

Consensus on Environmentally Sustainable Oral Healthcare: A Joint Stakeholder Statement

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FDI Consensus Panel on Sustainable Oral Healthcare

Professor Nicolas Martin BDS PhD FDS RCS – Clinical Chair in Restorative Dentistry & Project Leader

Dr Steven Mulligan BDS BSc(Hons) MJDF RCS – Clinical Lecturer in Restorative Dentistry & Project Investigator

Professor Paul Hatton BSc PhD FIMMM – Chair in Biomedical Materials Science & Project investigator

Professor Ian Shellard – Project investigator

FDI ‘Sustainability in Dentistry’ Task team.

FDI ‘Sustainability in Dentistry’ Founding Partners:

Colgate, Dentsply-Sirona, GlaxoSmithKline, Procter & Gamble and TePe.

FDI ‘Sustainability in Dentistry’ Participating Partners.

FDI “Sustainability in Dentistry’ Professional Services.

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Consensus on Environmentally Sustainable Oral Healthcare: Executive Summary

Climate change and environmental pollution are amongst the greatest health threats affecting the planet, humanity, and biodiversity. This is recognised in the *2030 United Nations Agenda for Sustainable Development* that includes an urgent call for action from all sectors. The entire oral healthcare community, including clinical professionals and industry, recognise that we have a responsibility to deliver products and interventions that improve oral health in a sustainable manner. 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 impactful and robust remediation strategies that cross boundaries and take 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 2027, Madrid, Spain)¹.

This document therefore represents the collective views from 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 consensus statement identifies 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^{2,3}: Reduce, reuse, recycle and rethink; Legislation, Policy and Guidelines; Waste management (including SUPs); Procurement & Logistics; Research & Education; and Materials for Clinical Use.

¹ Sustainability in Dentistry Statement. FDI World Dental Federation. May 2017, Madrid, Spain. <https://www.fdiworlddental.org/sustainability-dentistry-statement> (Accessed 08 February 2022).

² Martin N, Sheppard M, Gorasia G, Arora P, Cooper M, Mulligan S. Awareness and barriers to sustainability in dentistry: A scoping review. *J Dent.* 2021 Sep;112:103735. doi: 10.1016/j.jdent.2021.103735. Epub 2021 Jun 25. PMID: 34182058.

³ Martin N, Sheppard M, Gorasia G, Arora P, Cooper M, Mulligan S. Drivers, opportunities and best practice for sustainability in dentistry: A scoping review. *J Dent.* 2021 Sep;112:103737. doi: 10.1016/j.jdent.2021.103737. Epub 2021 Jun 26. PMID: 34182061.

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 & Challenges.** This recognises the importance of raising awareness of the impact of oral health professional practices and consumer behaviours on the environment, and challenges **all stakeholders to improve dissemination and understanding in this space.**
- **Drivers & Opportunities.** There are numerous drivers now operating that promote the development of - and engagement with - sustainable practice, and this represents a major opportunity to make improvements across the sector.
- **Remediation strategies.** This consensus statement makes specific recommendations and identifies potential best practices to deliver environmental benefits while potentially improving global oral health.

There is broad agreement that stakeholders in the dental sector could potentially make significant reductions in the volumes of waste generated, most notably from manufacturing processes, packaging, the high prevalence of single-use products (mostly plastic) and the increased use of personal protective equipment (PPE). Most of the contaminated biomedical waste impact lies downstream of the supply chain and with the oral healthcare professionals, patients and end-user consumers. There is now a desire and strong agreement to address this challenge to ensure that, through the actions of all stakeholders in the entire supply chain acting in unison, we reduce and limit our environmental impact to ensure sustainable planetary health in conjunction with effective and sustainable oral healthcare.

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. CO₂ emissions and plastic waste, packaging and end-user Single Use Plastics (SUP) are recognised as 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. There is an opportunity for all stakeholders to identify and embrace every element of sustainable practice and in this way achieve significant cumulative gains; the result of multiplied individual supply chain stakeholder practices, including the oral healthcare profession and end-users.

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 firstly through reduction and secondly with recycling:

- 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.
- 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.

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 knowhow and supporting technologies.

Education is considered as the fundamental component of any remediation strategy, with a focus on increasing awareness and identifying remediation solutions for each sector and for the supply chain as a whole. Any education strategy 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. For example, it is important to understand the merits, usefulness and indispensability of plastic in the healthcare sector and at the same time limit its use (through reduction) and recycle as part of a circular economy. The oral healthcare industry has a responsibility to promote innovation, research and 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 green practices, in alignment with the United Nations agenda. While recognising that our sector makes a significant contribution to oral health that improves 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.

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. We are in full concordance and working towards the integration of the UN Sustainable Development Goals into our practices, and in doing so, have the ambition of working as part of a circular economy.

Through our collective ambition to reduce the environmental impact of oral healthcare, we recognise that there is a substantial opportunity to work collaboratively across the sector, to engage in sustainable practices and benefits from modification and/or development at the local level and in a collaborative manner with supply chain stakeholders. We recognise the value of working together to establish a strategy to achieve meaningful and measurable environmental outcomes throughout the oral healthcare supply chain.

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.”¹

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 Federation², to collaborate with a strong and genuine ambition to engage with this UN Agenda for Sustainable Development.

The FDI assumes the responsibility of this leadership role, in its capacity as the World Dental Federation, that serves as the principal representative body for more than one million dentists worldwide, some 200 national dental associations and specialist groups in over 130 countries³. The FDI has convened the development of a joint stakeholder Consensus Statement on Environmentally Sustainable Oral Healthcare. This is achieved through a unique working partnership between the FDI-Sustainability in Dentistry task team, five project founding partners and wide participation of stakeholders in the oral healthcare supply chain (*Appendix 1*).

This consensus statement seeks to identify, understand and establish a remediation 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 establishes that Oral Health “is a key indicator of overall health, well-being and quality of life”⁴. This sentiment is echoed by the FDI World Dental Federation in its definition of oral health, highlighting that it is “vital to general health and well-being”⁵. 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 world population)⁶. This situation poses “a major health burden for many countries and affect people throughout their lifetime, causing pain, discomfort, disfigurement and even death”⁷. Oral diseases are most commonly expressed in form of caries (the most common health condition⁸); periodontal disease (affecting almost 10% of the world population⁴) and oral cancer (amongst the most common cancer worldwide⁹). The WHO further states that “Most oral health conditions are largely preventable and can be treated in their early stages”⁴.

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. 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, to prevent and manage 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 CO₂e emissions and pollution. The recently published draft COP26 special report on climate change and health, highlights the impact of healthcare on the environment¹⁰, with evidence of how “health professionals worldwide are already responding to the health harms caused by this unfolding crisis”¹¹. Significant progress in this field is 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.”^{12,13}.

