Oral diseases: a global public health challenge

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Abstract

Oral diseases are among the most prevalent diseases globally and have serious health and economic burdens, depriving people of health, wellbeing, and the ability to achieve their full potential. By virtue of their high prevalence, the most consequential oral diseases affecting global health are: dental caries, periodontal disease, tooth loss, and cancers of the lips and oral cavity. In this first of two papers, we describe the scope of the global oral disease epidemic, describe its origins in social and commercial determinants, and its costs in terms of human suffering and societal impact. Even though oral diseases are largely preventable, they persist with high prevalence as a reflection of pervasive social and economic inequalities, along with inadequate funding for prevention and treatment, particularly in low and middle-income countries (LMIC). As with most non-communicable diseases (NCDs), oral conditions are chronic and strongly socially patterned. Poor children, socially marginalised groups, and older people suffer the most from oral diseases and have more limited access to dental care. In many LMIC oral diseases remain largely untreated as the treatment costs exceed available resources. The personal consequences of chronic untreated oral diseases are often severe and include unremitting pain, sepsis, reduced quality of life, lost school days, family disruption, and decreased work productivity. The societal costs of treating oral diseases are a very high economic burden to families and the health care system. Oral diseases are truly a global public health problem with particular concern over rising prevalence in many LMIC linked to wider social, economic and commercial changes. By describing the extent and consequences of oral diseases, their roots in social and commercial determinants, and their ongoing neglect in global health policy, we aim to highlight the urgency of addressing oral diseases as a global health and NCD priority.

Key messages

- Oral health is an integral element of overall health and wellbeing enabling individuals to perform essential daily functions.
- Oral diseases include a range of chronic clinical conditions that affect the teeth and mouth including dental caries (tooth decay), periodontal (gum) disease and oral cancers.
- Despite being largely preventable, oral diseases are highly prevalent conditions affecting over 3.5 billion people around the world, with dental caries being the most common disease globally with increasing prevalence in many low and middle-income countries (LMIC)
- Oral diseases disproportionately affect poorer and marginalised groups in society being very closely linked to socioeconomic status and the broader social determinants of health.
- Oral diseases have a significant impact causing pain, sepsis, reduced quality of life, lost school days, family disruption, decreased work productivity, and the costs of dental treatment can be considerable for both individuals, and the wider health care system.
- Oral conditions share common risks with other non-communicable diseases (NCDs) including free sugars consumption, tobacco use, and harmful use of alcohol, as well as the wider social and commercial determinants of health.
- Of particular concern is the impact of free sugars consumption on the prevalence of both caries and overweight/obesity, and associated conditions such as diabetes.
- There is increasing recognition of the influence, power and impact of the global sugar industry as a threat to public health, which requires tighter regulation and legislation by governments.

Introduction

Oral health really matters. The teeth and mouth are an integral part of our body supporting and enabling essential human functions and the mouth is a fundamental feature of personal identity. Building upon existing definitions,^{1,2} oral health can be defined as: ‘multi-dimensional in nature including physical, psychological, emotional and social domains integral to overall health and well-being. Oral health is subjective and dynamic enabling individuals to perform essential functions including eating, speaking, smiling and socialising without discomfort, pain or embarrassment. Good oral health reflects an individuals’ ability to adapt to physiological changes throughout life and to maintain their own teeth and mouth through self-care in an autonomous and independent fashion’. Despite being largely preventable, oral diseases are highly prevalent across the life course and have a significant negative impact on individuals, communities and the wider society. Oral diseases are a truly global public health problem with particular concern over rising prevalence in many low and middle-income countries (LMIC) linked to wider social, economic and commercial changes.^{3,4}

Oral diseases are chronic and progressive in nature – for example dental caries affects very young children but is a lifelong condition that tracks across adolescence, adulthood and into later life. Oral conditions disproportionately affect poorer and socially disadvantaged members of society. There is a strong and consistent social gradient between socio-economic status and the prevalence and severity of oral diseases. Indeed, oral diseases can be considered as a sensitive clinical marker of social disadvantage, a ‘canary in the coalmine’ with oral diseases being the early indicator of population ill health linked to deprivation.⁵ Oral diseases and oral health inequalities are directly influenced by the wider social and commercial determinants, the underlying drivers of poor population oral health.⁶

Oral diseases are however a neglected topic, rarely seen as a priority in health policy.⁷ Oral health and the dental profession have become somewhat isolated and marginalised from mainstream developments in health policy and health care systems. The current model of dental care delivery and clinical preventive policy has failed to tackle the global burden of oral diseases. The ‘westernised’ model of modern dentistry (high technology and treatment focused) is unaffordable and inappropriate in

many LMIC.⁸ In high-income countries, dentistry is failing to meet the needs of large segments of their populations and is increasingly focusing on the provision of aesthetic treatments largely driven by profit motives and consumerism.⁹ More of the same is not the solution. A radically different approach is needed to tackle the global challenge of oral diseases.

