Turun yliopisto
University of Turku

# IMPROVING ORAL HEALTHCARE IN SCOTLAND WITH SPECIAL REFERENCE TO SUSTAINABILITY AND CARIES PREVENTION

Brett Duane

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# Abstract

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**Improving oral healthcare in Scotland with special reference to sustainability and caries prevention**

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Dentistry must provide sustainable, evidence-based, and prevention-focused care. In Scotland oral health prevention is delivered through the Childsmile programme, with an increasing use of high concentration fluoride toothpaste (HCFT). Compared with other countries there is little knowledge of xylitol prevention. The UK government has set strict carbon emission limits with which all national health services (NHS) must comply. The purpose of these studies was firstly to describe the Scottish national oral health prevention programme Childsmile (CS), to determine if the additional maternal use of xylitol (CS+X) was more effective at affecting the early colonisation of mutans streptococci (MS) than this programme alone; secondly to analyse trends in the prescribing and management of HCFT by dentists; and thirdly to analyse data from a dental service in order to improve its sustainability.

In all, 182 mother/child pairs were selected on the basis of high maternal MS levels. Mothers were randomly allocated to a CS or CS+X group, with both groups receiving Childsmile. The intervention group consumed xylitol three times a day, from when the child was 3 months until 24 months. Children were examined at age two to assess MS levels. In order to understand patterns of HCFT prescribing, a retrospective secondary data analysis of routine prescribing data for the years 2006-2012 was performed. To understand the sustainability of dental services, carbon accounting combined a top-down approach and a process analysis approach, followed by the use of Pollard's decision model (used in other healthcare areas) to analyse and support sustainable service reconfiguration.

Of the CS children, 17% were colonised with MS, compared with 5% of the CS+X group. This difference was not statistically significant (P=0.1744). The cost of HCFT prescribing increased fourteen-fold over five years, with 4% of dentists prescribing 70% of the total product. Travel (45%), procurement (36%) and building energy (18%) all contributed to the 1800 tonnes of carbon emissions produced by the service, around 4% of total NHS emissions. Using the analytical model, clinic utilisation rates improved by 56% and patient travel halved significantly reducing carbon emissions.

It can be concluded that the Childsmile programme was effective in reducing the risk for MS transmission. HCFT is increasing in Scotland and needs to be managed. Dentistry has similar carbon emissions proportionally as the overall NHS, and the use of an analytic tool can be useful in helping identify these emissions.

**Key words:** Sustainability, carbon emissions, xylitol, mutans streptococci, fluoride toothpaste, caries prevention.

# Tiivistelmä

Brett Duane

***Suuterveyden edistäminen kestävän kehityksen ja kariesprevention kannalta***

Turun yliopisto, Lääketieteellinen tiedekunta, Hammaslääketieteen laitos, Sosiaalihammaslääketiede. Suun terveystieteiden tohtoriohjelma (FINDOS-Turku), Turku, Suomi
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Hammaslääketieteen pitää tuottaa kestävää sekä näyttöön ja ennaltaehkäisyyn perustuvaa hoitoa. Skotlannissa suuterveyden ennaltaehkäisyä hoidetaan Childsmile-ohjelmalla, jossa hyödynnetään yhä enemmän korkeapitoisia fluorihammastahnoja (HCFT). Verrattuna muihin maihin Skotlannissa tiedetään hyvin vähän ksylitolipreventiosta. Englannin hallitus on asettanut tiukat päästörajoitukset, joita kaikkien valtakunnallisten terveydenhuoltopalvelujen (NHS) on noudatettava. Tutkimuksen tarkoituksena oli 1) kuvailla Skotlannin suuterveyden ennaltaehkäisyohjelmaa Childsmilea (CS) ja selvittää vähentäisikö äitien käyttämä ksylitoli (CS+X) tehokkaammin lasten varhaista mutans streptokokki (MS) -kolonisaatiota verrattuna perusohjelmaan, 2) tutkia HCFT-tuotteiden reseptimääräyksiä ja käyttöä, 3) sekä suorittaa todennäköisyyslaskelmia hammaslääkärien vastaanotoilta saaduista tiedoista niiden kestävän kehityksen parantamiseksi.

Satakahdeksankymmentäkaksi äiti-lapsi-paria valittiin tutkimukseen korkeiden MS-tasojen perusteella. Äidit satunnaistettiin CS- ja CS+X-ryhmiin, ja kumpikin ryhmä osallistui Childsmile-ohjelmaan. CS+X-ryhmä käytti ksylitolia kolme kertaa päivässä lapsen ollessa 3–24 kk. Lapset tutkittiin kahden vuoden iässä MS-tasojen määrittämiseksi. Korkeapitoisten fluorihammastahnojen reseptikäytäntöjen tutkimiseksi analysoitiin vuosina 2006–2012 vallinneita käytäntöjä. Hammaslääkärivastaanottojen kestävän kehityksen arvioimiseksi hiilikirjanpidossa käytettiin ylhäältä alaspäin- ja prosessianalyysi-lähestymistapojen yhdistelmää, ja sovellettiin lopuksi Pollardin mallia (käytössä muilla terveyspalvelun alueilla) kestävän palvelun uudelleenjärjestelyn analysoimiseksi ja tukemiseksi.

Vain 17 % CS-ryhmän lapsista oli kolonisoitunut mutans streptokokeilla, ja vastaava luku CS+X-ryhmässä oli jopa 5 %. Ero ei kuitenkaan ollut tilastollisesti merkitsevä (P=0.1744). Viidessä vuodessa korkeapitoisten reseptihammastahnojen kustannukset 14-kertaistuivat, ja 4 % hammaslääkäreistä kirjoitti 70 % resepteistä. Matkat (45 %), hankinnat (36 %) ja rakennusten lämmityskustannukset (18 %) tuottivat vastaanotoille yhteensä 1800 tonnin hiilipäästöt, 4 % NHS:n kokonaispäästöistä. Käytettäessä analyysimallia vastaanottojen käyttöaste parani 56 %:lla ja potilaiden matkakustannukset puolittuivat, mikä vähensi hiilipäästöjä merkitsevästi.

Päätelmänä voidaan sanoa, että Childsmile-ohjelma tehokkaasti vähensi MS-transmissiota. Korkeapitoisten fluorihammastahnojen määrääminen on lisääntynyt Skotlannissa, mikä vaatii sääntelyä. Hammaslääkärien hiilipäästöt ovat samaa luokkaa kuin NHS:llä yleensä ja analyysimalli voi olla käyttökelpoinen päästöjen vähentämisessä.

**Avainsanat:** Ksylitoli, mutans streptokokit, fluorihammastahna, kariespreventio, kestävä kehitys, hiilipäästöt.

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IV. Duane B, Richards D, Söderling E, Pienihäkkinen K. The Maternal consumption of Xylitol to reduce Early dental Decay (MaXED) study: Does xylitol provide additional benefit to a dental prevention programme? Manuscript.

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# Definitions:

Carbon dioxide equivalent: Carbon dioxide equivalent ($CO_2$eq) is a distinct measure for describing how much global warming a given type and amount of greenhouse gas may cause, using the functionally equivalent amount or concentration of carbon dioxide ($CO_2$) as the reference (Facts101, 2014).

Carbon footprint: The amount of carbon dioxide equivalents released into the atmosphere as a result of the activities of a particular individual, organisation or community (Oxford Dictionary, 2014).

CONSORT: An evidence-based, minimum set of recommendations for reporting randomized trials.

DMF Index: DMFT and DMFS are used to numerically describe the prevalence of dental caries in an individual's permanent teeth. They are obtained by calculating the number of decayed (D), missing (M) and filled (F) teeth (T) or surfaces (S). Calculation of these figures requires determining the number of teeth with obvious cavitated caries lesions, that have been extracted, or that have fillings or crowns.

Prevented fraction (PF): The Prevented Fraction of a health problem, also known as preventive or preventable fraction, is the proportion of its incidence in a given time period that could be avoided by implementing an intervention in that population (SIGN 138, 2014).

Scope emissions:

1. Scope 1 emissions occur from sources owned or controlled by the organisation, for example, a hospital furnace.

2. Scope 2 emissions are GHG (greenhouse gases) from the generation of purchased electricity.

3. Scope 3 emissions are a consequence of the activities of the company but occur from a source not owned or controlled by the company. One example is the purchase of medical supplies.

# Abbreviations

| | |
|---|---|
| ADA | American dental association |
| CDS | Community dental service |
| CHI | Community health index |
| CO | Carbon monoxide |
| CS | Childsmile |
| CS+X | Childsmile plus xylitol (intervention group) |
| D**3**FS | D**3**FS is the number of decayed, filled, surfaces where the dental decay was at dentinal level |
| dmft | dmft is the number of decayed (d), missing (m) and filled (f) deciduous teeth (t) |
| DMFT | DMFT is the number of decayed (D),missing (M) and filled (F) adult teeth (T) |
| DEFRA | Department of environment, food and rural affairs |
| DHSW | Dental health support worker |
| DNA | Deoxyribonucleic acid |
| ECC | Early childhood caries |
| EPA | Environmental protection agency (USA) |
| EU | European union |
| FOTI | Fiber-optic transillumination (FOTI) is a visual technique that uses illumination to detect dental decay |
| FS | Fissure sealant |
| FV | Fluoride varnish |
| GHG | Greenhouse gases |
| GIC | Glass ionomer cement |
| GP | General (Medical) Practitioner |
| HCFT | High concentration fluoride toothpaste |
| HEAT | Health efficiency and access treatment (Scottish government targets) |
| HFS | Health Facilities Scotland |
| MaXED | The Maternal consumption of Xylitol to reduce Early dental Decay |
| MS | Mutans streptococci |
| NaF | Sodium fluoride |
| NHS | National Health Service |
| NMVOC | Non-methane volatile organic compounds |
| NDIP | National dental inspection programme |
| NO | Nitrous oxide |
| OR | Odds ratio |
| PAS | Publicly available specification |
| PF | Preventive fraction |
| PRISMS | Prescribing information system (Scotland) |
| RCT | Randomised controlled trial |
| RR | Risk ratio |
| SDCEP | Scottish dental clinical effectiveness programme |

| | |
|---|---|
| SEAT | South east and Tayside health boards |
| SES | Socio-economic-status |
| SIC | (UK) Standard industrial classification |
| SIGN | Scottish intercollegiate guidelines network |
| SPSS | Statistical package for the social sciences |
| SO2 | Sulphur dioxide |
| UK | United Kingdom |
| USA | United States of America |

**“Tackling social inequalities in health and tackling climate change must go together”**

**Sir Michael Marmot**
**Fair Society Healthy Lives**
**2010**

# 1. INTRODUCTION

Dental Public Health is the science and art of preventing oral disease and promoting health through the organised efforts and informed choices of society, organisations, communities and individuals. The Ottawa Charter, developed in 1986, proposed five basic principles to promote public health. These principles are to:

1. build healthy public policy,
2. create supportive environments,
3. strengthen community actions,
4. develop personal skills and
5. re-orient health services.

Traditional dental public health follows the principles of the Ottawa Charter (1986). Within Scotland healthy public policy is constructed to ensure that oral health is embedded across a wide range of healthcare strategies, such as obesity and smoking, and across all different population groups. A common risk approach is used (Sheiham and Watt, 2000) to address risk factors such as diet, hygiene, smoking, and alcohol use that are common amongst a number of chronic diseases. Dental Public Health policies can be classified as outlined by Rose (2001) as a population approach (e.g. the development of oral health education across the school population) or targeted at high risk groups, such as improving oral healthcare for elderly people living in care homes, or assisting children with high caries rates in areas of deprivation. Within Scotland there are a number of organisations that help shape policy. Dental Public Health endeavours to influence policy particularly within education and healthcare, both nationally and regionally.