Healthcare systems are responsible for around 5% of global greenhouse gas emissions, of which oral health is an important contributor^{14,15}. The delivery of general healthcare is currently not environmentally, socially or financially sustainable due to high amounts of CO₂e (carbon dioxide equivalent) and waste generation¹⁶. It is paradoxical that healthcare, with the central tenet to support and protect health and life, contributes to climate change through unsustainable practices and in doing so to disease.

The oral healthcare industry is keen to address this challenge and ensure that, through the actions of both individual stakeholder (companies, associations and other entities) and through those of 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. Sustainable oral healthcare would potentially not only result in substantial CO₂e reductions but could lead to enhanced patient care, staff satisfaction, cost savings and quality of life^{17, 18, 19}.

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 ASTM in the document ‘Standard Practice for Managing Sustainability in Dentistry E3014-15’ as “...*the degree of sustainable development in the context of a dental professional or dental service organisation. 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*”^{12,13,20}.

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 sustainability².

For the purpose of writing this consensus statement and provide an actionable 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 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, that will reduce and minimise our environmental footprint.

Objectives

1. Raise awareness and outline the opportunity relative to decreasing carbon emissions, decreasing plastics use, improving waste generation and management, and other environmental impacts in oral healthcare.
2. Raise awareness, promote impactful research and educate all sectors of the supply chain, to ensure broad consensus around sustainable oral health practice and sustainable lifestyle habits.
3. Acknowledge individual and joint responsibilities to understand and seek to minimise the environmental impact of our activities while the quality of products and healthcare provision.
4. Seek to work jointly and proactively, through voluntary participation, to achieve environmentally sustainable solutions for the good of our profession, the population we serve and the environment we share globally.

Document structure

Methodology – An explanation of the resources used, the process followed and stakeholder participation.

Sustainability in Oral Healthcare – The body of the document and leads with a broad introduction to this concept and provides a context for the exploration of the environmental ‘Routes to sustainability’ (*Table 1*).

Routes to Sustainability in Oral Healthcare – Each of these are considered individually with their own concept journey of *Awareness & Challenges* and the *Drivers & Opportunities*.

Remediation Strategy – The natural end point of the document, based on the preceding data, that sets an action plan framework for further development. This firstly considers broad principles, followed with detailed action points for each of the identified routes.

Methodology

The FDI World Dental Federation Sustainability in Dentistry Task Team has led this research process²¹. The process was based on an iterative series of drafts informed by a comprehensive three-wave Delphi inquiry^{22,23}, with the key stakeholder (partner companies) focus group (May-October 2021) and relevant published literature. A series of workshops (x4, November 2021) with multi-disciplinary world-wide participation of key stakeholder followed, to add the further perspective from other key stakeholders (*Appendix 1*). The additional data was categorised thematically and included in the relevant sections of the document. The final draft Consensus Statement Document was shared in a joint participation stakeholder agreement summit of the oral healthcare industry in March 2022; prior to publication as the 'agreed consensus statement' representing the views of all the signatory stakeholders.

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 & Challenges
 - *Awareness* of all stakeholders of the impact of oral health professional activities on the environment.
 - *Challenges* to develop and engage with sustainable practice.
2. Drivers & Opportunities
 - *Drivers* to develop and engage with sustainable practice.
 - *Opportunities* to develop and engage with sustainable practice.
3. Remediation strategy
 - *Recommendations & Best practice* for effective sustainable dental practice.

In this consensus statement, the agreements detailed are representative of the whole oral healthcare supply chain as individual stakeholders and acting as a single entity. As such, we have sought to include representation of each stakeholder group; that will act both as an individual organisation (operating to maximum effect within their internal framework of ESG) and also beyond their internal boundaries to engage and influence other stakeholders in the supply chain to provide a united and effective strategy.

There is extensive literature for sustainability in oral healthcare that considers a wider range of topics. Two recent and comprehensive scoping reviews have identified the range of themes that capture all the broad topics for consideration (Martin et al. 2021)^{24,25}: Environmental impacts, CO₂e, air and water; reduce, reuse, recycle and rethink; policy and guidelines; waste management (SUPs); procurement; research & education; and materials for clinical use.

The contextual background for this consensus statement considers the literature included in these two scoping reviews and additional relevant publications. Accordingly, statements of fact that are not cited, are attributable to the findings from the scoping reviews. Only the additional literature or reports, that are not included in the scoping reviews, are cited independently in this work.

The process was financially sponsored by the five partner companies (Colgate, Dentsply-Sirona, GlaxoSmithKline, Procter & Gamble and TePe); each providing equal financial contributions. The overall participant engagement represents all sectors of the oral healthcare supply chain with global representation (*Appendix 1*).

1	Reduce, Reuse, Recycle and Rethink
2	Legislation, Policy and Guidelines
3	Waste Management
4	Procurement & Logistics
5	Research & Education
6	Materials for Clinical Use

Table 1: Routes to Sustainability in Oral Healthcare

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 Development¹. We have identified that our activities are associated with all seventeen goals, with a strong and direct relationship to eight of these; presenting a real opportunity for positive sustainability action (*Appendix 3*):

- Goal 17 (Partnership for the Goals),
- Goal 9 (Industry, Innovation and Infrastructure)
- Goal 4 (Quality Education)
- Goal 3 (Good Health and Well-being)
- Goal 12 (Responsible consumption and production)
- Goal 6 (Clean water and sanitation)
- Goal 8 (Decent work and economic growth)
- Goal 12 (Climate action)

The ability to engage with these UN SDGs is founded on a carefully considered remediation strategy that itself is based on a comprehensive understanding of the background levels of awareness around these issues, the challenges to changes, the drivers to engage and the opportunities to do so. 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)^{24,25}.

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 CO₂ 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 *2/3 of all emissions from the oral healthcare sector and about 8% of the total UK NHS air pollution attributable to travel*²⁶. 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 **CO₂ emissions** from the healthcare industry are increasingly being understood. This accounts for a significant percentage of national emissions (e.g., in the UK, accounting for approximately 5% of emissions) 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 CO₂ emissions associated with travel and transport at the point of patient care. Oral health care 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 8 billion as of October 2021); the practice of dentistry and personal oral healthcare is a significant consumer. As a conservative estimate, a bathroom tap delivers about 4 litres/minute. If we estimate that half the world population cleans their teeth once/day and runs the tap for one minute; the daily global water usage from cleaning our teeth equates to 6,400 Olympic swimming pools/day. This figure, is in addition to the consumption of water up and down the supply chain; which is undocumented.