In this first paper of a two-part Series on Oral Health, we highlight the evidence of the global clinical and public health importance of oral diseases in terms of their prevalence, patterns of oral health inequalities and their impact on individuals, families and society. Analysis will also highlight the underlying social and commercial determinants – the broad range of interacting biological, behavioural, psycho-social, economic, commercial and political drivers that create the ‘conditions in which people are born, grow, live, work and age’ that cause poor population oral health.^{6,10} Finally we will present a unifying framework that places oral diseases in a broader context and directly linked to other non-communicable diseases (NCDs).

Clinical overview of oral diseases

A wide range of diseases and disorders affect the soft and hard tissues of the mouth including an array of craniofacial disorders, congenital anomalies, injuries and various infections. However, the key clinical conditions globally which are considered public health priorities include dental caries (tooth decay), periodontal (gum) disease and oral cancers.

Dental caries is the localised destruction of dental hard tissues (enamel and dentine) by acidic by-products from the bacterial fermentation of free sugars.^{11,12} The caries process is dynamic with alternating periods of demineralisation and remineralisation of the tooth structure relative to the fluctuations in pH of the plaque biofilm. In general, the lower the pH, the greater is the tendency for dissolution of the hard tissues. When the pH in the biofilm falls below a ‘critical’ level for a sustained period following consumption of free sugars, this leads to progressive demineralisation and the sustained loss of calcium and phosphate from the mineral substance of the tooth. At the very early (sub clinical) stages and even once sufficient mineral is lost and the lesion appears clinically as a white spot on the tooth surface, caries can be reversed or arrested, especially in the presence of fluoride.^{13,14} If caries progresses and leads to

cavitation, the condition can cause significant pain and discomfort, and, when it spreads to the dental pulp, infection, and ultimately sepsis and tooth loss. Optimal exposure to fluoride is important in limiting the disease progression as fluoride promotes remineralisation. Caries at cavitation level is the usual criterion for caries detection in most epidemiological studies worldwide. The most commonly used dental caries index is the DMFT index - the sum of Decayed, Missing and Filled teeth due to dental caries (small letters for primary dentition/ capital letters for permanent dentition).¹⁵ The DMFT index thus captures the cumulative experience of past and present dental caries, whether untreated (the number of decayed teeth) or treated (filled teeth or missing teeth extracted due to caries).

Periodontal diseases are chronic inflammatory conditions that affect the tissues surrounding and supporting teeth. Initially, periodontal disease presents as gingivitis – reversible inflammation of the periodontal soft tissues resulting in gingival bleeding and swelling. In susceptible individuals with a compromised immune response, gingivitis may lead onto periodontitis which progressively destroys the periodontal tissue support including the bone surrounding teeth.¹⁶ Periodontitis is characterised as the loss of periodontal tissue support manifested through clinical attachment loss, presence of periodontal pocketing, gingival bleeding and radiographically assessed alveolar bone loss. The main cause of periodontal disease is poor oral hygiene leading to the accumulation of pathogenic microbial biofilm (plaque) at and below the gingival margin.^{17,18} Tobacco use is also an important independent risk factor for periodontal disease. Through a shared inflammatory pathway, periodontal disease is associated with other chronic diseases including diabetes, cardiovascular diseases and dementia.^{19–22} In older adults, periodontal disease has been causally linked with aspiration pneumonia, that often results in serious morbidity and mortality.²³ Periodontitis may ultimately lead to tooth loss and negatively affects chewing function, aesthetics and quality of life.

Cancer of the lips and oral cavity is a broad category of localisation for neoplasm defined by the International Classification of Disease, 10th revision as cancer of lips, tongue, gum, floor of mouth, palate, cheek mucosa, vestibule of the mouth and retromolar area (C-00 to C06).²⁴ Squamous cell carcinoma is the most common type. The major risk factors for oral cancers are tobacco, alcohol and areca nut (betel

quid).^{25–27} In many high-income countries human papilloma virus (HPV) infection is responsible for a steep rise in incidence of oro-pharyngeal cancers among young people.²⁸ Rates of oral cancers are greater among men, older age-groups, and those from poorer backgrounds – with socioeconomic inequalities observed both between and within countries.²⁹

Global epidemiological overview of oral diseases

According to the Global Burden of Disease (GBD 2015) study, 3.5 billion people worldwide live with dental conditions which are mostly: untreated dental caries in the deciduous and the permanent dentitions, severe periodontal disease, edentulism (complete tooth loss) and severe tooth loss (having between 1 and 9 remaining teeth).³ According to the International Agency for Research on Cancer, lip and oral cavity cancers are among the top 15 most common cancers in the world.²⁴