Dental Public Health endeavours to create supportive environments for oral health. Within an optimal supportive environment fluoride toothpaste would be accessible at an appropriate level to the population. Children would be able to access toothbrushes and, in areas where toothbrushing may not occur at home, would be able to access such facilities at school. Prevention would be supported by the publically funded dental service, with fissure sealants and fluoride varnish financed to support their use.

Appropriate oral health promotion would occur across the community with input into community events, supporting advocacy for oral health and ensure toothbrushing programmes enjoy community participation, ownership and leadership. Personal skills would be supported. This might consist of developing toothbrushing habits of school children or the promotion of health oral health habits such as chewing sugar-free gum.

Finally, in an optimal society, health services would be re-oriented. This is particularly true within dentistry since, traditionally, the service has focused on restorative care despite the fact that there is continuing evidence of the benefits of a preventive approach involving fluoride. Services continually need to become more prevention focused.

Dentistry is, however, predominantly a clinical service. Within Scotland the service is predominantly publicly funded and, along with the broader health service, has a significant environmental impact. Oral health services are required to both prevent and treat oral disease, yet the provision of an oral health service consumes materials (with their own environmental impact), produces waste, consumes energy and involves both staff and patient travel to and from the care centre. An oral health promotion programme should be supported and promoted to reduce dental disease. Yet within a tooth-brushing programme travel occurs and this contributes to air pollution and global warming. There is growing evidence that this environmental impact has a negative influence on health both directly (e.g. air pollution) and indirectly through global warming.

The 21st century dilemma is to improve health. Primary and secondary care services are essential but they also create an environmental impact which in turn creates poor health and increases inequalities. The health sector must consider its wider public health impact beyond its responsibility for providing clinical and curative services. Health promotion policy not only needs to encourage policies that promote equality (and reduce inequality) but also contribute to a healthy environment. When one considers the Ottawa Charter with this more holistic view, an optimal oral health system is one that contributes, as described above, to oral health, while also ensuring its contribution to the global carbon footprint and environmental damage is kept at a minimum. Systematic assessment of the health impact of a healthcare system is important and must be followed by actions to ensure positive benefit to the health of the public. This impact assessment may require a re-orientation of services - not just in their focus, but also in their location.

As Sir Michael Marmot (Marmot, 2010) wrote, “Tackling social inequalities in health and tackling climate change must go together”. This thesis discusses a strategy taken within Scotland to both improve the effectiveness of oral healthcare whilst also considering its sustainability. For clarity the thesis is divided into two parts:

i) Improving the sustainability of oral health
This section focuses on climate change and the role of Public Health in improving the sustainability of oral healthcare. For the purpose of this thesis sustainability is defined as the three ‘P’s - profit, people and planet.

ii) Improving the effectiveness of oral health
This section focuses on prevention in dentistry, with special emphasis on education, fluoride, xylitol, fissure sealants, and community programmes.

# 2. LITERATURE REVIEW

## 2.1 Improving the sustainability of oral healthcare

### 2.1.1 Climate change

Climate change is the process whereby greenhouse gases (carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) increase within the planet. Their increase leads to the trapping of heat within the atmosphere causing a rise in planetary temperature. Emissions of carbon dioxide are responsible for half the change; the other gases responsible include methane, carbon monoxide, halo-carbons and nitrous oxide. Emissions of carbon dioxide have been responsible for over half of the warming influences to date. Methane, carbon monoxide, halo-carbons and nitrous oxide also have a significant warming influence (Climate science for beginners, 2014).

Within the last 120 years this increase in global greenhouse gases has led to an increase in the mean ambient global temperature of 0.85 degrees Celsius. The water temperature of the sea has also escalated, absorbing most of the increased energy stored in the climate system. Along with the rise in sea temperatures, the ice sheets are decreasing, the ocean is become more acidic, and the atmospheric concentrations of greenhouse gases are rising (Climate science for beginners, 2014).

### 2.1.2 The health effects of climate change

Climate change is considered by some as the biggest threat to human health in this century (Costello *et al,* 2009). According to Pruss-Ustin and Corvalan (2006) the death of 2.5 million people every year is attributable to environmental factors such as air pollution, extreme weather events and workplace conditions. Approximately 150,000 deaths are directly attributable to climate change (Schwartz *et al,* 2006).

Changes in climate can influence human health via biological or ecological processes. Global warming is expected to influence health directly and indirectly by impacting food security, water quality/quantity and an increased prevalence of some vector-borne diseases (McMichael, 2003). Grasso *et al* (2012) reviewed the literature that has examined the relationship between climate change and diseases. The infectious disease most likely to be influenced by climate change is malaria: a close relationship between malaria transmission and temperature spikes has been demonstrated by Githeko and Ndegwa (2001). Global warming will have a direct impact on disease, as an increase in cardiovascular disease, heat exhaustion due to thermal stress, loss of life due to flooding (Grasso *et al,* 2012) and malnutrition. The problems with climate change will be exacerbated because all of the issues are inter-related. For example, an increase in temperature can cause both malnutrition and increased malaria. Malnutrition is also linked with malaria and diarrhoea (Grasso *et al,* 2012).

Stern (2007) has highlighted the possible impact of temperature changes of one, two and five degrees. In Sub-Saharan Africa and Asia an exponentially increasing relationship was demonstrated between climate change, malaria, diarrhoea, and malnutrition. Ezzati *et al* (2002) highlighted the disproportionate effect that climate change will have on developing countries, specifically Sub-Saharan Africa and Asia, compared with colder comparatively wealthier countries.

### 2.1.3 Climate change: what needs to be done?

Burke (2012) highlights the steps that need to be taken to reduce climate change including the political obstacles that must be faced. Costello (2009) suggests three levels of action are required to manage climate change. Firstly, policies must be put in place to reduce carbon emissions and increase carbon bio-sequestration. A reduction in carbon emissions must, at least initially, underpin sustainability in order to slow down global warming and stabilise temperatures (McMichael, 2003). Secondly, the planet needs more research to be undertaken so that we understand the links between climate change and disease occurrence (Cooney, 2010). Thirdly, appropriate public health systems are needed to adapt to the adverse effects of climate change. The capacity of the human race to manage climate change also relies on the generation of accurate informational, technological, and scientific capacity (Costello, 2009).

### 2.1.4 Legislation enforcing sustainable healthcare

The UK passed legislation in 2008 (Climate Change Act, 2008) to establish the world's first legally binding climate change target. This legislation aims to reduce the country's 1990 Green House Gas (GHG) emissions by 80% by the year 2050. The legislation not only sets carbon budgets but is underpinned by a number of other supporting initiatives, including the development of GHG emission statistics, research to inform energy and climate change policy, investment in low carbon technologies and subsidies for individuals and businesses to become more sustainable.

Within industry the European Union (EU) emissions trading scheme (EU ETS,14) aims to deliver a significant proportion of the UK's carbon emission reductions between the years 2013 and 2020. This scheme works under a 'cap and trade' principle, where a carbon producing industry is allocated a certain amount of emissions. Under the scheme industry must monitor and report their emissions. If the industry exceeds what is permitted by their allowances they must purchase allowances from other businesses within the scheme - if they save carbon emissions they are allowed to sell their surplus allowances.

Within the National Health Service (NHS), the Scottish Government sets national performance targets known as HEAT targets (2014). The term HEAT is an acronym for the grouping of the targets, which are labelled as **H**ealth Improvement, **E**fficiency and Governance, **A**ccess to Service, and **T**reatment Appropriate to individuals. NHS Boards must publish how they meet their targets within their local delivery plans. There are approximately 24 targets in 2014/2015 of which two (reduce $CO_2$ emissions and reduce energy consumption) relate specifically to sustainability. The HEAT target states that health boards must reduce $CO_2$ emissions from hospital sites for oil, gas, butane and propane usage annually by 3% to 2014/15; and continue to reduce energy consumption annually by 1% to 2014/15. The HEAT targets have been set to ensure NHS Scotland can contribute to the Climate Change Scotland Act 2009 and also to support NHS Scotland's role as an environmental leader within the public sector.

NHS Scotland (as a collective term for all Scottish health boards) is committed and motivated to reduce carbon dioxide emissions. In the last four years NHS Scotland has reduced its $CO_2$ emissions and energy consumption by 7.9% and 5.8% respectively.

As part of the Climate Change Act (2008) the United Kingdom has established a Committee on Climate Change, an independent body to advise it on how to manage climate change. This management includes advice on setting five-year carbon budgets (Reducing the UK's greenhouse gases, 2009) for the UK Government. The Committee advises the Department of Energy and Climate Change and is supported by economists, scientists and corporate staff. The committee provides yearly progress reports to the UK Government.

### 2.1.5 NHS contribution to the global carbon footprint

In February 2009, Health Facilities Scotland (HFS), commissioned Arup, a a consulting company of engineers - in conjunction with the Stockholm Environment Institute (SEI) - to calculate both the size and make-up of the carbon footprint of NHS Scotland (HEAT Targets, 2014). The carbon footprint was a consumption-based carbon footprint as it included Scope 1, 2 and 3 emissions. The carbon footprint was 2.63 $MtCO_2eq$ representing 3.6 % of Scotland's total carbon footprint. Building energy (about 25% of the footprint) included all direct emissions from NHS buildings; this data was drawn from the annual returns boards make to Health Facilities Scotland.

Travel contributed 25% of the carbon footprint and included all direct and indirect emissions from the movement of people (staff travel, patient travel and visitor travel). For the report, travel emissions were estimated using Scottish National Travel Survey data (Transport Statistics Bulletin, 2006) in conjunction with known estimated numbers of staff, patients and visitors. Top-down data was used as there were no reliable travel surveys undertaken by NHS Scotland boards. In relation to travel, around two thirds of all travel emissions resulted from patient journeys with the other one third relating to staff travel.

Procurement made up 52% of the NHS Scotland footprint and included all embodied indirect emissions of the goods and services consumed in the health service, excluding energy and travel. Calculating carbon emission for procurement was based on the use of Scottish Government Input-Output tables (Scottish Government, 2014). Scottish Government health expenditure is categorised into 123 standard industrial classification (UK SIC, 2007) sectors. Using the SIC codes procurement expenditure was combined with carbon intensities for each SIC sector (which is derived from national re-environmental accounts (Office National Statistics, 2014). Interestingly, one third of all procurement-related carbon emissions originated from pharmaceuticals emissions.

### 2.1.6 Public health interventions to reduce the effects of climate change and resulting co-benefits

Public Health is the science and art of preventing disease, and promoting health through the organised efforts and informed choices of society, organisations, communities and individuals. The role of Public Health in preventing climate change associated diseases is in its infancy. In order to reduce the problems associated with further production of carbon dioxide equivalent gases the profession needs to act at a grass roots level to educate and motivate organisations to reduce their carbon emissions. However, even if (and it is a big 'if') carbon emissions suddenly stabilise or decrease, Public Health still has a professional duty to reduce the diseases that will inevitably develop with current carbon dioxide levels. Interventions which Public Health Practitioners should consider include any of the three actions proposed by Costello (2009).