Beyond actual environmental impacts, we should also consider the demographics of our population, at a global and regional level. Ageing populations in MHICs are increasingly dentate and in need of complex oral healthcare, that 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 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 her/his 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 to reduce 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 patients and professionals. As a supply chain, we are presented with the choice of operating in the manner of a linear economy that is hugely wasteful of resources with an accompanying high pollution cost (*Figure 1*); 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 2*). The current, mostly linear supply chain economy, presents a barrier to reducing the impact of the industry on the environment.

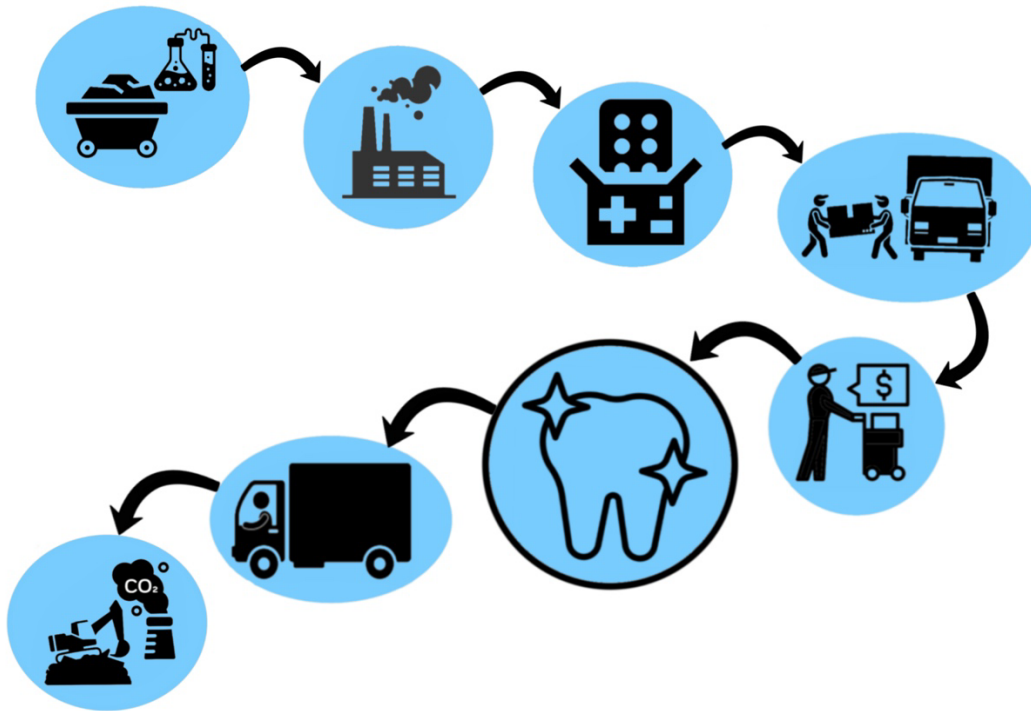


Figure 1- Linear economy in oral healthcare. A point-to-point journey for products with all resulting waste with zero-value. *Mineral extraction, production and synthesis of raw materials >>> Manufacture of equipment, materials and sundries >>> Packaging >>> Product Distribution and Logistics >>> Product Procurement >>> Clinical and Consumer Healthcare >>> Waste Collection with different levels of contamination >>> Waste Disposal through landfill and incineration.*

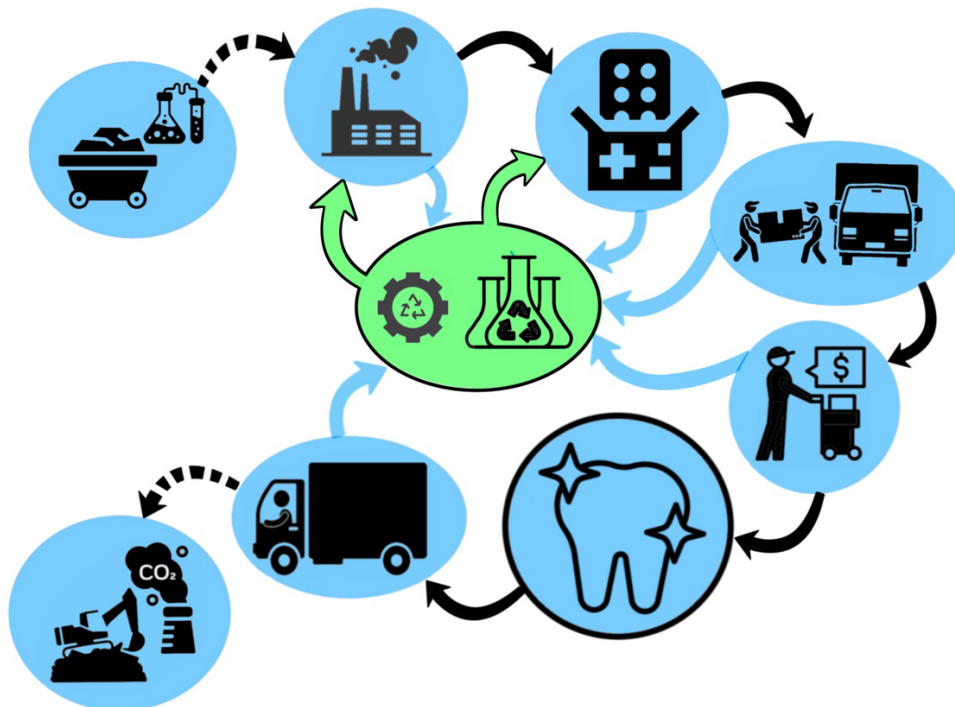


Figure 2-Circular economy in oral healthcare. *Reduced reliance on the extraction and synthesis of raw materials and disposal in landfill or incineration. Waste from materials and packaging are diverted back into the supply chain through mechanical and chemical recycling.*

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 that are showing increasing awareness of this need. Notwithstanding, within the supply chain there appears to be a reduced level of awareness downstream, amongst the end-user community (dental professionals, patients and consumers) of the impact of oral health on the environment and need for sustainable practices within the supply chain.

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 frameworks [Environment, Social and Governance (ESG)] or through the alignment to UN Sustainable Development Goals¹ (See *Sustainability in Oral Healthcare*). 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.

Companies mostly recognise the benefit and need to characterise and understand environmental impacts arising from the core business. This is derived from various sources, that include: Leverage insights from Life Cycle Analyses (LCA) studies, published studies and research work with internal and external experts, NGOs and research organizations; 3rd party verification of footprint by category; studies completed on all major product formats; 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 Life Cycle Analysis (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^{27,28}. Within this low level of awareness in the oral health care sector, there is a wide range between different challenges in different world regions, each with its own very particular challenges. Anecdotal evidence indicates that this is a particular problem in LMICs with high levels of product packaging and associated high shipping and transport needs.