Dental caries

Epidemiological evidence indicates that lifetime prevalence of dental caries has declined in the last four decades, but this is mainly in high-income countries with the most significant decline seen in 12-year-old children.^{30,31}

Evidence on the burden of untreated caries in deciduous teeth stems from 192 studies which included 1,502,260 children aged 1-14 in 74 countries.³ In 2010, untreated caries in deciduous teeth was the 10th most prevalent health condition affecting 9% of the global child population; the global age-standardised prevalence remained unchanged between 1990 and 2010 (9%); the age-standardised global incidence was 15,205 cases per 100,000 person-years in 2010 slightly and not significantly fewer than the 15,437 cases per 100,000 cases reported in 1990. In 2015 the GBD study reported the prevalence of untreated caries in deciduous teeth was 7.8%; the age-standardised prevalence rates in 2015 were comparable to 1990 estimates.³ Untreated caries in deciduous teeth peaked amongst children aged 1-4 years.

Untreated caries in permanent teeth was the most prevalent health condition in 2010 affecting 35% of the global population or 2.4 billion people worldwide.³² Data came from 186 studies totalling 3,265,546 individuals aged 5 years or older in 67 countries.

The global age-standardised prevalence remained stable between 1990 and 2010 at 35%. The age-standardised incidence was 27,257 cases per 100,000 person-years in 2010, not significantly different from the 1990 estimates of 28,689 cases per 100,000 person-years. Prevalence reached two peaks, the first at age 25 years and another later in life at around 70 years, the latter probably explained by root caries. The most recent data from 2015 confirmed that untreated caries in the permanent dentition remains the most common condition (34.1%). In contrast to earlier data, the peak of untreated dental caries in the permanent dentition is now seen in the younger 15-19 years old group.³ Figure 1 shows the latest estimates of the prevalent cases of untreated dental caries in permanent teeth per 100,000 population. There has only been a 4% decrease in number of prevalent cases of untreated dental caries globally from 1990 (31,407 cases per 100,000) to 2017 (30,129 cases per 100,000). The global distribution and inter-country variations in prevalence have also remained the same during this period. Overall, the burden of untreated dental caries for primary and permanent dentition remained relatively unchanged over the last 30 years challenging the conventional view that dental caries burden has generally improved.

Figure 1 here

Periodontal diseases

Case definition of periodontal disease in epidemiological studies is a challenge but generally is based on measures of probing periodontal pocket depth and clinical attachment loss. Globally, severe periodontitis was the sixth-most prevalent health condition affecting nearly 11% or 743 million people worldwide. The global age-standardised prevalence and incidence remained stable since 1990: 10.8% and 11.2% for prevalence and an incidence rate of 701 cases per 100,000 person-years and 696 cases per 100,000 person-years in 2010 and 1990 respectively.³³

Tooth loss

Tooth loss reflects the end-point of a life-time of dental diseases - mainly dental caries and periodontal diseases- and the history, or a lack of, dental treatment. In 2010, 158 million people or 2.3 % of the global population was completely edentulous (no natural teeth). Figures of the prevalence of severe tooth loss revealed a significant improvement between 1990 and 2010, a fall from 4.4% to 2.4%. Incidence

rate also declined from 374 cases per 100,000 person-years in 1990 to 205 cases per 100,000 person-years in 2010.³⁴

Oral cancer

Lip and oral cavity cancers are among the top 15 most common cancers in the world with 500,550 incident cases in 2018. The total number of deaths due to cancer of lip and oral cavity accounts for 177,384 (67% in males) in 2018 or an ASR of 2.8 per 100,000 males and 1.2 per 100,000 females. Oral cancer has the highest incidence among all cancers in Melanesia and South Asia among males and it is the leading cause of cancer mortality among males in India and Sri Lanka. The age-standardized rate per 100,000 males is the fourth highest of all cancers among males living in countries with a low and medium Human Development Index (8.7 per 100,000 males).²⁴

Socioeconomic inequalities in oral health

Stark and persistent socioeconomic inequalities exist in oral diseases in a consistent and graded fashion across the social hierarchy, a classic example of a social gradient in health. Those inequalities have been extensively described in the literature and some recent studies (using state-of-the-art quasi-experimental methods) highlight causal relationships between socioeconomic status and oral health.³⁵ A systematic review was performed to assess the association between socioeconomic position and caries including 155 studies totalling 329,798 participants. The association between low educational background and having caries experience was significantly higher in countries with high Human Development Index even after adjustment for potential confounders. Lower socioeconomic position was significantly associated with any untreated caries lesions or any caries experience.³⁶ Costa and colleagues identified associations between poor socioeconomic status (SES) and severe dental caries among adults;³⁷ an increase of 10.35 units in the proportion of people with lower socioeconomic status was associated with an increase of one unit in DMFT. Klinge and Norlund identified that disadvantaged socioeconomic circumstances were associated with poor periodontal health, even after controlling for smoking, a well-known risk factor for periodontal diseases.³⁸ Evidence from a systematic review of case control studies showed a consistent association between low SES and oral cancer

in both low and high-income countries, even after adjustment for behavioural confounders.³⁹

