undergraduate dental curricula with the engagement of national dental associations and governments to support and actively promote sustainability throughout oral healthcare.

In conclusion, all elements of our complex oral healthcare sector undoubtedly make a significant contribution to oral health, which improves quality of life for millions of people worldwide. While sustainability has advanced in recent years by both individual businesses and clinical professionals, this consensus statement demonstrates clearly the potential for far greater future impact as a direct result of improved coordination and collaboration between diverse stakeholders. Further engagement by governments and their agencies to improve legislation and provide support for research leading to the translation of new technologies will further accelerate the transition to a sustainable, circular economy and improved oral health.

Appendix

Map of Consensus Statement to the United Nations Sustainable Development Goals

CS THEMES → / ↓UN SDGS	Reduce, reuse, recycle, rethink	Legislation, policy and guidelines	Waste management	Procurement and logistics	Research and education	Materials for clinical use	Remediation strategies
No poverty							
Zero hunger							
Good health and well-being	XX	X	X	X	XX		
Quality education	X		X	XX	XX	X	X
Gender equality							
Clean water and sanitation			X			X	X
Affordable, clean energy							
Decent work and economic growth	X			X	X		X
Industry, innovation and infrastructure	XX	X	XX	XX	XX	XX	X
Reduced inequality							
Sustainable cities and communities							
Responsible consumption and production	XX			X		X	X
Climate action	X					X	X
Life below water							
Life on land							
Peace, justice and strong institutions							
Partnership for the goals	XX	XX	XX	XX	XX	XX	X

Table 1: Number of statements or comments within each section of the Consensus Statement that relate directly to one (or more) of the 17 UN SDGs. The table is not an indication of any of the following: (i) How much focus/effort the stakeholders collectively or individually believe should be afforded to a specific CS topic or action; (ii) The relative importance that the stakeholders, collectively or individually, apply to a specific UN SDG; (iii) The speed or effectiveness with which any specific CS recommendation can be implemented.

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The Oral Healthcare community, including clinical professionals and industry, acknowledges the shared responsibility to deliver products and interventions that improve oral health in a more sustainable manner.

To deliver this, the community is working in alignment with the UN Sustainable Development Goals. Key to establishing this collaborative stakeholder consensus is a deep contextual understanding of the challenge. This is achieved through a comprehensive account of the levels of awareness of the environmental impacts, the challenges to resolve these impacts together with the drivers and opportunities to promote sustainable practices.

This report concludes with a strategic action framework that makes specific recommendations and identifies best practice to achieve these goals. The promotion of excellent oral healthcare and the development of a circular economy are core to this strategy. Additionally, it is also important to recognise the opportunities to collaborate across the sector, and throughout supply chains, to develop and promote sustainable practices to achieve meaningful and measurable environmental outcomes in the sector.

In this context, the FDI World Dental Federation convened the development of this volume, *Consensus on Environmentally Sustainable Oral Healthcare: A Joint Stakeholder Statement*. This consensus statement brings together a global coalition of stakeholders, representing all aspects of industry, health professionals, experts, legislative authorities and governments. The statement uses a truly collaborative, multi-stakeholder approach to identify the major challenges facing oral healthcare, the complex drivers that underpin current behaviours and practices, and the best opportunities to improve and deliver sustainable oral healthcare for people and the planet.

Concluding with an impactful and robust strategic action plan that crosses all boundaries, the statement identifies a series of actions and recommendations for best practice that address the sustainability issues facing the whole sector.

Written by The University of Sheffield colleagues Prof Nicolas Martin, Dr Steven Mulligan, Hon. Prof Ian J Shellard and Prof Paul V Hatton, *Consensus on Environmentally Sustainable Oral Healthcare: A Joint Stakeholder Statement* is the result of a collaborative working partnership between the FDI-Sustainability in Dentistry Task Team and the project founding partners (Colgate-Palmolive, Dentsply Sirona, Haleon, Procter & Gamble and TePe) with the wide participation of stakeholders throughout the oral healthcare supply chain.

The five founding partners of the Sustainability in Dentistry project are Colgate, Haleon, Procter & Gamble, Dentsply Sirona and TePe

Sustainability in Dentistry

FDI World Dental Federation

Read more about the FDI Sustainability in Dentistry project

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