There is a recognition of a need to engage with regulatory bodies, such as ISO (TC106 Dentistry)²⁹, and the International Dental Manufacturers Association (IDM)³⁰ to ensure an alignment of manufacturing and sustainability.

Notable lack of awareness amongst the whole of the industry, that the single most effective route to sustainable care is through the provision of good quality care, that includes prevention at its core. Essentially, good oral healthcare, through prevention or delivery, results in fewer interventions and a reduced environmental impact ^{21,28}.

2 – Challenges

The greatest barrier to the implementation of sustainability is ‘set behaviours and attitudes’ within the profession and even more so in LMICs; where the greatest 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 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 ‘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 and 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. 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 whilst balancing costs and priorities is a challenge, if done right, it enhances the company's trust and value. Notwithstanding, it is acknowledged that 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; that can be very numerous and diverse, requiring 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.
- 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 vs minimising waste – disposable vs reusable).
- The 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 working solely within the structure of their internal corporate responsibility or ESG (Environmental, Social and corporate Governance) frameworks and in doing so, failing to engage more widely with the supply chain.
- Legislative frameworks for manufacturing, packaging, distribution and safe clinical care that ‘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 of 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.

Challenges to operating in a Circular Economy

- Identification and implementation of a framework that will engage the whole supply chain. This 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.
- Manage the environmental sustainability of products (and associated transport and packaging) entering and leaving the company within the supply chain.
- Understand that neither providers nor customers wish to compromise performance for more sustainable options.

- Need to engage all stakeholders, and in particular end-users (private citizens and professionals) with a sustainable culture with respect to health-care 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 of its practice.
- 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.
- Manufacturers need to make products and associated packaging more recyclable, whilst ensuring appropriate recovery of these products for subsequent recycling.
- 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 (Company 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 permeate outwith to the broader supply chain.

A series of specific stakeholder drivers are identified:

- Company employees see the status of their company within the industry as an important opportunity to promote sustainability in the sector.
- It is essential to engage in a non-partisan collaboration with other supply chain stakeholders to achieve impact.
- Company culture is a key driver to sustainability improvement.
- Improving sustainability is a driver to improve business profitability.
- Auditing measurable specifics (e.g., waste, energy and recycling) drive improvement.
- Legislation can drive compliance and public advocacy through trade associations, rewarding best practice and informing public policies.

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:

- Promote company sustainability leadership and recognition externally as well as internally is important to them.
- Reinforce perception that sustainability is a growth driver and that doing good (or being sustainable) is good for business.
- Empower employees to be part of the change, help them contribute and feel meaningful.
- Promote behaviour change through education, support/praise engagement and recognize success.
- Engage with employees to create a feeling of ownership.
- Proactively influence and make a difference in the everyday work.

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 UN-SDGs^{Error! Bookmark not defined.}. This strong pervasive level of engagement is a major driving force for sustainable practice in companies, as part of the corporate 'mission' for companies.

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. These are three general key drivers that present significant opportunities to our oral health care industry.

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:

- 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.
- Designed to raise awareness (through education) and embed a sustainability culture across all functions of the company.
- Designed to drive the quality of the engagement across the business.
- Promote individual responsibility.
- To integrate sustainability throughout the company business with identification of areas of strongest impact.
- Build sustainability into the business growth strategic plan.
- Work in line with the UN Sustainable development goals^{Error! Bookmark not defined.}.

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 impact on end users and across the supply chain; with notable reduction in CO₂ emissions and waste generation^{21,28}.

Generic drivers for a more sustainable supply chain

- Strongly established social ethical responsibilities within companies that 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 active supply chain stakeholders up and down the supply chain and work to achieve big benefits from full and comprehensive engagement with supply chain stakeholders.
- 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’³¹.

4 – Opportunities

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

Environmental impacts - CO₂e, air and water

Companies have an opportunity to develop a carbon-positive supply chain through the following actions:

- **Strive for circular solutions in the supply chain:** Reducing our footprint and moving towards circular solutions in the supply is not only the right thing to do, it also helps make logistic operations more efficient and resilient.
- **Identify and engage with opportunities to implement a circular economy.** Working with stakeholders and expertise to provide guidance, and seek opportunities at both individual stakeholder level and as a ‘joined up supply chain – from mineral extraction to waste management’. Promote, inspire, help, engage upstream and downstream with environmental sustainability. For example, focus 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. 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 the importance of **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. Notwithstanding, such a collaboration requires:

- Active and strategic collaboration and clear procurement policies (clear KPIs and expectations).
- Collaborative approach to distribution and use of products that focuses on energy, water efficiency and reduction.
- Build the mastery, incentives and the means to adopt more sustainable practices (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 focus 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.

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; establish partnerships to drive change and find sustainable solutions; and work 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 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 (e.g., EMF, EPR, RSB, CGF and WRI)
- Help suppliers understand and define goals for themselves.
- Engage, discuss and find mutual positive feasible business value.
- Establish closer dialogue and networking.

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

- Obtain baseline measurement of individual stakeholder carbon impact; to identify opportunities and to enable activities that will reduce this.
- Reward engagement and impact through awards.
- Establish '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 decarbonize our global supply chain.
- Establishment of internal sustainability 'road maps' towards Net Zero Carbon that will indicate a practical, prioritised, challenging and impactful route.
- Reduce 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 delivery²¹.
- 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. Moreover, each sustainable practice 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 is achieved through different routes, ideally considered in a collective and synergistic manner; where the sum of the parts yields more positive outcomes. Any potential remediation strategy, needs to be based on a sound understanding of the existing levels of awareness amongst the various stakeholders and the inherent challenges that exist, both in the systems they represent and 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^{24,25}. 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.

Route 1 - Reduce, Reuse, Recycle and Rethink

Awareness & Challenges

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

There is a realisation of the 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)**. 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 as waste for incineration or landfill³². 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., UK Plastics Pact that has set targets for 2025 with the headline of 100% of plastic packaging to be reused, recycled or compostable³³).

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). 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 (municipal domestic systems). Plastic devices, for example, are often assembled from multiple polymers in multi-layer constructs and combined (glued/welded) in complex shapes are very 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 equates to approximately 2bn dental SUP items per year (14.4 tonnes)³⁴. The additional PPE

required during the COVID-19 pandemic increased this figure to approximately 2.4bn 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 ^{27,34,41}.

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 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 allows).
- Actively exploring use of recycled materials & 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 commitment³⁵).

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^{28,31}. 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 is 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**; this being key to holding a strong company image that will influence an equally strong drive of a sustainability strategy and as a consequence of this, foster a strong positive customer response.