Studies testing socioeconomic inequalities in dental caries over the life course are rare and mostly come from population-based birth cohorts from New Zealand (Dunedin) and Brazil (Pelotas). Findings from the Dunedin study showed that untreated dental caries in adulthood were negatively associated with childhood SES. With increasing socioeconomic status, the amount of poor oral health indicators decreased, even after controlling for childhood health and adult socioeconomic position. Moreover, low adult SES had a significant effect on poor adult dental health after controlling for low childhood SES.⁴⁰ Findings from the 1982 Pelotas birth cohort study showed that poverty in at least one stage of early life had an effect on adolescent's dental caries experience, oral health-related behaviours, and dental service use.⁴¹ At 24 years of age, the study findings revealed that poverty experienced in early life was associated with unsound teeth.⁴² In Sweden, most of the socioeconomic inequalities were already set early in life and remained even at old age.⁴³

Marginalised groups and disability

Extreme oral health inequalities exist for the most marginalised and socially excluded groups in societies, such as homeless people, prisoners, those with long-term disabilities, refugees and indigenous groups, a classic example of a cliff-edge of inequality⁴⁴ (Figure 2). Homeless people living in high-income countries have more untreated dental caries, more severe tooth loss, and are more likely to experience toothache compared to the general population.^{45–49} Prisoners also experience very poor oral health.^{50–55} One study in the US reported that prisoners had 8.4 times more untreated caries compared to non-institutionalised US adults.⁵⁶ In prisoners, the unmet treatment need is further complicated by restricted access to dental care.^{53–55} The picture for homeless people and prisoners in low-income countries is less documented. Disability in the context of oral health may be understood as a disability or an activity restriction which directly or indirectly affects oral health, and which is situated within the personal and environmental context of the individual.⁵⁷ Worldwide, people living with a wide range of disabilities have been shown to experience greater unmet dental need including untreated caries compared to the general population.⁵⁸ Indigenous children, even in high-income countries (US,

Canada, New Zealand, and Australia), are particularly vulnerable, with the prevalence of early childhood caries (ECC), ranging from 68% to 90%.⁵⁹ Schroth and colleagues highlighted that indigenous child populations have a higher prevalence of ECC and the disease is generally more severe compared to non-indigenous populations.⁶⁰ Adults and older people from indigenous populations also experience very poor oral health and high treatment needs,^{61–64} a problem compounded by the fact that often these communities live in rural and remote areas where access to dental care is very limited.^{64,65}

Figure 2 here

Impact of oral diseases on individuals, families and society

Economic burden of oral diseases

Dental diseases impose a substantial economic burden to society.⁶⁶ The economic burden is due to direct costs (treatment expenditures), indirect costs (productivity losses due to absence from work and school), and intangible costs (such as pain, problems with biting/chewing/eating, speaking, tasting, expression of emotions such as smiling, involved in social activities and finding a partner). Worldwide, in 2015 dental diseases accounted for direct costs of US-\$356.80 billion and indirect costs of US-\$187.61 billion.⁶⁷ In a comparison of expenditures on various diseases in the EU-2018 in 2015 (see Appendix), dental diseases (EUR 90 billion) ranked third behind diabetes (EUR 119 billion), and cardiovascular diseases (EUR 111 billion).

Dental diseases may also exacerbate the burden of other diseases and thereby contribute to the economic burden of these conditions. For example, periodontal disease has been linked to poor glycemic control among diabetes patients. For such patients, it has been shown that periodontal treatment can reduce total and diabetes-related healthcare costs.⁶⁸

Children

The toothache that follows from untreated caries is persistent and often severe.^{69–71} In a review of seven studies, Slade found the prevalence of dental pain ranged from 5–33% and to increased with child age, caries severity, and decreasing socio-economic

status.⁶⁹ People from LMIC and indigenous populations in high income countries, have a lifetime history of dental pain that generally exceeded 50% of children^{72–77}

Dental problems can result in lost time from school and to negatively impact on school performance possibly exacerbating social inequalities.^{4,78–84} Numerous studies show that untreated dental caries and associated oral problems substantially decrease quality of life for both the child, as well as their caregivers.^{85–90}