Firstly, Public Health should ensure there is both a bottom-up and top-down approach to measuring, monitoring and reducing carbon emissions. From a top-down approach it is important to have organisational policies that promote sustainable healthcare. Within the UK, most NHS organisations have sustainability as part of their key performance indicators. Within Scotland, NHS Scotland organisations are expected to embed sustainability in their function of providing health services in order to contribute to the Scottish Governments' purpose and wider strategic objectives (CEL2012-02). From a bottom-up approach it is important that carbon emissions are considered and modelled across the system. Managers should be encouraged to procure sustainably, and promote active travel. Individual organisation employees should be encouraged to consider sustainability. Secondly, through good quality research public health professionals need to increase the understanding of the impacts of both climate change and the effectiveness of climate change interventions. Thirdly, Public Health Practitioners can play an active part in ensuring policies are developed to adapt to climate change.

Many interventions that reduce greenhouse gas emissions, e.g. reduction in energy, active transport (cycling and reduced use of cars), and renewable energy generation, have both health co-benefits and economic benefits. Cycling, for example, improves population levels of cardiovascular disease and lowers obesity (Haines *et al,* 2010). Cycling to work reduces costs for employees. Reducing energy use by use of installation and monitoring energy consumption also has cost benefits.

### 2.1.7 Modelling the carbon emissions of a health service

The carbon emissions of a health service are modelled in a number of ways. PAS (Publicly Available Specification) 2050 (PAS, 2011) gives guidance on how to assess greenhouse gas emissions within goods and services. The document attempts to clarify how one calculates the life cycle of a product or service including calculation of cradle to gate and cradle to grave GHG emissions, defining the scope of which greenhouse gases need to be included, the treatment of emissions and data requirements. Despite this guidance there are still many different ways of calculating carbon emissions.

The Academy of Medical Royal Colleges (2014) emphasised that there is no common methodology for the measurement of the carbon footprint of clinical services. This may not be problematic per se when an organisation is measuring their carbon emissions in order to analyse how they can make their own organisation more sustainable but, as the Academy suggests, it becomes much more problematic when organisations are required to be benchmarked from a sustainability perspective.

For the Government to reduce the carbon emissions needed to meet Government targets (e.g. Climate Change Act, 2009), significant changes to care are going to have to take place (CSH, 2013). One way of doing this may be through education. Another is to develop a system capable of providing bottom-up information measuring the carbon emissions of a specific patient pathway. In the same way that service lines, as natural business units of a healthcare entity, calculate financial costs, carbon accounting should also take place (OP89, 2013). The Sustainable Healthcare Commission recommends that carbon accounting should use the same principles as those used in financial accounting, collect data at a patient level wherever possible and integrate carbon reporting with existing information systems.

There are a number of different UK based tools to model and measure carbon. Initially carbon emissions could only be directly measured by experts in carbon modelling. Pollard *et al* (2013) for example used a bottom-up mathematical model to analyse healthcare policy and service reconfiguration. The model calculated the individual unit emissions generated within a hospital trust and was broadly consistent with the models of the World Business Council for Sustainable Development. In this model, for each location, patient need was calculated using data obtained from hospital statistics. The capacity required at each site in terms of physical space (e.g. outpatient rooms, clinic days, theatres, and surgical beds), resources and staff was calculated based on demand. The tool attempts to theoretically optimise both supply and demand to lower carbon emissions.

Connor *et al* (2009) collected the first carbon footprint of an individual specialty, in this case the renal service. In this calculation activity data was collected and greenhouse conversion factors were used to convert the data into carbon dioxide equivalents per year. Pharmaceuticals made up 35% of the overall emissions of the renal service followed by medical equipment (25%). The Department of Environment, Food and Rural Affairs (DEFRA) conversion factors (DEFRA/DECC, 2010) used in Connor's study enable a healthcare provider to calculate their carbon emissions once the healthcare providers have drawn together a list of the consumables that are used in every day practice.

Recently, more user-friendly web-based tools have become available to help healthcare providers measure and monitor their carbon emissions. The Green Champions Training Resource Scotland (2014) tool encourages healthcare professionals to consider the materials, water and energy that they use to provide patient healthcare. It provides instruction on how to analyse the data, establish key performance indicators (e.g. paper use per number of employee days, percentage of waste recycled) and plot monthly usage. The tool also encourages healthcare professionals to consider sustainability. No evaluation can be found, however, on the tool, and no carbon calculations are supported by the tool. A lack of carbon calculations means this tool would not allow a service provider to benchmark one healthcare site over another.

The General Practitioner (GP) footprint reader (2014) is more detailed. It takes the measurement of carbon emissions one step further and allows a healthcare provider to enter energy use (electricity, gas, oil etc.), travel (patient and staff) and procurement (entry by healthcare provider of the types of goods and services used) into a detailed website.

## 2.2 Improving oral healthcare

### 2.2.1 Dental caries as a disease

Caries is defined as a localised destruction of susceptible hard tissues by acidic by-products from bacterial fermentation of dietary carbohydrates (Fejerskov and Kidd, 2003). Bacteria live on teeth in micro-colonies encapsulated in an organic matrix of polysaccharide and proteins. This biofilm or plaque helps protect each micro-organism from desiccation, host defences, and predators and provides protection against antimicrobial agents (Fejerskov and Kidd, 2003). This bacterial ecosystem metabolises dietary carbohydrates, an acidogenic process which causes a drop in pH and, ultimately, can cause a demineralisation of the tooth structure (Marsh and Nyvad, 2008). The progression of dental caries is dependent on the daily ecological balance between demineralisation and remineralisation (Marsh and Martin, 1992). Dental caries will occur therefore depending on both the factors that govern remineralisation and the factors that enhance demineralisation. Eventually, if demineralisation increases, the net mineral loss weakens the tooth structure and a cavity forms (Takahashi and Nyvad, 2011).

Mutans streptoccocci (MS) are often considered the most important bacteria in the initiation of dental caries (Tanzer *et al,* 2001). Takahashi and Nyvad (2011) describe the carious process in three stages. Stage 1, the equilibrium phase, is where clinically sound enamel surfaces contain mainly non-MS and *Actinomyces* and in which acidogenesis is rare. At Stage 2 risk factors of caries increase, with the amount of bacterial acid that is produced raised, the new environment selectively promoting the growth of low pH non-MS. At Stage 3 the caries process continues to lower the pH with the more acidogenic bacteria becoming dormant. It is at this stage that MS and lactobacilli become much more prominent.

Alaluusua and Renkonen (1983) and Köhler *et al* (1984) have demonstrated that children who are colonised early with MS have an increased risk of caries occurence. Several studies suggest that children may acquire MS from their mothers, and a recent meta-analysis supports this idea (da Silva Bastos *et al,* 2015). Mothers with high MS counts can transmit the MS to their children by, for example, sharing food and kissing the child on the mouth (Li and Caufield, 1995; Berkowitz *et al,* 2006). It is likely that this so-called window of infectivity is actually open – Söderling *et al* (2001) demonstrating a gradual increase in colonisation of MS during the first six years of a child's life, and Straetemans *et al* (1998) demonstrating a similar pattern of colonisation. This vertical transmission usually occurs from mother to child but transmission can occur from father to child and also horizontally through contact with fellow nursery school children (Berkowitz *et al,* 2006). A reduced transmission of MS from mother to child could lead to subsequent reduction in children's dental decay, and there is evidence for this (Köhler *et al,* 1984; Isokangas *et al,* 2000; Söderling *et al,* 2000; Olak *et al,* 2012).

### 2.2.2 Caries epidemiology

Within Scotland five-year-old and eleven-year-old children (Primary 1 and Primary 7) receive an examination on alternate years through the National Dental Inspection Programme (NDIP, 2014 and NDIP, 2013). Children's teeth are noted as decayed if the disease is obvious in the dentine level. On average, 24% of children receive an examination, producing very comprehensive population estimates. In 2014, 32% of five-year-old children had dental decay. Across Scotland the average number of decayed, missing and filled teeth (dmft) was 1.27. In 2013, 20.6% of the eleven-year-old population were examined. Of these children 27.2% had obvious dental decay experience, compared with 47.1% in 2005. The average DMFT of eleven-year-olds has improved from 0.7 in 2011 to 0.6 in 2013.

These results are a significant improvement since the 2004 survey (NDIP, 2004) when 51% of children had dental decay – and the average dmft was 2.36. Scottish dental oral health, although improving, is still worse than that of its English neighbour. Within the most recent figures for five-year-olds, the average dmft was 0.94. The English and Scottish data are broadly comparable as they follow a detailed protocol (NHS Dental Epidemiology Programme, 2012/2013), although there are differences in sampling of children in the two countries.

The UK has a comprehensive dental epidemiology programme. In Western Europe epidemiology programmes are not standardised from country to country. Looking at the Malmö oral health database (Oral Health Database, 2014) it can be seen that caries prevalence is generally improving, and this is extensively documented in children. The database provides a useful guide to caries around the world. However, the reader should interpret the figures with caution. Although disease levels are measured in dmft/DMFT, and are therefore broadly similar, there are differences in methodology in collecting the data. There are also differences in when the surveys were collected. Within Europe, for example, caries figures range from a comparable recent DMFT per child for 2012 of 0.6 in Denmark, but a higher disease rate of 0.7 in Finland for 2009. French DMFT data on twelve-year-olds seems high at 1.2, however, the survey was conducted in 2006 and is therefore not broadly comparable.

### 2.2.3 Caries and inequality

Health inequalities are preventable and unjust differences in health status experienced by certain population groups (Health Inequalities, 2010, Marmot, 2010). There is considerable research showing that people in lower socio-economic groups or areas of deprivation are more likely to experience chronic ill-health and die earlier than those who are more advantaged. Health inequalities occur between a number of different groups including people of different socio-economic status, between different genders, between different ethnic groups, between the employed and unemployed and between people with stable housing and the homeless (Health Inequalities, 2010).

Marmot (2010) proposes that there is a social gradient in health, and that this social gradient should be lowered requiring action across all the social determinants of health. As stated by Marmot, reducing health inequalities is a matter of fairness. Action should not be taken simply by targeting the most disadvantaged but with a scale and intensity that is proportionate to the level of disadvantage. Marmot has termed this proportionate universalism. He argues that economic growth should not be considered the most important measure of a country's success, but that measures such as the fair distribution of health, well-being and sustainability are also important.

Inequalities in dental health have not decreased significantly over the last few years, and Public Health Practitioners have increasingly focused on the social determinants of health in an attempt to reduce this disparity. To better understand these wider determinants, Public Health needs to consider the wide range of influences at a community, family and child level (Fisher-Owens *et al,* 2007).

### 2.2.4 Prevention of dental caries

To consider how one might prevent dental caries, one needs to analyse the risk factors for the disease. Prevention could focus on individual risk factors such as improving oral hygiene, diet, focusing on increasing fluoride levels (such as encouraging the evidence-based use of fluoride supplements) or improving "bacterial risk". Prevention could also take a population approach, by opting, for example, to implement community water fluoridation. Increasingly, Public Health Dentistry is supporting a targeted population approach or a Marmot-style Universal Proportionalism to target vulnerable population groups. Such an approach would favour a toothbrushing programme focusing on vulnerable populations, a free toothbrush/toothpaste scheme to lower socioeconomic groups, and/or funding a fluoride varnish programme as part of routine dental care for vulnerable groups.

From an oral health perspective, a programme developed to meet Marmot requirements would give every child the best start in life, e.g. it would ensure all parents have the appropriate education and tools for appropriate prevention, and enable children to maximise their capabilities and have control over their lives. A common risk approach is useful in understanding these wider determinants (Fisher-Owens *et al,* 2007). An oral health promotion programme would be embedded across all health areas including child health teams, community programmes, and dental services.