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 emphasize citizen responsibility and the inherent value of a used product and its associated packaging.

Drivers & Opportunities

As per the United Nations' waste management inverted pyramid³⁶, **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 3). Reuse is not considered a viable option for SUPs that arise from 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 our industry.

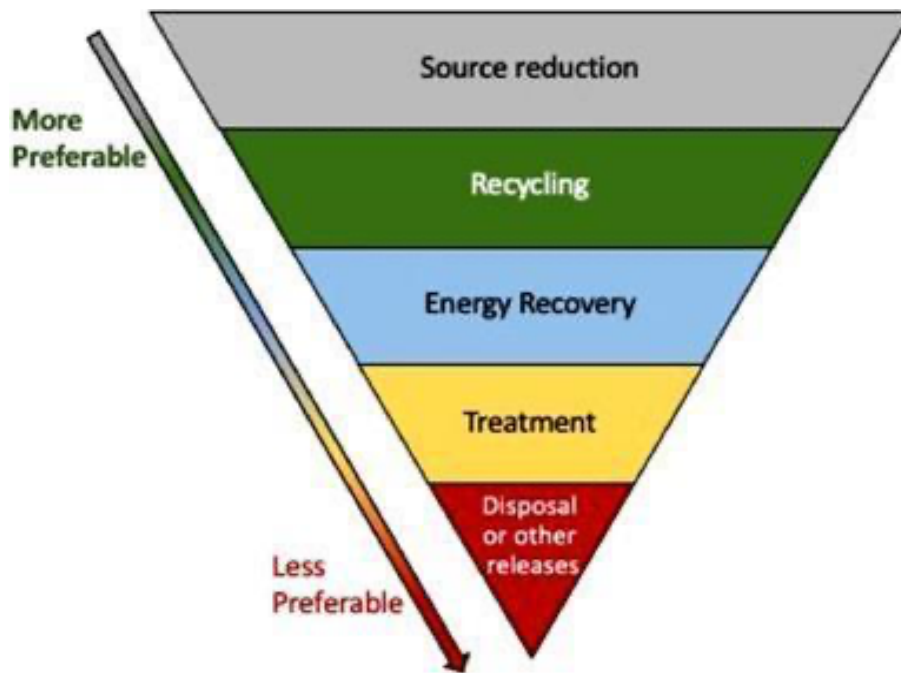


Figure 3: Waste management inverted pyramid (adapted from the original publication – UNEP, 2013)

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).

Company focus

Need to 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.

Need to 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.

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

Need to increase our knowledge base, with a specific focus on:

- Identify the biggest contributor sectors, within companies or supply chain, to plastic waste and encourage new technology to reduce this.
- Understand the consequences of replacing a material with another and the impact that this will have. In this context, understand the complexity of plastic and the difference between, for example, bioplastic, biodegradable plastic and fossil-based plastic from a LCA perspective and compare this to the alternative replacements.

- Understand how plastic products and/or associated containers/packaging are used today. Identify essential vs superfluous plastic that can be eliminated. Identify the benefits of recycling for specific items in terms of net carbon footprint.
- For 'essential' plastics, identify the resources that need to be put in place to drive an improvement of the sustainability profile.
- 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.
- Consider alternative materials, that can replace current ones; and that can be produced at scale.
- Work with the supply chain to develop and impact recycling of plastics from packaging and clinical use.
- Educate and inform about waste management and take plastic waste to a circular economy to prevent it from ending up in landfill or incineration.

The different supply chain stakeholders (e.g., manufacturer, distributor and end-user) to **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 full value 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.
- 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.
- Establishing a baseline knowledge analysis, through life cycle analysis, with the engagement of suppliers, distributors, and end-users.

Clinical and society focus

Reduction is best achieved through the delivery and maintenance of good oral health, focused on prevention and high-quality interventions²⁸. This approach focuses on a reduction for the need of restorative consumables and interventional 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 do not **require** revising. This model is an excellent fit for dentistry. The whole supply chain benefits through this and in doing so has a direct beneficial impact on waste and CO₂ emissions.

Understand the need to contextualise challenges and opportunities for plastic use and recycling, according to the local geographical and societal framework. Local assessment on what is achievable and what will have biggest impact in the different world regions or countries^{20,37}. A global code of good practice should make adjustments for global regional variations to ensure that it is practical and achievable.

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 ³⁸. Notwithstanding, there is also an acknowledgement that it goes beyond funding to include other elements such as infrastructure, culture & sustainability mindset.

The 'Supply & 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 & 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, that may require further regulations to address supply chain sustainable outcomes.

Products are heavily regulated at a national and international level, to ensure their safety 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:

- Lack of a forum that enables discussions and engagement with policy regulatory bodies, end users, other stakeholders up and down stream.
- 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 that fails 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'³⁹, 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 as a driver and 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 not-logical, 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 amongst industrial companies that **lawful 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. Notwithstanding, there is a need to be mindful of setting artificial boundaries or incentives relative 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 standardized 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 & Opportunities

Legislation should act as an advocacy tool, to support sustainable practice by incentivisation, rather than limit 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.

The introduction of new legislation/regulation is a significant driver and opportunity for stakeholders to influence the content of such legislation. Ultimately, legislation will dictate the actions of any stakeholder and we should use this opportunity to drive the required changes to deliver a framework that is fit for purpose in every respect.

Industry needs to embrace new 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.

Effective partnerships in the industry to promote research and harness best practice research models (e.g., LCA methodology) could help inform legislation to improve industry sustainability profile without compromising on oral health outcomes. In this context, the implementation of common policy is considered as 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 responsible sourcing of biomaterials and fuels.** Forging alliances with expert organisations, such as The Roundtable on Sustainable Biomaterials (RSB)⁴⁰

There is a recognition of the need for **Legislation to drive change as profit remains the priority for businesses**. There is also an associated conflict of interest between legislation that drives safety and the need to achieve sustainable targets.

Legislation can help drive progress across companies, industries, and countries, also across the supply chain. Having a common (and clear) legislative framework across Europe 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.

Policy makers and legislative powers need to **avoid the introduction of new regulations and legislation with apparently competing drivers** (e.g., Patient safety vs sustainable materials).

Route 3 - Waste Management

Awareness & 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 this³⁴.

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 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, that currently does not exist as waste that is passed downstream becomes the responsibility of the end-user.

Plastic packaging and SUPs

Single use plastic forms an essential and indispensable part of current healthcare provision at all levels and in all clinical environments. 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 with no risk of contagion. 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^{27,41}.