For young children with extensive dental caries, treatment under general anaesthesia is often the only realistic approach. Such care is expensive and often only viable in high-income countries. Two US studies indicate that the average cost of dental treatment under general anaesthesia varied between over \$5,500 (2008 USD) and \$7,303 (2012 USD) per child.⁹¹ Globally, few data exist to document the use of general anaesthesia to treat dental diseases. Schroth and colleagues reported that day surgery to treat ECC among Canadian children less than 6 years old occurred at a rate of 12.1 per 1,000 children and accounted for 31% of all day surgeries performed in this age group.⁶⁰ In Australia, between 2011 and 2012, the total number of hospital procedures requiring a general anesthetic (GA) due to dental reasons among children under 5 years of age reached 7,890 (8.1% of the total number of GAs).

Adults

Many adults have poor access to dental care, which means they also must deal with acute and chronic dental pain and diminished quality of life.⁹² Population-based studies of 4-week prevalence of all cause oro-facial pain was 26% in the UK,⁹³ and 53% in Canada.⁹⁴ A 2012 report from Brazil estimated that nearly 25% of the adult population had experienced dental pain within the previous six months.⁹⁵

In many countries, access to dental care for adults is often challenging, as the financing and care delivery models are often more limited than medical care. The US is a good example, where adult dental care for low-income individuals has minimal public funding. The result is that many patients wait until their dental problems become painful, or serious infections develop, which then drives them into hospital emergency departments (ED) for urgent care. In the US there was a 16% increase in ED visits for dental conditions between 2006 and 2009, with nearly one million

patient visits. Unfortunately, EDs are usually not equipped to address oral problems other than oro-facial trauma, so that services are limited to palliative measures such as temporary pain management with opioids.⁹⁶

National surveys of oral health-related quality of life conducted in several western European countries, Australia, and the US show that dental conditions all contribute to a lower life satisfaction.^{97–103} In adults, oro-facial pain is common and is the most consistent contributor to decreased quality of life.¹⁰⁴

A limited amount of research attests to the social cost of oral conditions in adults as it relates to effects on employment status and work productivity.¹⁰⁵ A nationwide study performed in Canada found that dental-related issues resulted in an average of 3.5 hours of lost working time per person per year, adding to a national total of 40 million lost work hours, which they estimated led to over Can\$1 billion in lost productivity.¹⁰⁶ A study from the U.S. suggests gender-specific effects of oral health on earning capacities in the labor market.¹⁰⁷ A nationally representative study of employed adults in Australia found that 9% of employed persons missed one or more half days in a year due to dental problems with lost productivity costs of Aus\$660 million.¹⁰⁸ In a regional survey of working adults in Brazil, Nardi and colleagues reported that oro-facial pain led to 15% of respondents being absent from work in the 6 months prior to the survey.¹⁰⁹ In an interventional study in the US Hyde and colleagues found that unemployed welfare recipients who had been unsuccessfully seeking employment for at least 3 months and who completed a course of dental treatment were two times as likely to achieve favourable/neutral employment after the dental care compared to those who did not receive any care.¹¹⁰

Older Adults

As a consequence of changes in certain health-related behaviours e.g. reduction in smoking and widespread use of fluoride toothpastes, adults in many high-income countries are retaining more of their natural dentition as they age.³⁴ While a desirable trend, many of the teeth now being retained into old age have longstanding dental restorations and, in most older adults, have some degree of advanced periodontal disease.

This trend in tooth retention has led to an increased need for more complex restorative care for a growing number of older adults. However, due to restrictions in public funding for adult dental services, treatment costs are a substantial barrier to care. Additionally, many dentists are not well trained in providing care for patients with complex medical problems. Reduced mobility and transportation difficulties associated with old age are adding to the challenge of accessing oral health care.¹¹¹ The result tends to be lower dental service utilisation among older people, leading to an accumulation of untreated dental conditions or a late-stage disease diagnosis resulting in a poor prognosis. Community-dwelling older people report the same concerns as working age adults regarding their oral health. These concerns include a high perceived need for dental care,¹¹² associated problems with pain, eating, oral comfort¹¹³ as well as problems with the use of dentures.¹¹⁴ Poor oral health in later life has also been shown to affect social relationships and loneliness^{115,116} and poor nutrition.¹¹⁷

Social and commercial determinants of oral diseases

The WHO conceptual framework for the social determinants of health highlights how structural determinants, such as economic, social and welfare policies, can generate social hierarchies and influence the socio-economic status of individuals within societies.¹¹⁸ Socio-economic status can then influence health through the circumstances in which people live, work and age and their risks for disease. These intermediate determinants include housing and working conditions, social capital, psychosocial factors such as stress and social support, behavioural and biological factors and access to good quality health care.