#### 2.2.4.1 Prevention through education

Three Cochrane Reviews highlight the need for further research on the effectiveness of health education on modifying caries risk behaviour. Kay and Locker (1996) examined the quality of oral health promotion research to assess the effectiveness of health promotion at improving oral health. The systematic review reported on a number of groups (e.g. elderly, adults and people with special needs). Unfortunately the authors were unable to reach definite conclusions about the effectiveness of oral health promotion. Oral health promotion did change knowledge levels, but the review could not definitively conclude that any change in behaviour or clinical disease indices resulted specifically from the oral health promotion programme. The only oral health promotion programmes that did show changes in disease indices were those that involved the use of fluoride. A more recent Cochrane Review by Harris *et al* (2012) reviewed five studies to evaluate the effectiveness of one-to-one dietary interventions delivered within a dental setting. All five studies reported changes in dietary behaviour. Two of the studies were multi-intervention, making causation problematic. There is, however, some evidence to suggest that one-to-one dietary interventions can change behaviour. A third, more recent paper, by Chaffee *et al* (2013) draws similar conclusions to Kay and Locker (1996). In this study healthcare workers were trained in guidelines for infant nutrition. The oral health of infants within these health centres was then compared to that of a control group of infants in health centres with conventionally trained staff. The results showed no difference in the oral health between the two groups. The well-designed study struggled with a high drop-out rate, which may have had an impact on its results.

Plutzer and Spencer (2008) investigated the efficacy of an oral health promotion programme where mothers were given oral health promotion education on at least four occasions. Early childhood caries (ECC) in their children was compared with children in a control group, and was significantly lower in the oral health promotion group. As the authors suggest, this study was biased towards women who chose to have their antenatal care predominantly at teaching hospitals. However, the results should not relate to socio-economic background as this was recorded without significant difference between the two groups. Of the mothers, 70.6% remained in the study. The results were similar to Köhler *et al's* study (1984) and, as the author suggests, this intervention may be more effective as first-time mothers are possibly more receptive to health promotion interventions than mothers in general (Grace *et al,* 2006).

The majority of evidence suggests therefore that a simple oral health improvement programme consisting of education only is unlikely to be effective at reducing oral disease.

#### 2.2.4.2 Fluoride prevention

After 1970 the epidemic of dental decay faced by countries within the developed world declined considerably. The general consensus is that this reduction was due to the widespread, growing use of fluoride (Moore, 1973).

Fluoride was first shown to reduce caries in the 1930s when Dean (1944) established the cause and effect relationship between fluoride and caries prevention. Topical fluoride has been shown to reduce dental caries primarily by discouraging demineralisation and encouraging remineralisation of the tooth tissue (Clark and Slayton, 2013). The use of fluoride in reducing dental caries has been shown by Splieth *et al* (2008) to be highly cost effective, considerably reducing the cost of operative dentistry through the life of the individual.

A number of different delivery methods have been developed to deliver fluoride both from an individual and a population perspective. These include water fluoridation, fluoride toothpastes, fluoride mouthwashes, and fluoride varnish.

Water fluoridation was first implemented in Grand Rapids, Michigan, USA in around 1945 (Story of fluoridation, 2015). Today, water is fluoridated for 10% of the UK population (Public Health England, 2014a) to around one parts per million (ppm), and despite controversy over its use there is significant evidence to show a population benefit in fluoridating the water supply (University of York, 2000).

In the UK, fluoride toothpastes are available over the counter and used widely by the population. There is significant evidence as to their effectiveness (Marinho, 2003a). Within children, there has been significant research looking at the relationship between the use of fluoride toothpaste and dental decay. Ellwood *et al* (2004) examined the relationship between providing free toothpaste and caries levels of five-year-old children. Toothpaste containing either 440ppm or 1450ppm was posted at three- month intervals to children from the age of one to one-and-a-half to five years. The children who received the toothpaste had significantly less caries and required fewer extractions than the comparison group.

There are several studies which demonstrate the efficacy of tooth-brushing by children within schools - Jackson *et al* (2005), for example, demonstrated an overall caries rate reduction of 10.9% ($P<0.0001$) when 517 children brushed their teeth for 21 months in a school setting. Curnow *et al* (2002) undertook a two year Randomised Controlled Trial (RCT) of supervised school brushing and showed a reduction in the proportion of children with dental decay (D3FS and FOTI) with a preventive fraction of 0.44. In a later study by Pine *et al* (2007), the same children were re-examined at age 12 with the intervention group still showing lower caries occurrence.

A Cochrane Review was undertaken by Marinho *et al* (2003a) comparing fluoride toothpaste with placebo toothpaste for children up to 16 years of age. In this review the authors concluded that the preventive fraction (PF) of using fluoride toothpaste, compared with non-users was 0.24. The authors also noted that the effect of fluoride toothpaste increased with higher concentration, higher frequency and supervision.

In another review, Twetman *et al* (2003) compared daily brushing with toothpastes at concentrations of 1000 -1100ppmF to those at 1500 ppmF and found a mean difference in PF of 9.7% in favour of the higher concentration. Walsh (2010) completed a review of 79 RCTs involving fluoride toothpaste in children up to 16 years, demonstrating a preventive fraction of 23% for fluoride toothpastes (1000-1250ppm), increasing to 36% for higher concentration fluoride toothpastes (2400-2800ppm).

In adults, fewer studies have examined the relationship between the concentration of fluoride in the toothpaste and its relationship to caries reduction. Ekstrand *et al* (2013) demonstrated the effectiveness of 5000ppm toothpaste in an elderly population compared with 1450ppm toothpaste arresting active root surface lesions with a preventive fraction of 0.62 for the 5000ppm toothpaste. Srinivasan *et al* (2013) demonstrated a similar effect with high fluoride toothpaste (5000ppm) when compared with 1350 ppm toothpaste in adult patients.

Gels, mouthwashes and varnishes are also used to deliver fluoride. Marinho *et al* (2002) performed a systematic Cochrane Review of 25 fluoride gel studies involving 7747 children, and demonstrated a 19% prevented fraction in caries reduction with its use. The same author (Marinho *et al,* 2003b) demonstrated a PF of 26% in 36 studies where children were given fluoride mouthrinses. A year later Marinho *et al* (2004b) demonstrated a similar PF (26%) for studies where children used toothpastes, mouth rinses, gels and varnishes. The conclusion from this Cochrane Review was that there was no significant difference between fluoride toothpaste, mouth rinse or gel. More recently, Marinho *et al* (2013) performed a meta-analysis demonstrating a PF for fluoride varnish of 43%.

From the studies reviewed it can be demonstrated that there is consistent and strong evidence that the use of fluoride can significantly reduce dental caries.

#### 2.2.4.3 Prevention with xylitol

A number of studies have investigated the role of xylitol in caries prevention. Most reviews agree that xylitol reduces dental decay when consumed by children in high enough doses (Mäkinen, 2011; Rethman *et al*, 2012; Fontana and González-Cabezas, 2012). The mechanism of action for xylitol is not yet fully understood and may well be complex: xylitol consumption reduces the amount of plaque, decreases its acidogenicity and reduces the extracellular polysaccharides of MS (Söderling, 2009, Splieth *et al*, 2009, Milgrom *et al*, 2012).

Even though the importance of MS as “caries-bacteria” can be questioned (Bradshaw and Lynch, 2013), the early MS colonisation of a child’s teeth has been shown to increase the risk of caries occurrence (Alaluusua, 1983 and Köhler, 1988). Xylitol has in several studies decreased mother-child transmission of MS (Lin *et al,* 2015*).* The mechanism behind this phenomenon may be the decrease in the mother’s MS or their polysaccharide-mediated adhesion (Söderling, 2009). For the most important mother-child studies and their end-points, see Table 1.

**Table 1.** Mother-child studies involving xylitol.

| Study | Design | n(MS-pos) | Xylitol Dose (Frequency) | Intervention (mo) | Vehicle | Child's age at MS assay/caries registration (mo) | Major outcome |
|---|---|---|---|---|---|---|---|
| Söderling, 2000 | RCT | 195 (yes) | 6-7g (4) | 21 | Chewing gum | 24 | MS↓ |
| Isokangas, 2000 | RCT | 195 (yes) | 6-7g (4) | 21 | Chewing gum | 24 | Caries ↓ |
| Thorild, 2003 | RCT | 173 (yes) | 1.95g(3) | 12 | Chewing gum | 18 | MS ↓ |
| Thorild, 2006 | RCT | 173 (yes) | 1.95g(3) | 12 | Chewing gum | 48 | Caries ↓ |
| Fontana, 2009 | RCT | 97 (yes) | 4.2g (3) | 9 | Chewing gum | 9-14 | MS - |
| Nakai, 2010 | RCT | 107 (yes) | 5.28g (4) | 13 | Chewing gum | 24 | MS ↓ |
| Olak, 2012 | RCT | 60 (yes) | 5.8g (4) | 36 | Lozenges | 36 | Caries ↓ |

Within a Finnish group of mothers, habitual maternal consumption of xylitol for 21 months reduced the probability of MS colonisation of two-year-old children (Söderling *et al,* 2000, Söderling *et al*, 2001), resulting in a lower caries occurrence in five-year-old children (Isokangas *et al,* 2000). In Söderling’s study the mothers, all of whom had high MS levels, consumed a daily dose of 6-7g xylitol in the form of chewing gum. The two control groups did not chew gum. In Söderling’s study, the MS colonisation at 12 months was only 6.8%, compared with the control groups 18.2% (PF 63%). At 24 months, the MS colonisation was still lower in the xylitol group (9.7%) compared with the 48.5% colonisation in the control group (PF 80%).This intervention was shown by Laitala *et al* (2013) to be reflected in the caries occurrence of the primary teeth of ten-year-old children.

A similar effect of xylitol on MS transmission as in the Finnish study was demonstrated using a much lower dose of xylitol by Thorild *et al* (2003), who compared the MS levels of Swedish children whose mothers consumed 1.95g xylitol with two control groups of children whose mothers consumed gum containing chlorhexidine and fluoride. The intervention lasted one ýear. When the children were 18 months of age, the MS colonisation was lowest in the xylitol group, the colonisation being 11.8 % in the xylitol group, compared to 37.8% in the fluoride control group (Thorild *et al*, 2003). In agreement with this finding, the lowest caries occurrence at four years was observed in children whose mothers consumed xylitol. However, (Thorild *et al,* 2006) by the time the children were ten years old this difference in dental decay was no longer evident (Thorild *et al,* 2012).

A Japanese study (Nakai *et al,* 2010) also showed a statistically significant difference between MS colonisation; at the age of two years, 13% of xylitol group children (4/31) were colonised with MS compared with 37% of children (17/46) in the control group. In this study the dose of xylitol was 3.86 grams, higher than in the Thorild studies, but lower than that used in Söderling's study. The Japanese study also required mothers to start chewing xylitol gum early, from when they were 6 months pregnant until the child was 9 months old. The Japanese study measured colonisation at 6, 9, 12 , 18 and 24 months. It demonstrated significant differences between the MS colonisation in the two groups at 9 months, 12 months, and 24 months, but no significant difference at 18 months. The differences between the groups were largest right after the xylitol consumption stopped.

In Indiana Fontana *et al* (2009) gave mothers 4.2 grams of xylitol to consume daily for 9 months, and compared the levels of colonisation of their children to the levels of MS colonisation in children of mothers who consumed sorbitol and mothers within a reference group. Fontana used a checkerboard DNA hybridisation process to analyse saliva and plaque samples in predentate infants and demonstrated no significant differences in MS levels between any group of children. The insignificant difference may have been due to the rather short intervention time - mothers were only required to consume xylitol for 9 months.