The manufacturing versatility, cleanliness and the sterility guarantee of plastic devices, together with their cost effectiveness makes reusing and/or recycling economically unattractive. There is a recognition that this **reliance on SUPs creates a highly wasteful linear economy** for SUPs in which they fulfil all the major requirements of a risk-averse industry that operates within very tight budgetary constraints.

Whilst recognising the intrinsic usefulness of SUPs to oral healthcare, it is also imperative that we 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 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 amongst supply chain stakeholders for the development of plastic items that can be easily recovered and recycled.
- 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 on different markets for handling of waste makes it complex.
- Fitting the economics of recycling into the company business model.
- Regulatory restrictions. E.g., the need to ensure that extractables and leachables from primary containers do not interact or affect the product.
- Safety requirements on medical devices – The need for food grade recycled materials. These are not available at scale and are in competition with other larger industries, such as the food industry.
- The need to overcome end-user (private citizen) consumer habits, characterised by low engagement with sorting and separating bathroom waste products (i.e., toiletries and personal health care products).
- Lack of global recycling capability that will provide recycled high-quality plastics in the required volume.
- The impact of infectious diseases associated with a requirement/desire for higher levels of patient safety that is coupled with tough legislation.
- Maintaining patient services and safety during the COVID-19 epidemic has moved the focus from the environment.
- Regulation and legislation are focused (at the exclusion of many other considerations, including sustainability) on high safety standards for the end-user

- Need to consider the environmental impact of single-use metallic instruments that could potentially safely be reprocessed. This needs to be considered from the perspective of manufacturing quality, safety profile and regulation.
- There is widely accepted inadequate knowledge and poor attitudes towards the generation and management 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, 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 & 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 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 both recyclable with appropriate drop-off downstream facilities.

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

Recycling pre-clinical plastic waste (products and packaging) that arise 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 (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.

- Follow 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.
- Define plastic waste as a resource that is part of a circular economy rather than waste.
- Include 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 biobased).
- Accept joint and shared responsibility for the management of this waste with all sectors of the supply chain, including the recycling industry.
- Establish collaborative partnerships and communicate effectively with peers, NGOs and other stakeholders that will drive and enable innovation, new designs, build infrastructure and secure quality recycled resin.
- Influence consumer mindset, but with the required infrastructure in place that enables the consumer to act in a responsible way.
- Develop a fully circular supply chain that can handle small-format items at commercial scale.

Route 4 - Procurement & Logistics

Awareness & 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 as 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 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 to not be associated with higher overheads than conventional (less-sustainable) practices. The rationale for this is that the sustainable option may have high upfront costs for implementation but more sustainable processes tend to be lower cost ongoing (and are likely to be more so 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. Dental practices operate in small discrete entities to meet the needs of their local population; the majority of dental practices have very limited storage facilities, relying on daily deliveries and collections. This results in increased distribution costs involving many journeys contributing further to CO₂ emissions. There is need to consider if the existing model of dental care is effective or if larger centres with optimised distribution logistics, storage and dedicated transport links is a more efficient concept from a patient care, financial and sustainable perspective.

Procurement is not understood well at the level of dental practices. There is a need to provide educational programmes to enable smart purchases – Bulk buying, less packaging, shared distribution costs.

Manufacturing distribution logistics is very disjointed and wasteful of resources. There is an opportunity for companies to collaborate in optimisation of distribution logistics.

Drivers & Opportunities

Each stakeholder needs to engage in environmentally sustainable practices and in this way allow for the supply chain to organically develop into 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**; that will result in an improved circular economy. Examples of this are:

- Include 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, transport of products to save journeys and transport.

Sustainable operations are a business opportunity for the companies

- Operational sustainable practices with increased efficiency require less energy, water, distance travelled, produce fewer CO₂emissions and waste, which result in cost savings.
- The production of better products and increased consumer engagement and product loyalty etc.
- 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 and sharing best practice is 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 level of engagement. Such summits should work in both directions and not only 'transmit from the buyer' but also 'receive from the supplier'.

New service models must be considered, that meet the needs of the population, through the provision of effective oral healthcare with environmentally sustainable gains. This service should aim for the provision improved logistics with less transport of goods, reduced commute 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 & Education

Awareness & Challenges

Research

There is a clear need for primary research into all aspects of our industry, that 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, 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 priority⁴².

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^{2,Error! Bookmark not defined.}.

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 the pedagogic 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^{43,44,45}.

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 aspect of running future dental practice. 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 individual entities 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 consumer empowerment to drive green oral health care products. Greater recycling rates of consumer end user (e.g., promote better management of bathroom waste plastics).
- The use educational programmes to overcome human factors and attitudes that remain a strong barrier to changes in sustainable practice and this should be explored.
- 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 & Opportunities

Sustainability works hand-in-hand and synergistically with the core principles of 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**²⁸. It is important that these umbrella principles are not used as a tool to discriminate 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 healthy oral care 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 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’ (Important and easy) that can drive and act as precursors for greater engagement** (E.g., FDI sustainability infographics²¹).

Within the context of oral healthcare providers, there is recognition that **sustainability is a strong driver for successful clinical practice business models**³¹– ‘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 is 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. Focus on prevention needed.

Company Stakeholders

There is an acknowledgment that **the dental industry is an influential driver and provider of professional education, that can include sustainability.**

Within companies, there is a **need to increase awareness, understanding brand loyalty and motivation of the work force.** 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.

More broadly, **the oral healthcare industry** (the entire supply chain) **has a responsibility to promote innovation, research and harness best practice models from experience that will identify and support sustainable practices within the supply chain.** This is considered essential to provide actionable data for industry facilitates innovation and progress.

Companies have an opportunity and responsibility to engage, promote and resource impactful research activities in the field of environmental sustainability. Research outcomes are:

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 and;
5. Identify and support feasible sustainable business practices.

In this context, there is an **opportunity for companies to re-distribute internal resources**, that have been allocated to marketing, ESG and other sustainable projects, **to promote sustainable practice**. In this way widening the scope of these resources to have a greater, complementary and synergistic (with other activities) effect; internally and across the supply chain.

Beyond this, 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 for the **need of a science-based approach to sustainability interventions, adoption of best-in-class and sharing of best practice across the sector**; that 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 of 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; (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 health care (medicine) should be considered as 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 sheer high number of oral healthcare professionals globally presents an invaluable opportunity to disseminate influential and impactful messages. Examples of this are:

- To drive awareness with patients on the importance of preventive dentistry and at home habits;
- Educate on responsible consumption (e.g., the disposal of products or packaging or not wasting tap water during oral care routines);
- Reduce 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 8bn 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, increase awareness and remediation actions through carefully channelled educational programmes; a process that is currently underway that considers how sustainability can be included in the undergraduate dental curriculum^{43,44,45}. 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 of sustainability and prevention within a paid for healthcare system.
- 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 policy makers 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.
- Other educational opportunities exist that should be explored to gain maximum levels of awareness and engagement.