Although the social determinants of health have been well known for some time, the implementation of policies to address these determinants has been slow. While the dental public health community has been advocating the importance of integrated upstream and community-based approaches,¹¹⁹ oral health care and approaches to disease prevention still operate to a large extent in a non-integrated dental ‘silo’. Dental policymakers tend to rely on simplistic downstream interventions; in part, due to the dominance of a clinical interventionist philosophy and because of the challenges of generating evidence of impact for the more complex upstream

interventions. The biomedical approach to prevention thus prevails and shapes policies favouring the delivery of clinical preventive interventions and chair-side oral health education advice, rather than population-wide upstream strategies.

Conceptually a number of models have adapted the WHO social determinants framework to oral health.^{6,120,121} Additionally, there is growing recognition,^{122,123} for the need to move from current clinical approaches towards policy initiatives that tackle oral health inequalities at the structural level, focusing on the social determinants of health and the shared common risks between oral diseases and other NCDs such as free sugars, tobacco and alcohol use and their wider driving determinants.⁶

Globally there has been a steady overall increase in the production of sucrose, the most widely available sweetener since the 1980s (See appendix). As a consequence in many LMIC dental caries levels are on the increase at the same time as reported marked increases in the consumption of sugars^{3,4,124} including sugary drinks.^{125,126} Economic development has moved millions out of poverty resulting in a rapid nutritional transition, defined as a set of adverse changes in diet, physical activity and health.^{5,124} Multi-national corporations are expanding their reach from near-saturated markets in high-income countries to instead targeting new opportunities in emerging economies. The increased availability of unhealthy consumer goods including high-sugar foods and drinks is shifting behaviours and contributing to the increase in NCDs.¹²⁷ It is recognised that this represents a ticking time bomb with poorer health resulting in reduced productivity and burgeoning health care costs. Buse and colleagues have highlighted that “we cannot treat our way out of the NCD epidemic”, a radically different approach is needed.¹²⁸

Hastings has argued that equal concern now needs to be focused upon both the commercial, as well as the social determinants of health.¹²⁹ Commercial determinants of health are defined as “strategies and approaches used by the private sector to promote products and choices that are detrimental to health”.¹²⁷ In 2013 the Director General of the WHO stated that “efforts to prevent non-communicable disease go against the business interests of powerful economic operations”.¹³⁰ It is recognised that the profit margins for trans-global corporations are immense compared with the

public finances available for health improvement interventions.¹²⁸ Particularly relevant for oral health policies is the case of the global sugar industry (Panel). The tactics used by the sugar industry include discrediting major research and recommendations on diet and nutrition, enlisting the support of politicians to block reports and policy, funding ostensibly independent organisations to obtain access to key decision-makers and to legitimise statements downplaying the role of sugars in the aetiology of disease.^{131–134} A recent scoping review¹³⁵ has identified methods by which corporate interests can “drive research agendas away from questions that are most relevant for public health” and calls for the development of strategies to counteract the influence of industry sponsorship on research.

Panel – here

Four channels through which trans-national corporations can negatively influence health have been proposed. Firstly, through marketing that aims to enhance the desirability and acceptability of products; secondly via lobbying, to influence public health policy and legislation; thirdly by using corporate responsibility strategies to enhance the acceptability of the producers via activities such as sponsorship of sporting events and health care initiatives; and finally, by extended supply chains.¹²⁷ A conceptual framework combining the social and commercial determinants of oral health is presented to highlight the interacting influences and processes (Figure 3).

Figure 3 – here

Advertising to children is extensive, via multiple channels, with profound effects on food preferences, purchase requests, consumption patterns and health. The importance of early years’ environments conducive to health it is now well recognised and tackling the marketing of foods to children is seen as a vital strand in the global strategies for the prevention and control of NCDs. Indeed, the WHO has called on member states to develop appropriate multi-sectoral approaches to deal with the marketing of foods and non-alcoholic beverages to children.¹³⁶ Individuals may not have full control over exposure to these risk factors if they have insufficient funds to purchase goods which are beneficial to their oral health.¹³⁷ For example, fluoride toothpaste has been shown to be much less affordable in countries with lower per

capita household expenditure than in countries with higher household expenditure levels.¹³⁸ Another example of how consumer prices can influence oral health is given by the proportion of income needed to purchase sugar-sweetened beverages which has decreased worldwide since 1990 but particularly in LMIC.¹³⁹

Knai and colleagues have proposed a systems approach for analysing the commercial determinants of health.¹⁴⁰ Such an approach has the potential to promote a better understanding of the broader political, institutional, and cultural contexts in which health outcomes, risk factors and behaviours are embedded. They argue that taking a systems approach to understanding commercial determinants of NCDs helps identify more clearly how unhealthy commodity industries market their products, gain agency over policy and politics, and legitimise their increasing presence in public health decision-making. The involvement of such players in decision-making processes is said to parallel broader shifts in the nature of governments, particularly with many government activities now being devolved to arm's-length organisations.