Recently, Olak *et al* (2012) demonstrated a significant difference in caries occurrence between Estonian children of mothers who consumed 5.8g xylitol and mothers who did not. The study commenced when the children were three months of age, and continued for 33 months. Although the difference was significant between the two groups, the confidence interval was large indicating the uncertainty of the amount of caries risk reduction.

As a summary, the results on the effective dosage of xylitol in decreasing mother-child transmission of MS appear rather controversial. However, the length of the intervention seems to be an important factor affecting the magnitude of decrease of the MS transmission. The optimal time to start the xylitol intervention seems to be three - six months, and it should continue preferably until the child is two years of age.

#### 2.2.4.4 Prevention through a multi-strategy oral health improvement programme

Blair *et al* (2006) researched the effects of an oral health programme in Glasgow. The programme, based in part on Ottawa Charter principles had three aims: i) to sustainably distribute 1000ppm fluoride toothpaste, ii) to advocate nursery food and drinks policies and, iii) to promote dental attendance at an early age. The paper lists a large number of community interventions that were supported as part of the programme including nursery training, parent workshops, introduction of healthy snacks policies, and community oral health promotion events. The authors describe the temporal association between the introduction of the community-based dental health promotion activities and reported decreases of 35% and 40% in mean dmft scores. Blair's results are impressive but do need to be treated with some caution. This research was not carried out as a randomised trial; and, as it was a longitudinal study, it is difficult to attribute true causation.

Wennhall *et al* (2005) recruited 804 two-year-old, predominantly immigrant children into a Swedish oral health improvement programme for 12 months. During this time they were given education, toothbrushing instruction and fluoride tablets and offered discounted toothpaste. Compared with the control group, the number of children consumed snacks and drinks less often at night. Caries prevalence within the intervention group was lower. It is difficult to know whether the education was responsible for the lower dental caries levels or whether it was the use of fluoride; the reader is not told how the participant's parents answered the questions on sweet drinks and meal snacks consumption so it is difficult to know how accurate the results are. It would have been useful to know how much of the caries reduction was related to the purchasing of discounted toothpaste - information on how many parents bought the fluoridated toothpaste is not given. Information on the use of fluoride toothpaste at home was also not recorded. Of more concern was the risk of allocation concealment, with no randomisation to either the intervention group or the reference group, and the use of a reference group two years older than the reference group.

In conclusion, it is not always easy to understand how effective multi-strategy oral health improvement programmes are; there is certainly evidence that a programme which includes fluoride will reduce dental decay; the use of education programmes to change disease levels is not always efficacious.

### 2.2.5 National guidance

SIGN 138 (2014) was published in 2013. It recommends a number of evidence-based dental interventions to prevent caries in children and young people aged 0-18 years. Within Scotland, SIGN is an important document as it is used as a template for policy development - including the further development of oral health improvement programmes such as Childsmile Practice. The document recommends that the oral health team follow the Scottish national oral health and nutritional guidance (NHS Health Scotland, 2012) to reduce dental caries. The guidance focuses on improving the modifiable risk of diet, specifically in relation to the areas of conflict between oral health and nutrition messages, which are discussed in detail.

SIGN 138 (2014) states that oral health promotion interventions within the dental setting should facilitate daily toothbrushing with fluoride toothpaste; children should use twice daily either

1000-1500ppm (for standard risk) or 2800ppm toothpaste (for enhanced risk). The document, in line with the updated Cochrane Review (Marinho *et al,* 2013), recommends that all children in Scotland should receive fluoride varnish twice yearly, and resin based fissure sealants should be applied to the permanent molars of all children.

In line with Smith *et al* (2003), SIGN 138 (2014) advocates that the presence of either maternal active decay or maternal oral MS have not been proven to be predictive indicators of caries risk in children. The Scottish Dental Clinical Effectiveness Programme (SDCEP) document Prevention and Management of Dental Caries in Children (2010) has similar recommendations to that of SIGN 138 (2014). This is not surprising as they are both Scottish documents, with similar authors. SDCEP reinforces the need to assess the child, to define a child's specific needs, develop a personal care plan, and prioritise the management of pain, the prevention of caries and, finally, the management of caries. It also recommends a recall system based on risk.

The document endorses, for standard prevention, the need to give toothbrushing advice to children and parents at least once a year, initially as hands-on brushing. Dietary advice should be given at least annually and in line with SIGN 138 (2004), sodium fluoride (NaF) should be applied twice a year. Unlike the more up-to-date document, SIGN 138 (2014), the SDCEP document does not recommend fissure sealants for children unless they are specifically at risk. Fluoride varnish application, 2800ppm toothpaste and fissure sealants are all recommended as part of an enhanced care plan for children at additional risk. Collaboration with the health visitor or school nurse is also recommended to provide home support for prevention.

SIGN 138 (2014) states that the main risk factors for dental caries are diet, poor oral hygiene, microbiological, sociodemographic (Disney *et al,* 1992), and history of previous caries. SIGN 138 also states that caries in young children is associated with high oral levels of MS (O'Sullivan and Thibodeau, 1996). Caries can also increase in people without access to prevention such as fluoride toothpaste, fluoride varnish and fissure sealants.

# 3. AIMS OF THE STUDY

1. To calculate the carbon emissions of the NHS Fife dental service.

2. To theoretically reconfigure the dental service to improve productivity and reduce carbon emissions.

3. To determine if the Childsmile (2014) programme with the additional maternal use of xylitol is more effective than the Childsmile programme alone at affecting the early colonisation of MS, an important risk factor for the child's tooth decay.

4. To determine, within the South East of Scotland health boards, if:
   - High concentration fluoride toothpaste (HCFT) prescribing had increased.
   - Public Dental Service dentists had different prescribing patterns than those working in the independent (non-public) dental service.
   - Dentists prescribed similar amounts of HCFT.

# 4. MATERIALS AND METHODS

All five studies (i,ii,iii,iv,v) were carried out within the National Health Service (NHS) in Fife, an area in Scotland to the north of Edinburgh, and the south of Dundee.

## 4.1 Improving the sustainability of oral healthcare

### 4.1.1 Measuring the carbon footprint of the dental service

#### 4.1.1.1 Building a process map

A calculation was performed of the carbon emissions of the NHS Fife Community Dental Service using an input-output analysis for procurement data (from all external suppliers), and a bottom-up, process analysis for direct emissions - including waste, electricity, and gas consumption as per PAS 2050 ( PAS, 2011). Carbon-related travel was also calculated.

#### 4.1.1.2 Checking boundaries and prioritisation

The boundary of the carbon footprint calculation includes all energy consumed, waste produced and all dental products used (Wiedman, 2008). PAS 2050 (PAS, 2011) does not account for the carbon emissions from the construction of the building in which the dental service is housed so, in line with this specification, these greenhouse gases were not included. However, in line with Connor (2010) and to ensure a comprehensive footprint could be accounted for, patient and staff travel was included.

#### 4.1.1.3 Collecting data

Data was collected where possible to meet the requirements of PAS2050 (PAS, 2011). However, some of the dental clinics had only been functional for 18 months, and hence, data was not available for all establishments. To calculate electricity measurements, readings were taken directly from four clinics, and where dental services were provided in shared health clinics, pro-rata measurements were used.

DEFRA conversion factors were used as per Table 2.

**Table 2.** DEFRA/DECC: 2010 conversion factors.

| Unit activity data | Conversion factor |
|---|---|
| Electricity | 0.58284 kg $CO_2$eq per KWh |
| Gas | 0.18523 kg $CO_2$eq per KWh |
| Water | 0.404 kg $CO_2$eq per KWh |
| Waste | 0.447 kg $CO_2$eq per KWh |

Only one water reading was available from one clinic, with waste readings taken from four stand-alone clinics and two shared health care facilities, the latter being proportioned on the basis of floor area. Procurement-related emissions consumed in the CDS were calculated from financial records, mapped to SIC (UK SIC, 2007) and converted using DEFRA supply chain (DEFRA/DECC, 2010) emission factors.

#### 4.1.1.4 Calculating the footprint

The $CO_2$eq was calculated by adding the direct emissions (gas, electricity, waste, travel) to the indirect emissions (procurement).

As per Table 2, direct emissions were calculated by multiplying the unit activity data (e.g. power consumption kWh) by the carbon dioxide equivalent ($CO_2$eq) emission factor per unit. Indirect emissions for procurement were calculated from financial records, multiplying the DEFRA supply chain emission factors (DEFRA/DECC, 2010).

#### 4.1.1.5 Direct carbon emissions by the CDS

There were only four clinics where direct measurement of energy use was possible. In the other clinics, either there were no meters fitted to record energy use, or the dental unit was housed within an integrated health care facility preventing the independent measurement of specific CDS energy use. To measure the energy use of these clinics, a proportion of the energy use of the integrated health care facility was calculated as per Connor (2009) on a square meter basis. Information on new clinics (if not available) was estimated from similar new-build clinics, and extrapolated according to patient numbers.

Waste figures were collected from NHS Fife Estate Services for four clinics. These data were extrapolated for all 22 CDS clinics. The waste was divided into paper and cardboard, mixed clinical, and special waste. Conversion factors were used based on NHS (2008) and Connor (2009). For special waste, a specific conversion factor for amalgam was calculated at 3800 kg CO2eq per tonne of special waste. This amount was calculated using the EPA online calculator (2011), and excluded in its calculation were GHGs, carbon monoxide (CO), nitrogen oxide (NO), non-methyl volatile organic compounds (NMVOC) and sulphur dioxide (SO2).

Information on water was only available from one clinic. However, as the carbon emissions relating to water are very low, this was not considered problematic (DEFRA/DECC, 2010).

The end-of-life carbon footprint was calculated using the DEFRA emission factors (DEFRA/DECC, 2010) for waste treatment. This was to avoid double counting of the carbon emissions associated with waste and procurement. To calculate staff travel to work, each staff member was given a questionnaire (n=169) requesting information on both modes of travel used and average distances travelled. One hundred questionnaires were returned. A similar questionnaire collected information from patients (n=850, from 17 clinics). Additional information was collated from the R4 clinical software (2015) in order to give additional information on home-clinic distance.

#### 4.1.1.6 Handling uncertainty

Due to a number of factors (including uncertainty in the relevance of some of the DEFRA conversion factors [DEFRA/DECC, 2010] within dentistry, the lack of consistent metering of energy use within the dental services, and the need, where applicable, to apportion energy use for dentistry from a shared health service) assumptions were necessary in the calculation of the NHS Fife CDS carbon footprint. Waste could only be measured based on the size of rubbish bins provided at the clinics. The assumption was made that the rubbish bins were always full, but there was uncertainty surrounding this.

#### 4.1.1.7 Indirect carbon emissions from the Community Dental Service

In order to calculate the embedded GHGs in procurement an input–output analysis is required, using accounting information which is categorised into specific industry classification codes (UK SIC, 2007) and converted into $CO_2$eq per £ using DEFRA/DECC, 2010 conversion factors.

The measurement of the indirect carbon emissions within buildings is problematic. In keeping with PAS 2050 (PAS, 2011) capital costs for new buildings are not included within this study. However any leased buildings contribute carbon emissions via their lease cost and this was taken into account.

### 4.1.2 Remodelling the carbon emissions of a dental service (ii)

#### 4.1.2.1 Description of the model used

A mathematical model developed by Pollard (2013) considers the contributing components which make up a patients treatment, including electricity, gas, building capacity, and travel to and from the care centre. The model helps improve the efficiency of healthcare services by appropriately locating treatment centres and ensuring there is an optimal mix of treatment provision. The model is reviewed in Pollard's paper (2013).

#### 4.1.2.2 Model as applied to Fife CDS

Once the carbon calculation had been measured within Fife, the Pollard model (2013) was applied in order to optimise the efficiency of the service using a four step process.