The promotion and integration of sustainable practice into continued professional development programmes, such as the programme run by the Green Impact initiative⁴⁶. 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 message²⁸: *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**^{27,41,47}.

Remote clinical services and tele-dentistry present an opportunity, requiring further professional engagement and associated legislation to ensure its effectiveness.

Notwithstanding it is an acknowledged fact that oral healthcare professionals look up to national associations and governments or legislations 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 & 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.

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 sophisticated and standardised Life Cycle Analysis** (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 pathways⁴⁸:

- Disposal to landfill of expired materials
- Incineration of waste materials
- Microparticulate waste from use of dental materials^{49,50}
- 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 well in accordance with the manufacturer's instructions; and
- Through effective maintenance programmes.

There is an existing high level of awareness associated with the environmental impact of dental amalgam^{51,52,53,54}. The 'Minamata Convention on Mercury' has stipulated a reduction or cessation of dental amalgam is to in most countries⁵⁵. 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 ^{2,Error! Bookmark not defined.,56,57}.

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, that 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.
- Availability of new materials.
- Product safety considerations.

- High testing requirements to meet quality standards (stability & consumer acceptance etc..) and the time to undertake these.
- Availability at scale whilst maintaining a low environmental impact profile.
- Understanding the complexity of sustainability and its actual impact it (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.
- Understand that durability is key to sustainability, so that replacements are obviated during the lifetime of the patient.

There is an increasing desire for ‘cosmetic dentistry’ with potential consequences to oral health, as stated in the joint statement by UK specialist dental societies⁵⁸ “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”. Arguably, the same is possibly true of other non-restorative procedures, such as elective cosmetic maxillo-facial surgery and orthodontics with oral health and psychological consequences. It should be noted that **these cosmetic, elective treatments also have an environmental impact that is potentially avoidable.**

Drivers & 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 bench mark 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, enable 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, TC106 can be used as a vehicle to incorporate sustainability into all the dental standards²⁹. It may 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 a 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.”⁵⁹

Specific opportunities for the manufacturing industry:

- Review and challenge the shelf-life of materials – e.g., replace with a concept of functional vs 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.
- Review the value of glass ionomer and improvements in longevity for treating elderly patients.
- Undertake standardised LCA of materials will help to identify opportunities and acceptable trade-offs/compromises.
- Review the expiry and shelf life of materials versus packaging style (compules)
- Review and consider 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.

Remediation strategy

A broad remediation strategy has been identified on the basis of the previous elements of this report, that 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 real *opportunities that exist or that can be created through this collaborative working partnership*. The impact and effectiveness of this remediation strategy 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.

The remediation strategies 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 remediation strategy, that is collaborative and non-partisan**, 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.
- Learning best practice from other sectors and reciprocating with translation to other sectors.
- Demonstrate leadership in healthcare.

This remediation strategy complements the **strategic objectives identified in the Executive Board Report by the Director-General of the WHO (January 2022)⁶⁰**:

- **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 health care** – Integrate essential oral health care and ensure related financial protection and essential supplies in public health care.

- **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 policy-making.
- **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 remediation strategy presented in this document provides a framework for future *strategic action* and as such does not intend to provide detailed granular detail for specific approaches or projects. Three key principles govern the effectiveness of this strategy: Collaboration and leadership, person-centred oral healthcare and the role of enabling agencies.

Each of the routes to sustainable oral health is explored with focused statements of action: Reduce, reuse, recycle and rethink; Legislation, policy and guidelines; waste management; procurement; research and education and; materials for clinical use.

Collaboration & 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 is 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 amongst 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, 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.
- Establish centralised, non-partisan, platforms for sharing examples of good practice and data.

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.**

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, that 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.

Enabling agencies

External organisations (e.g., Government, professional institutes, legislative authorities, etc.) **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'⁸. Key to this 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.
- Create 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).
- Work with trusted non-partisan leaders to continue to support good practices and drive action (e.g., RSB, WRI, EMF, etc...).
- Create 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 legislation 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.

Remediation through 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 domains²⁸: *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, results in an overall reduction in CO₂ emissions; (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. For example, the activity from the Flexible Plastics Consortium is a good example of progress in this respect³².

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.
- Establishment of partnerships, collaboration and communicating examples of good practice.
- Speaking with one voice to drive change.
- Via 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 limit 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 enables discussions and engagement with policy regulatory bodies, end users, other stakeholders up and down stream.
- Active and regular input to 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 patient's and consumer's oral health.
- Incentives and support for sustainable business practices that demonstrate sustainable outcomes, rather than limit 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) 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.

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 to be a lesser challenging route to circularity, than the use of clinical or consumer contaminated plastic. 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.
- There should be 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 biobased 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 of 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 as 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 & Logistics

The supply chain should unite as a single entity to develop less cumbersome systems and processes with improved logistics capacity with sustainability as a key driver; that 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, manage 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 the environmental sourcing, ethical manufacturing, supply chain distribution and procurement.

Identify mechanisms for the re-distribution 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 a particular market.

Route 5 - Research & 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 sponsor relevant and impactful scientific studies⁶¹.

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 industry wide LCAs in healthcare to help identify or exclude options that will engage significant opportunities.

Conduct combined health-economic-sustainability impact analysis 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** amongst **all stakeholders with a focus on end-users (clinical and consumers).**

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.
- **amongst 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.
- **amongst 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 care²⁸.

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, 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 commute) and pollution associated with the manufacturing, supply and provision of restorative materials or other products.

Research focus on 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 TC (Technical Committee) ISO TC 106 Dentistry.

Conclusion

Climate change and environmental pollution represent two of the greatest problems facing humanity and the planet. The oral healthcare sector recognises the value and positive impact of further improving environmental sustainability at every stage of 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 author 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 diverse 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. Key remediation strategies have been identified as a result of this collaborative programme, that are based on defined opportunities to improve sustainability in the delivery of improved oral health. These remediation strategies are based on the evidential and experiential knowledge alongside insights and expert opinions from the diverse stakeholder community engaged by the FDI. Furthermore, remediation strategies 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 also therefore 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 coordinate to develop even more resource efficient systems and processes, with improved logistics capacity. *Reduce* and *recycle* should be the focus a remediation strategy as being the most practical and readily implementable approach. That is, a reduction of packaging, pre-clinical, 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 governments, professional bodies, and legislative authorities including regulators) are strongly encouraged to support the 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 designing products and services, that enable them to reduce their oral health related carbon footprint.