The adverse influence of corporate players in governmental public health policy is well documented, with coherence of approaches often apparent across industries¹⁴⁰ Efforts employed include criticising health-promotion policies as overbearing governmental interference (nanny state) and insisting on the importance of consumer choice and individual responsibility. Knai and colleagues argue that corporations have an impact through being able to create systems that are resilient to public health interventions, having the capacity to adapt and diversify.¹⁴⁰ Buse and colleagues have expanded on the role of industry in influencing decision-making and describe a conceptual framework for governing the commercial drivers of NCD risk.¹²⁸ They emphasise the need for the development of new and more robust processes for governance and accountability of NCD prevention at the global level.

Conclusion

Oral diseases are a significant global public health problem which are highly prevalent and have major negative impacts on individuals, communities and society. Globally over 3.5 billion people suffer from oral diseases which are chronic and progressive in nature starting in early childhood and progressing across adolescence,

adulthood and into later life. Oral diseases disproportionately affect poorer and marginalised groups in society being very closely linked to socioeconomic status and the broader social and commercial determinants. Increasing consumption of free sugars particularly in LMIC is causing an increase in dental caries, as well as other NCDs such as obesity and diabetes. Dental treatment alone cannot solve this problem. A radically different approach is now needed to tackle this global health challenge.

(4,990 words)

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Contributors

All authors jointly formulated the major concepts of this paper and approved the final version. MAP, RGW, LMDM, RW and SL initially drafted and edited sections of this paper. MRM and RKC analysed and generated the 2017 Global Burden of Disease map and the figure on global sugar production. CCG-H and BD generated the figure on social gradients in oral health and RV designed the social and commercial determinants framework. CK, HB, and PA made critical revisions for important scientific content. RGW provided overall supervision. All authors provided information and references for this paper.

Declaration of interests

The authors have stated explicitly that there are no conflicts of interest in connection with this article. The authors alone are responsible for the views expressed in this paper, and they do not necessarily represent the views or policies of the institutions with which they are affiliated.

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Costs of dental care

Panel – Big Sugar – a David and Goliath Battle

The global sugar industry provides a perfect example of the commercial determinants of health in action. Although free sugars are used in the production of many processed foods and drinks, soft drinks are a major source of sugar in the global diet. The international soft drinks market is dominated by a small number of companies and in particular Coca-Cola and PepsiCo. These two companies alone account for over a third of worldwide soft drinks sales¹⁴¹ with accumulated revenues in excess of US\$100 billion in 2014¹⁴², a sum that exceeds the GDP of Slovakia and another 125 countries around the globe.¹⁴³ Commercial economic power readily translates into political power and policy influence.¹³² Between 2009 and 2015 Coca-Cola, PepsiCo and the American Beverage Association spent US\$114 million lobbying at the US federal level.¹⁴⁴ In 2003, after a joint expert committee recommended limiting free sugars to less than 10% of total energy in an advisory report¹⁴⁵ commissioned by the WHO and Food and Agriculture Organization (FAO), the global sugar industry successfully lobbied the WHO Director General to exclude the recommendation from the WHO's 2004 Global Strategy on Diet, Physical Activity and Health.¹⁴⁶ Among other tactics, the US Sugar Association, working through two US senators, threatened to get US funding for the WHO withdrawn (US\$406 million).¹⁴⁷

The soft drinks industry spends a great deal on advertising and marketing their products. In 2013 US drinks companies alone spent US\$866 million on advertising sugary drinks and energy drinks.¹⁴⁸ Direct marketing to children and young people include brand appearances on prime-time television programmes, marketing in social media and mobile marketing. Industry is also increasingly targeting its marketing campaigns to specific ethnic minority groups – US\$83 million was spent on marketing sugary drinks and energy drinks on Spanish language television in the US, a 44% increase since 2010.¹⁴⁸

Although sugary drinks consumption is highest in North America, Latin America, Australasia and Western Europe, sales are now falling in many high-income countries and instead significant growth is expected in many low and middle-income countries.¹²⁵ Coca-Cola outlined plans to invest more than US\$4 billion in China between 2015 and 2017 and by 2020 they intend to spend US\$12 billion on marketing their products across Africa. PepsiCo has set aside US\$12 billion for its Indian operations by 2020.¹⁴² In contrast, the WHO's total budget for 2017 was US\$4.4 billion.¹⁴⁹