#### 4.1.2.3 Step-by-step process for modelling

1. To calculate demand for the number of appointments for the given population, an analysis was performed using patient postcode data, current numbers of appointments available and their location. For each appointment an assumption was made on the type of care provided based on an analysis of care in a similar CDS.

2. To calculate the demand for the requirements and carbon emissions for each individual procedure, total electricity, gas, building time, and staff time were calculated.

3. Using activity data obtained from a similar CDS in Orkney, it was proposed that an examination took 15 minutes, a filling 60 minutes, a scale and polish 19.8 minutes and a

root canal treatment 45 minutes. Using information available on the power required to run dental equipment (e.g. dental light 52 W, curing light 3600 W) the equipment usage per appointment type was calculated in minutes. Aggregating equipment usage per procedure enabled the rate of power consumed in KWh to be calculated for each procedure.

4. The total demand was then calculated aggregating the results from Step 1 and Step 2, for each of the 28 types of dental care (e.g. examination, filling, extraction).

5. To calculate capacity for the entire CDS, an analysis was performed of the current clinics, the current staff, the number of staff needed for each procedure, and the time it took to provide optimal care for the given population of patients for each of the above dental care procedures.

6. The Pollard model (2013), through mathematical modelling, compared the capacity required at each site based on patient postcode (assuming patients would prefer the closest site), with the available capacity. Within this modelling, clinics where demand for care is high - that have insufficient capacity - were theoretically re-configured (e.g. surgeries could be increased); clinics with insufficient demand were also theoretically re-configured.

7. The model allows a health service planner to ensure optimal care is provided whilst also minimising travel, staff usage, and carbon emissions.

#### 4.1.2.4 Comparison of five scenarios

To determine the most efficient re-configuration of the CDS five scenarios were considered. For each scenario a calculation of carbon emissions, patient travel and staff use was measured. These scenarios are:

1. Baseline Scenario: Existing provision of treatment. In this scenario 22 sites were operating, generating 317 tonnes $CO_2$eq.

2. Baseline B: Assuming no reconfiguration of dental clinics but all patients chose to see their preferred provider at their nearest dental clinic. In this scenario 21 sites generated 107 tonnes $CO_2$Eq, as the patient travel reduced to around 1/3.

3. Scenario 1: All clinics with excess capacity were reconfigured (the number of clinics reduced where appropriate but no overall dental units were closed). This scenario required less lighting, and slightly reduced energy was required to run fewer sites

4. Scenario 2: Sites with less than 40% utilisation (based on patients accessing care close to home) were closed and the remaining sites reconfigured. This scenario required similar energy use to Scenario 1.

5. Rationalisation: Sites with less than 60% utilisation in Scenario 2 were closed and the remaining sites were reconfigured. This required less staff to run the clinics, but with some sites closing did increase the patient travel required to travel to dental care. The GHG emissions, although lower than baseline increased to 158 tonnes of $CO_2$eq.

## 4.2 Improving oral healthcare

### 4.2.1 Childsmile and the MaXED trial (iii)

In 2006, a health improvement programme called Childsmile was established in Scotland to improve the health of children. The following programme was implemented across the country and consisted of three parts;

1. Childsmile Core
2. Childsmile Nursery and School
3. Childsmile Practice

#### 4.2.1.1 Childsmile Core

Childsmile Core was part of a Scottish Government programme based on the evidence-based provision of toothbrushes and toothpaste to children. All children in Scotland (regardless of the deprivation quintile in which they reside) were entitled to receive one toothbrush and toothpaste (1500ppm) pack at the age of six months, twice at age three, twice at age four, and once at age five.

#### 4.2.1.2 Childsmile Nursery and School

All children in nursery school participated in a toothbrushing programme, and all children in the most deprived 20% of schools, received toothbrushing programmes at Scottish primary school classes for children who are aged five and six years.

Childsmile Nursery and School also includes a fluoride varnish programme which provides fluoride varnish twice a year to every child four to eight years of age attending a nursery or school in the most deprived 20% of Scottish quintiles.

#### 4.2.1.3 Childsmile Practice

Childsmile Practice was developed to ensure that children up to 18 years of age receive the best, evidence-based dental care. Within the Dental Practice setting, dental nurses were specially trained to deliver both fluoride varnish to a child’s teeth and to provide evidence-based oral health promotion advice. Within the home setting dental health support workers supported children by providing oral health improvement advice to parents, and encouraging the dental registration of children who ordinarily might not seek dental care to register with a dentist.

#### 4.2.1.4 Childsmile workforce development

The role of the dental health support worker was developed in order to support the Childsmile process. In nurseries and schools, dental health support workers were trained within Childsmile Core and Childsmile Nursery and School to support the delivery of toothbrushing packs, ensure the smooth running of the toothbrushing programmes, and provide simple oral health information sessions to children.

To support Childsmile Practice, dental health support workers developed links with health visitors and support families who requested help. For these families, often in areas of higher need, dental health support workers provided oral health information and toothbrushing resources and assisted children in attending dental practices.

#### 4.2.1.5 Childsmile (generic) training

Before the MaXED trial the dental health support workers attended bespoke courses developed by National Education for Scotland (Turner *et al,* 2010). The course consisted of an eight-week part-time series of lectures and workshops to improve support workers' understanding of it:

- dental public health
- inequalities
- the social and medical model of health
- caries as a disease and the use of fluoride in its prevention
- health and safety and infection control
- breast feeding
- early nutrition
- communication
- working with children and child protection.

Extended duties dental nurses were taught enhanced prevention in the practice setting including how to apply fluoride varnish to children's teeth and provide informative oral health education. In order for these skills to be used, special permission was granted by the General Dental Council, the organisation that governs dentistry within the UK.

### 4.2.2 The MaXED (Maternal consumption of Xylitol to reduce Early dental Decay) trial (iv)

#### 4.2.2.1 Childsmile Practice and the MaXED trial

An important part of Childsmile Practice was ensuring children were supported to both obtain optimal oral health prevention and at an appropriate time receive evidence-based dental care, by receiving support when needed in registering with a dentist. In a conventional Childsmile Practice setting dental health support workers would develop links with health visitors and support families who requested help. It may be that dental health support workers needed to visit families once, or on numerous occasions to deliver this support. Dental health support workers were resourced to provide oral health information and toothbrushing resources for the children.

When mothers enrolled in the MaXED trial it was agreed that a modified Childsmile Practice programme would be offered to all mothers. Within the Childsmile Practice programme mothers were visited once or twice. Within the MaXED Childsmile Practice programme mothers were visited on a regular basis and offered oral health advice and, oral health resources. The increased visits were to ensure that Childsmile mothers were visited as frequently as mothers receiving xylitol within the MaXED trial.

#### 4.2.2.2 Childsmile (MaXED) training

Dental health support workers, already trained in the Childsmile (Turner *et al,* 2010) programme, received additional training in research methods, informed consent, the properties of xylitol, dental caries as an infectious disease and the use and processing of Dentocult ® SM Strip Mutans tests.

#### 4.2.2.3 Subjects

Mothers residing in Fife were invited to participate into the MaXED study, providing their child was no more than four months old, and that they were the child's main carer. Potential participants were given information about the study both verbally and in writing via standard patient information sheets. Information included a description of xylitol and the research process. Ethical permission for the MaXED study was obtained from the Tayside Committee on Medical Research Ethics, and the study was entered as a Clinical Trial on the Clinical Trials database (identifier NCT01038479).

#### 4.2.2.4 Study design

All in all, 182 mothers were accepted into the study with an equal number of mothers assigned to each arm of the study - i.e. 91 mothers assigned to Childsmile (CS) and 91 mothers assigned to the Childsmile plus xylitol group (CS+X). Each group was visited when the child was three, four and six months old and then every three months until the child was two years old. At each visit mothers were given information on oral health, toothbrushing, use of toothpaste and, in line with Childsmile Practice, were supported, if necessary, to attend a dentist. The xylitol group were given, in addition, xylitol chewing gums or lozenges purchased from Xlear Incorporated (American Fork, Utah, USA). Mothers in the CS+X group were advised to eat six grams of xylitol, three times during the day, from when their child was three months of age until the child turned 21 months.

#### 4.2.2.5 Data collection

Dental health support workers collected information on the amount of xylitol consumed, the type of toothpaste used, whether the mother smoked, if there was any reaction to the product and general health information about the mother.

#### 4.2.2.6 Assessment of mutans streptococci

In order to evaluate the levels of MS in mothers, Dentocult ® SM Strip Mutans tests were used (Orion Diagnostica, Espoo, Finland). As dental health support workers are not clinical staff, mothers were taught how to take their own MS samples. Plaque was collected from the labial surface of lower incisors and buccal surfaces of upper molars. Stimulated saliva samples were also collected from mothers. When the child was aged 24 months plaque was collected from their lower incisors.

Following Dentocult ® SM Strip Mutans instructions, all bacterial samples were tested on the relevant strips, placed in a vial and incubated at 37 ºC for 48-96 hours. Tests were read and interpreted by Brett Duane, with the first 30 tests being validated by Eva Söderling and Kaisu Pienihäkkinen. For each bacterial sample a code of 0 (no growth), 1 (low growth; log CFU 5), or 2 or 3 (high; log CFU 5) was given based on the highest value of MS score, found either in plaque or saliva.

#### 4.2.2.7 Outcome measure

The primary outcome measure was child MS colonisation at two years of age.

#### 4.2.2.8 Sample size

Sample size calculation was difficult as there were uncertainties in the literature as to effect of xylitol in reducing MS. A power calculation was made based on a two-group continuity-corrected chi-squared test with a 0.05 two-sided significance level with 90% power to detect the difference between a Group 1 proportion of 0.50 and a Group 2 proportion of 0.25 when the sample size in each group is 85. Assuming a drop-out rate of 20% we planned to recruit 204 available subjects.

#### 4.2.2.9 Randomisation

The randomisation process took place in the Robertson Centre for Biostatistics. The centralised telephone randomisation service provided the dental health support worker with a participant code and an automatic allocation to either CS or CS+X.

#### 4.2.2.10 Blinding

The analysis of the Dentocult ® SM Strip was carried out by BD, who had been appropriately trained and validated and was blinded to the participant’s identity and allocation.

#### 4.2.2.11 Statistics

The statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) software (SPSS v 15.0. SPSS Inc.). A Fisher’s exact test was used to test the difference in prevalence of MS colonisation between the CS and CS+X groups. Fisher exact tests were also used to differentiate the child gender in each group and maternal smoking rates. Calculations were performed for Absolute Risk Reduction and confidence intervals.

### 4.2.3 Fluoride toothpaste prescribing (V)

#### 4.2.3.1 Gathering data

Prescribing data for Scottish health providers, including dentists is collected on the centrally held Scottish Prescribing Information System (PRISMS, 2014) database, which is updated monthly and can provide information on the prescribing patterns of dentists by their provider number and their health board.

The SEAT boards (South East and Tayside) boards consist of NHS Fife, NHS Tayside, NHS Borders, NHS Forth Valley and NHS Lothian.


**Figure 1.** Scottish Health boards (figure is used with permission under open access, NHS Healthboards, 2015).

An initial request to PRISMS for all prescribing information of dentists within the SEAT (South East and Tayside) boards was undertaken for the period 2006-2012. An initial analysis of this information demonstrated amongst other things, unexpectedly high prescribing of high-concentration fluoride toothpaste.

Following this, a second request for information on the prescribing of high-concentration fluoride toothpaste (HCFT) was undertaken for the period 2006-2012 from individual healthboards within the SEAT area. These healthboards had access to their own PRISMS data.