There is a need to promote and support 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, tele-dentistry, 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, that 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 amongst 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 policies 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 who represent 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, the whole sector undoubtedly makes a significant contribution to oral health that improves quality of life for millions of people worldwide. While some improvements in sustainability have been made 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 1- Contributors

Task Team

Nicolas Martin	Chair, Sustainability in Dentistry Task Team; FDI World Dental Federation
Steven Mulligan	Councillor, Sustainability in Dentistry Task Team; FDI World Dental Federation
Duygu Ilhan	Councillor, Sustainability in Dentistry Task Team; FDI World Dental Federation,
Jim Zenk	Chair, FDI Dental Practice Committee; FDI Sustainability in Dentistry Task Team

Founding partners

Ann Tracy	Chief Sustainability Officer; Colgate-Palmolive
Gareth Ruddock	Senior Global Marketing Director, Oral Health-Conscious Consumption; GlaxoSmithKline, Consumer Healthcare
Maria Jung	Communication Manager; TePe
Cristina Morillo	Director Global Oral Care ESG Brand & Communications; P&G
Joel Hornberger	Director, Global Environmental, Health & Safety; Dentsply-Sirona

Participants

Ali Theyab	Head of Advisory Board, International Association of Dental Students (IADS)
Andreas Syrek	Global Medical Director and Chief Dental Officer; 3M Oral Care
Angela Rovera	ANDI, Italian National Dental Association
Anna Nilvéus Olofsson	Manager Odontology and Scientific Affairs; TePe
Annette Altenkirch	Innovation Manager, MULTIDENT Dental GmbH
Arish Naresh	Chief Executive, Omeo District Health and President; International Oral Health Association
Bart Dopheide	General manager Scientific Services; GC Europe NV
Burkhardt Gabriele	Head of Product Segment Treatment Auxiliaries; Coltène/Whaledent and Certified Partner of Terra Institute
Chrispinus Mumena	Head of Dental Clinical Sciences Department; School of Medicine, Copperbelt University, Zambia

Participants

Christopher Fox	Chief Executive Officer; International Association for Dental Research
Claudia Rodriguez	President, "SOCİ Colombian Dental Implant Association; El Bosque University
Clio Boura	Head of Packaging Oral Healthcare; GlaxoSmithKline Consumer Healthcare
Corrie Jongbloed-Zoet	President, International Federation of Dental Hygienists (IFDH)
Donna Hackley	Instructor; Harvard School of Dental Medicine
Elizabeth Shick	Associate Professor; University of Colorado
Falk Schwendike	Director, Oral Diagnostics, Digital Health and Health Services Research; Charité - Universitätsmedizin Berlin. FDI Science Committee
Hasan Jamal	Paediatric Dental Surgeon - BDS, DCLinDent Paediatric Dentistry, MSc Regenerative Dentistry, MSc Biomaterials
Helena Ossmer Thedius	Director Marketing & Innovation; TePe
Helen Whelton	Head of College of Medicine and Health, University College Cork. Chief Academic Officer HSE South, South West Hospital Group
Ian Shellard	Director, Aqos Consulting Ltd
Jeff Platt	Professor and Chair, Department of Biomedical Sciences and Comprehensive Care, Indiana University School of Dentistry
Jefferson Clarke	Barbados Dental Association
John Milne	National Dental Advisor Care Quality Commission
Jonas Billen	EHS Specialist – Kulzer GmbH
Julian Fisher	Coordinator and Senior Researcher, Planetary Health and Global Oral Health, Charité University Berlin, Germany
Julie Hunt	Senior Director Global Oral Care R&D, Sustainability, P&G
Les Kalman	Assistant Professor, Schulich Dentistry
Manon Agrissais	Senior R&D Project Leader, SDI Limited
Manu Mather	Head: Health Policy; Public Health Foundation of India and Professor in Dental Public Health, Queen Mary University of London
Mick Armstrong	FDI Dental Practice Committee Vice-Chair, British Dental Association Health and Science Committee Chair
Pam Clarke	Member of Royal Australian College of Dental Surgeons, International Dental Manufacturers Association
Paul Batchelor	Associate Centre for Sustainable Healthcare, Hon. Professor School of Medicine UCLan

Participants

Paul Farrar	Research & Development Manager, SDI Limited
Paul Hatton	Professor of Biomaterials Science, School of Clinical Dentistry, University of Sheffield
Raman Reddy	Dental Officer at Rakiraki District Hospital, Fiji
Rick Glass	Vice President – Global Sourcing, Henry Schein, Inc.
Virginia Hochstetter	Head of Sustainability and Corporate Responsibility, Straumann Group
Wha Than Lin	Member of Executive Committee, Secretary of Oral Health Education Committee, Myanmar Dental Association

Appendix 2 - Glossary and Definitions

Acronyms and Abbreviations

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 ⁶² .
CO2e	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 & Safety strategy and then streamlines its implementation and management
EMF	Ellen MacArthur Foundation (Global Commitment) ²⁴
EPR	Extended Producer Responsibility (for Packaging) ⁶³
ESG	Environmental, Social and Governance (Business Operational Framework).
FDI	Federation Dentaire Internationale (World Dental Federation)
KPI	Key Performance Indicators
ISO	International Standards Organisation
IDM	International Dental Manufacturers Association
LCA	Life-cycle Analysis
LMIC	Low-Medium Income Countries
MHIC	Medium-High Income Countries
NGO	Non-Governmental Organisation
PPE	Personal protective equipment.
WHO	World Health Organisation
RSB	Roundtable on Sustainable Biomaterials. ⁴⁰ 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, Recover.
UN-SDGs	United Nations' Sustainable Development Goals ^{Error! Bookmark not defined.}
WRI	World Resources Institute ⁶⁴

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 ⁶⁵ , Plastics 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 oral healthcare supply chain that includes any and every stakeholder-associated provision of raw materials, goods, 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 <i>removing</i> carbon dioxide from the atmosphere rather than adding it.
Sustainability in Dentistry Task Team	The group charged by 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.

Appendix 3 – Map of Consensus Statement to the United Nations Sustainable Development Goals

CS THEMES →	Reduce, Reuse, Recycle, Rethink	Legislation, Policy and Guidelines	Waste Management	Procurement and Logistics	Research and Education	Materials for Clinical Use	Remediation Strategies
↓ UN-SDGS							
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

The table records the number of statements or comments within each section of the Consensus Statement that relate directly to one (or more) of the 17 UNSDGs.

It does NOT indicate:

- How much focus/effort the Stakeholders collectively or individually believe should be afforded to a specific CS topic or action.
- The relative importance that the Stakeholders, collectively or individually, apply to a specific UNSDG.
- How quickly or effectively any specific CS recommendation can be implemented.

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