Information requested included details of the following:

1. HCFT prescribing by list number within Scotland; an NHS dentist registers with NHS Scotland Practitioner Services at any given location and acquires a specific list number. A different list number is required for each separate location.

2. A list of all NHS dentists and their specific list numbers. This allowed identification of individual prescribers by their name and location.

3. Type of prescription (2800 or 5000 ppm toothpaste).

4. HCFT prescribing in patients categorised by Community Health Index number.

An analysis of the data was undertaken. The data was collated into an Microsoft Excel worksheet and categorised according to healthboards. The pivot chart function of Microsoft Excel was used to look at the different prescribing patterns.

Analysis included the following:

- Individual prescribers were ranked in order of the amount of prescribing they undertook.
- Prescribing patterns of the public dental service were compared with the independent dental sector. Dentists were grouped using their list number by location.
- Conversations were held with the clinical director from each Public Dental Service within SEAT in order to sort dentists as either working for the public dental service or high street dental practice.
- ●Prescribing of 2800 ppm toothpaste compared with 5000 ppm toothpaste.

The recording of Community Health Index (CHI) information on dental prescriptions was not analysed as during the time period it was seldom recorded. Prior to 2008 all patients who received a free prescription were obligated to record their exemption category. This might, for example, include jobseeker’s allowance, pensioner etc. However, in 2008, the Scottish government abolished prescription charges. As every Scottish citizen is now entitled to free prescriptions, this exemption category is no longer reliably completed by the pharmacy profession. Additional data was requested directly from the PRISMS database on the types of patients who were receiving prescriptions of HCFT. Therefore, the data we received on categories of exemption was felt to be inaccurate, and was not analysed.

# 5. RESULTS

## 5.1 Improving the sustainability of oral healthcare

### 5.1.1 Measuring the carbon footprint of the dental service

The Fife CDS produces approximately 1.8 kt $CO_2$eq per year equalling an average of 17.9 kg $CO_2$eq per patient visit. The majority of these emissions come from travel, which constituted 46% of carbon footprint. Within travel broadly similar amounts originated from patients and staff. For staff, most travel was carried out by car (99%), for patients, travel was by car (69%), public transport (23%), and the remainder by foot or bike.

Procurement accounted for around one third of the total emissions, with energy use accounting for the remaining emissions.

There was considerable variation in the carbon emissions between dental clinics. The carbon dioxide equivalent emissions ranged from 11.6 $CO_2$eq emissions per patient in Rosyth and Oakley to a much higher 41 $CO_2$eq in Stratheden.

Part of the variation is due to differences in travel between the clinics, but surprisingly, newer clinics had almost twice the electricity use per patient, and used more than 2.43 units per patient more gas than older clinics.

The results from this study can be extrapolated (based on numbers of dentists) nationally. The 1798.9 $CO_2$eq tonnes from the 45 CDS dentists would, based on the 3251 Scottish dentists, equate to annual national Scottish production of 127,000 tonnes of $CO_2$eq.

### 5.1.2 Remodelling the carbon emissions of a dental service

The remodelled configuration of dental services can be seen in Figure 2.

Asking patients to travel to their closest health care provider (Baseline B) made one clinic redundant, thereby reducing the number of required clinics to 21. Scenarios 1 and 2 and Rationalisation all showed reduction in lighting, electricity consumption, and all (Baseline B, Scenario 1 and 2 and Rationalisation) significantly reduced patient travel and GHS emissions.

Figure 2 shows that the number of clinics was reduced from 22 to 13, and the total surgeries at the clinics from 59 to 37. Due to the remodelling there has also been a staff reduction from 154 staff to 104.

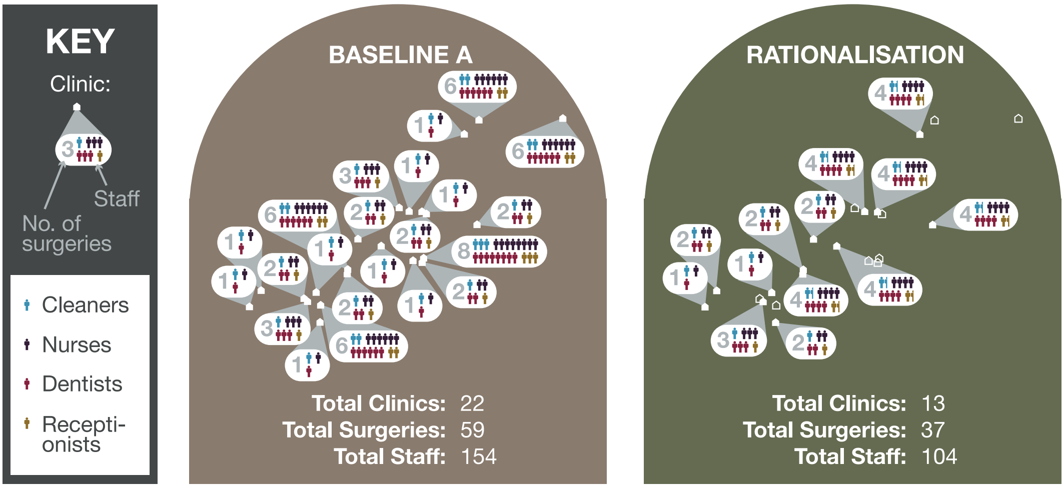


**Figure 2.** Pollard Model Overview (Duane *et al*, 2014, used with permission).

## 5.2 Improving oral healthcare

### 5.2.1 Childsmile and the MaXED trial

Most of the two-year-old children in the CS and CS+X groups showed no MS colonisation. Of the CS children, 17% (8/48) showed MS colonisation, while the CS+X group showed 5% colonisation (2/39). In spite of this difference in MS colonisation, the result was not statistically significant (P=0.1744). The absolute risk reduction for MS colonisation was 0.12 (95% confidence interval -0.01 to 0.24). The results can be seen in Table 3.

**Table 3.** Colonisation rates within Childsmile and Childsmile plus Xylitol.

| | MS colonisation | No MS colonisation | Total |
|---|---|---|---|
| CS | 8 (17%) | 40 (83%) | 48 |
| CS + X | 2 (5%) | 37 (95%) | 39 |

In this study, 242 mothers were screened for high MS counts, with 76% of the mothers (n=182) showing high MS levels and eligible to enter the trial. The mothers were randomised into a CS group or CS+X group. When the mothers were grouped by local Scottish Index Multiple Deprivation quintiles, 21% of mothers were from the most deprived quintile, 23% from the second-most deprived, with 28%, 13%, and 14% of the mothers respectively from quintiles 3, 4, 5. There was high loss of participants as the study progressed, with only 57% of CS mothers and 53% of CS+X mothers completing the trial. The differences in the drop-out rates between the two groups were not statistically significant (P = 0.2351). Furthermore, there were no differences in maternal smoking rates between the CS (n=13) and CS+X (n=14) groups, or differences in child gender with 51% male children in the CS group and 42% male children in CS +X.

### 5.2.2 Prescribing fluoride toothpaste

From 2006 to 2011, within the SEAT health boards, dentists wrote approximately 75000 prescriptions of HCFT. As can be seen in Figure 3, the number of items increased to more than £200,000, an increase in magnitude of around six.

Within the Public Dental Service, the prescribing of HCFT was almost twice that of the prescribing of the independent dental service, with 11.6% of the national prescribing originating from dentists within the Public Dental Service (6% of the dentist workforce).

The volume of prescribing of HCFT between dentists was quite variable, with 4% of the dentists responsible for 70% of the total items prescribed.

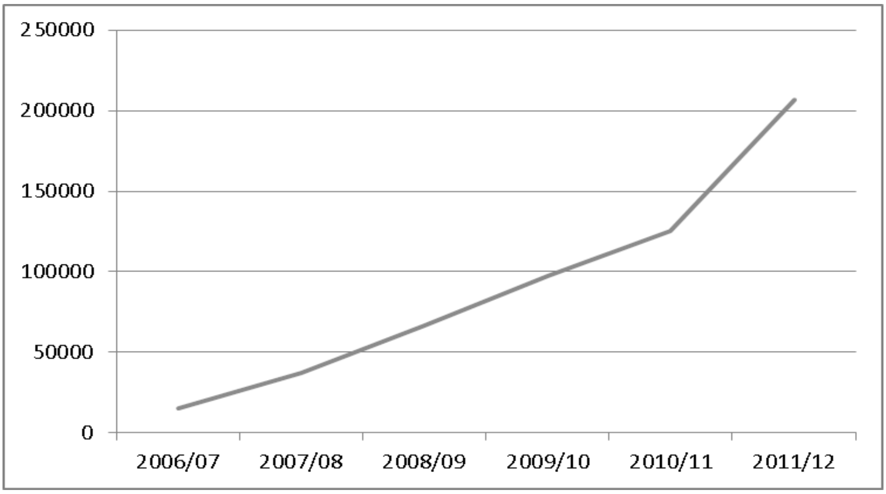


**Figure 3.** Rise in cost (British £) of high-concentration fluoride toothpaste prescribing 2006-2012 in the SEAT boards (assembled from data supplied by Information Services Division, Scotland).

# 6. DISCUSSION

## 6.1 Improving the sustainability of oral healthcare

The carbon dioxide emissions that were measured within the NHS Fife study were different in proportion compared to those collected in national studies such as the Scottish NHS carbon footprint study (NHS Scotland, 2009) and the NHS English study (Sustainable Development Unit, 2009).

There are a number of different approaches that can be undertaken when calculating carbon emissions. These include a top-down approach, where emissions are calculated using organisational, or national measurements, a bottom-up approach where emissions are calculated on a piece-by-piece fashion, measuring the simple process of a complex system; or a hybrid between the two.

The 2013 English report (Sustainable Development Unit, 2013) on carbon emissions within the NHS has procurement-related emissions as 61% (includes anaesthetic gases), travel as 13% (patient/visitor 8%, staff 5%), and energy use as16%. The NHS Fife study has travel-related emissions as twice as high as the national (English) study, at 33%. This could relate to the fact that NHS Fife is on the whole more sparsely populated than England. England has on average 413 people per square kilometre, whereas Fife has 277 people per square kilometre (Office for National Statistics, 2015). This difference in population density will alter access to healthcare services and require increased travel. The difference in travel may, however, relate to the methodology behind the calculation. In England, the national data is based on annual travel surveys (Transport Service Bulletin, 2006) - and is likely to be less accurate (Sustainable Development Unit, 2009). The authors of the English report recommend a bottom-up approach in the collection of travel data and it is this mechanism NHS Fife used to collect patient travel information. The NHS Fife travel data is also accurate, as it not only included information from a sample of patients attending dental surgeries, but also analysed 100,000 patient visits including their postcode in order to verify patient mileage.

The actual energy calculation for NHS Fife was useful as it demonstrated to the local NHS Health Board the higher than anticipated energy usage of the new dental buildings compared with older buildings. This finding was unexpected as the new buildings were built to BREEAM (2015) standards, with appropriate modern building techniques. It is hypothesised that the buildings used more energy because they were bigger than traditional dental surgeries, had air conditioning, and were therefore more energy intensive to run. Constructing new buildings creates significant carbon emissions, and these emissions must be offset against potential savings. This finding may encourage the NHS to question the assumption that relocating to newer purpose-built buildings will automatically generate carbon savings.

Within the Fife study procurement accounted for around one third of the total emissions. This is much lower than the 61% that makes up the national carbon footprint. This may be simply a reflection of how dentistry differs from other primary and secondary care services; the dental industry may simply procure less.

What could introduce inaccuracy into the procurement-derived carbon emissions is that the DEFRA emission factors (DEFRA/DECC, 2010), based on Standard Industrial Classifications (UK SIC, 2007), are not specifically related to dentistry. Items such as paper-based products were easy to map, whereas items such as dental supplies (amalgam, dental composite etc.) were mapped with medical supplies. It is not certain whether the medical and precision instrument code is accurate when used for dentistry. This study highlighted the need for more accurate ways of calculating carbon emissions from procurement. Public Health England has recently commissioned carbon modelling of specific dental procedures, and the results may influence future calculations of carbon emissions within dentistry.

In the 2013 update to the English NHS Carbon footprint (Sustainable Development Unit, 2013), the carbon-related emissions of items such as anaesthetic were calculated and included. In the NHS Fife study, dental anaesthetic use (e.g. the use of nitrous oxide) was not within the scope of the study. However, these gases have potentially serious environmental consequences and should be included. As the Sustainable Development Unit points out 5% of the carbon footprint for acute organisations is from anaesthetic gases (Sustainable Development Unit, 2015). Nitrous oxide has been reported (along with desflurane) as the most globe-warming anaesthetic gas and we know it is used routinely in dentistry (Sustainable Development Unit, 2015). Further research is needed to study its impact within dentistry.

The Pollard model (2013) was used to theoretically create different scenarios where buildings could be closed, reconfigured or open to reduce patient travel, improve human resource efficiency and resource (e.g. energy) use. The tool offers healthcare managers a useful resource to plan services that are efficient and offer care that reduces travel and associated carbon emissions.

The Pollard model (2013) resulted in the theoretical reduction of the carbon emissions of NHS Fife by 161 tonnes and 212 tonnes, depending on the scenario chosen. To put this into perspective, the average person's annual carbon footprint is approximately 10 tonnes, saving 16-21 individual carbon footprints per year (Carbon Calculator, 2014). Within our theoretical re-configuration of the NHS Fife we reduced the theoretical carbon footprint of the NHS by 10%, simply by reducing patient travel. The NHS is required to reduce its carbon emissions by 80% by the year 2050. If the NHS used a modelling tool like this to optimise the provision of healthcare it would go a long way towards achieving these targets.

By configuring services so that they are closer to home, travel was reduced by 700,000 kilometres, saving patients travel time and money. The model analysed the human resource costs and calculated the number of staff required at each site. Relocating staff from clinics with reduced demand to clinics with higher demand could, theoretically, lead to a more efficient workforce. By having fewer sites, the number of auxiliary services such as reception and cleaning can also be reduced.

The model makes the assumption that patients always travel to their place of healthcare from home, but this is not necessarily the case. School children for example may seek care in close proximity to their school. This may be the case particularly for shorter healthcare relationships e.g. when a child seeks care with an orthodontist. In the case of dentistry, it was thought that most people would have a relationship with their dentist based on where they lived.

The Pollard model (2013) provided some useful illustrations of how complex modelling can impart valuable insight into managing the delivery of healthcare. In the real world, however, it is not practical, cost-effective or appropriate to down-size one building and up-size another in order to match patient demand. In a system such as the Public Dental Service in Scotland where patient demand is relatively steady, the model needs to be an instrument which is used as part of a long-term planning tool. In other healthcare systems such as NHS England, where services are commissioned by the state, a system such as the Pollard model (2013) would be useful in ensuring that the right services are commissioned, and offered in the right place, in order to produce the lowest carbon footprint.

## 6.2 Improving oral healthcare

### 6.2.1 Childsmile and MaXED

A number of studies have looked at the relationship between maternal consumption of xylitol and MS transmission. They demonstrated both delayed MS colonisation (Söderling *et al,* 2000; Thorild *et al,* 2003 and Nakai *et al,* 2010) and a reduction in dental decay (Isokangas *et al,* 2000; Thorild et al 2006; Olak *et al,* 2012 and Laitala *et al,* 2013). Fontana *et al* (2009) could not demonstrate an effect from xylitol on the acquisition of bacterial species including MS. This may have been due to the short intervention time or the xylitol dose. Recently, the existing mother-child studies were subjected to a meta-analysis which concluded that xylitol reduced MS transmission in children of the MS-positive mothers (Lin *et al*, 2015). The MaXED study carried out in Scotland employed both an effective xylitol dose and a long intervention time. Although the MaXED study did show a difference in the MS colonisation between the CS and CS+ X groups (CS+X <CS), because of the number of mothers lost to the study, the statistical power was reduced, and therefore the difference was not statistically significant.

The risk of MS colonisation increases with higher maternal levels of MS (Law *et al,* 2007 and Da Silva Bastos *et al,* 2015). Within Scotland we found that over three quarters of the 242 mothers (76%) screened showed high MS levels with a Dentocult ® SM Strip Mutans test reading of 2 or 3. The prevalence of mothers with MS was quite high when compared with other countries. In 1274 Brazilian mothers, around 60% had high MS (Bretz *et al,* 2010), and in Finland 58% mothers had high MS levels (Isokangas *et al,* 2000). Other countries showed lower prevalence: 35% of 249 Swedish mothers (Thorild *et al,* 2003) and 27% of 400 Japanese mothers had high MS counts (Nakai *et al,* 2010). It is possible MS prevalence is so high in Scotland because Scottish oral health is traditionally poor, compared to other countries (NHS Scotland, 2008, Oral Health Database, 2014).

As Scottish mothers have high MS counts, it can be extrapolated that within this country there would normally be a high rate of MS colonisation in children (Lin *et al,* 2015 , Da Silva *et al*, 2015).

Childsmile has been responsible for the declining rate of oral disease in Scotland since its inception in 2006 (McMahon *et al,* 2014). As part of the Childsmile study there is, however, no measurement within the programme of MS levels. A number of studies have demonstrated the relationship between MS colonisation in children, and caries occurrence. If early MS colonisation can be reduced, caries risk in later life can be reduced (Köhler *et al*, 1988, Isokangas *et al* 2000, Laitala *et al*, 2012). Within this research, the levels of MS in both groups (CS and CS+X) were lower than expected. Berkowitz *et al* (1981), for example showed that by age two, around half of the children whose mothers are not enrolled in an oral health programme are expected to be colonised with MS (Lin *et al,* 2015).

It was difficult to recruit the sample of mothers originally proposed by the study statistician. The programme was widely marketed, with information sent to medical surgeries for display in waiting rooms, libraries, and through health visitors. Lead health professionals within NHS Fife were also briefed about the study. The dental health support workers expressed difficulty accessing mothers. The study did not record specific reasons for non-recruitment, but it is likely that the reasons were similar to those in other mother-child studies. In Brazilian mothers, Bretz *et al* (2010) demonstrated a difficulty reaching mothers because they were not home, or the address was incorrect. The MaXED study also required mothers to consume xylitol lozenges for 21 months, which may have reduced enthusiasm for the study. Xylitol is not well known in Scotland, whereas in the Nordic countries and Japan the health effects of xylitol are better known, which may why enrolment problems were not found in these countries. In Finland (Isokangas *et al,* 2000), 338 mothers were admitted to the maternal study, in Sweden 416 mothers (Thorild *et al,* 2003), and in Japan 400 mothers (Nakai *et al,* 2010).

With respect to the drop-out rates, there were no differences between drop-out rates in the CS and CS+X groups. It is therefore unlikely that the requirement to consume xylitol regularly was the reason for the high drop-out rate. In the Nordic countries, the drop-out rates for mothers were lower than what we experienced. In the trial by Söderling *et al* (2000), only 16% (31 of 195 mothers) had left the trial by the time their child turned two. Similarly, in the study by Thorild *et al* (2003) only 12% (21 of 173 mothers) withdrew from the trial before the child turned 18 months. It is possible that the drop-out rate is related to the differences in attitude between prevention and self-care in the Nordic countries compared with other countries.

Certainly in our study drop-out rates were high. In the USA, in the study by Fontana *et al* (2009) 32% (39 of 122 mothers) pulled out. In Japan, 28% of mothers had withdrawn from the study of Nakai *et al* (2010) by the time their children were two years old. In a similar study in Brazil, involving the maternal use of xylitol gum, fluoride, and chlorhexidine varnishes, 23% (37 of 158) mothers withdrew from the study.

### 6.2.2 Fluoride toothpaste

A number of documents support the provision of HCFT to individuals who are at risk of dental disease (Marinho *et al,* 2013, Public Health England, 2014b). There is also significant evidence to show that the use of HCFT lowers dental decay rates and is therefore presumed to be a cost-effective mechanism in the prevention of dental disease.

There is good evidence that the use of fluoridated toothpaste in children reduces dental caries (Marinho *et al,* 2013). There are only a handful of trials that provide evidence as to the efficacy of HCFT in children, with fewer demonstrating the efficacy of HCFT in people with special needs (Dreizen *et al,* 1977, Nordström and Birkhed, 2010). Although Cochrane trials show a dose relationship between fluoride and caries risk (Marinho *et al,* 2013), there is no specific research which investigates the efficacy of 2800ppm toothpaste over 5000ppm toothpaste. The prescribing of HCFT is increasing in part due to the number of guidance documents recommending its use. There is still a need for high-quality research demonstrating the cost effectiveness of the use of HCFT in vulnerable groups.

Only one study has looked at the alternatives to prescribing of HCFT. Ekstrand *et al* (2008) found that both fluoride varnish and HCFT were as effective at reducing dental decay, but that the actual delivery of the FV was 30 times more expensive to provide.

The increase in fluoride toothpaste prescribing has occurred since 2006 when it became possible for dentists to prescribe the product for their patients. Similar increases in prescribing have been noted in England (Health and Social Care Information, 2013). The cost is expected to rise, with a recent recommendation by PRESCIPP (2015) that the prescription of HCFT does not fall within the scope of practice of general medical practitioners and therefore is only authorised to be prescribed by dentists or specialists working with dental patients. If one considers that 4% of the list numbers prescribed 70% of the HCFT, it is anticipated that when the prescribing moves from being from "early adopters" to being prescribed, along with good practice by the majority of dentists the quantity, and therefore cost of HCFT will keep rising.

NHS Scotland has a commitment to reduce inequality (NHS Health Scotland, 2015). The data made it possible to demonstrate a higher prescribing of HCFT within the Public Dental Service. It is well known that people with special needs are at higher risk of dental disease (Gallagher *et al,* 2007) and the PDS cares for this group as part of its remit. It is therefore assumed that this group is receiving a higher proportion of HCFT toothpaste compared with people receiving care outside the PDS. As costs continue to rise it is important to ensure that the provision of HCFT can continue in order to achieve the goal of reducing inequality. At present, the data collected by pharmacies in Scotland is insufficient to allow an analysis of inequality and HCFT prescribing to take place. A useful way of collecting this information would be to use the Community Health Index.

# 7. CONCLUSIONS

1. The carbon emissions of the NHS Fife dental service were calculated. Although carbon emissions were similar in quantity to similar health services, dental services produce a high proportion of $CO_2$ emissions originating from travel than the health service as a whole.

2. It is possible to theoretically reconfigure the dental service to both improve productivity and reduce carbon emissions.

3. The rather low MS-colonisation of two-year olds whose mothers participated in the Childsmile program suggests that the program is effective in reducing the risk for MS transmission. Xylitol appeared to add to the Childsmile program, but due to the high drop-out rate, the effect was not significant.

4. It was demonstrated over the time period 2006-2012 within the South East of Scotland that HCFT prescribing had increased, with a different prescribing pattern demonstrated within the public dental service compared with the independent (non-public) dental service. There was considerable difference in the quantity of prescribing between individual dentists.

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