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References

1. Glick M, Williams DM, Kleinman D V., Vujicic M, Watt RG, Weyant RJ. A new definition for oral health developed by the FDI World Dental Federation opens the door to a universal definition of oral health. *J Am Dent Assoc* 2016;**147**:915-917.
2. Petersen PE. The World Oral Health Report 2003 : Continuous Improvement of Oral Health in the 21st Century - the Approach of the WHO Global Oral Health Programme. Geneva; WHO. 2003.
3. Kassebaum NJ, Smith AGC, Bernabé E, et al. Global, Regional, and National Prevalence, Incidence, and Disability-Adjusted Life Years for Oral Conditions for 195 Countries, 1990–2015: A Systematic Analysis for the Global Burden of Diseases, Injuries, and Risk Factors. *J Dent Res* 2017;**96**:380-387.
4. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. *Bull World Health Organ* 2005;**83**:661-669.
5. Watt RG, Mathur MR, Aida J, Bönecker M, Venturelli R, Gansky SA. Oral Health Disparities in Children. *Pediatr Clin North Am* 2018;**65**:965-979.
6. Watt RG, Sheiham A. Integrating the common risk factor approach into a social determinants framework. *Community Dent Oral Epidemiol* 2012;**40**:289-296.
7. Benzian H, Hobdell M, Holmgren C, et al. Political priority of global oral health: an analysis of reasons for international neglect. *Int Dent J* 2011;**61**:124-130.
8. Yee R, Sheiham A. The burden of restorative dental treatment for children in Third World countries. *Int Dent J* 2002;**52**:1-9.
9. Holden ACL. Consumer-driven and commercialised practice in dentistry: an ethical and professional problem? *Med Heal Care Philos* 2018;**21**:583-589.
10. WHO Commission on Social Determinants of Health. Closing the Gap in a Generation. Geneva; WHO. 2008.
11. Fejerskov O, Nyvad B, Kidd E. Dental Caries : The Disease and Its Clinical Management. Copenhagen, Denmark: Blackwell Monksgaard; 2003.
12. Selwitz RH, Ismail AI, Pitts NB. Dental caries. *Lancet* 2007;**369**:51-59.
13. ten Cate JM, Featherstone JD. Mechanistic aspects of the interactions between fluoride and dental enamel. *Crit Rev Oral Biol Med* 1991;**2**:283-296.

- 655 14. Pitts NB, Zero DT, Marsh PD, et al. Dental caries. *Nat Rev Dis Prim* 2017;**3**:17030.
- 656 15. Klein H, Palmer C. Dental Caries in American Indian Children. Washington DC: U.S. Public
657 Health Service; 1938.
- 658 16. Chapple IL. Time to take periodontitis seriously. *BMJ* 2014;**348**:g2645.
- 659 17. Löe H, Theilade E, Jensen SB. Experimental Gingivitis in Man. *J Periodontol* 1965;**36**:177-
660 187.
- 661 18. Tonetti MS, Jepsen S, Jin L, Otomo-Corgel J. Impact of the global burden of periodontal
662 diseases on health, nutrition and wellbeing of mankind: A call for global action. *J Clin*
663 *Periodontol* 2017;**44**:456-462.
- 664 19. Lockhart PB, Bolger AF, Papapanou PN, et al. Periodontal Disease and Atherosclerotic
665 Vascular Disease: Does the Evidence Support an Independent Association? *Circulation*
666 2012;**125**:2520-2544.
- 667 20. Chapple ILC, Genco R, working group 2 of the joint EFP/AAP workshop. Diabetes and
668 periodontal diseases: consensus report of the Joint EFP/AAP Workshop on Periodontitis and
669 Systemic Diseases. *J Periodontol* 2013;**84**:S106-S112.
- 670 21. Daly B, Thompsell A, Sharpling J, et al. Evidence summary: the relationship between oral
671 health and dementia. *BDJ* 2017;**223**:846-853.
- 672 22. Glick M. The Oral-Systemic Health Connection: A Guide to Patient Care. 2nd Editio. Glick M,
673 (ed.). Quintessence Publishing; USA. 2019.
- 674 23. Awano S, Ansai T, Takata Y, et al. Oral Health and Mortality Risk from Pneumonia in the
675 Elderly. *J Dent Res* 2008;**87**:334-339.
- 676 24. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics
677 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185
678 countries. *CA Cancer J Clin* 2018;**68**:394-424.
- 679 25. Mehrtash H, Duncan K, Parascandola M, et al. Defining a global research and policy agenda
680 for betel quid and areca nut. *Lancet Oncol* 2017;**18**:e767-e775.
- 681 26. Warnakulasuriya S. Causes of oral cancer – an appraisal of controversies. *Br Dent J*
682 2009;**207**:471-475.
- 683 27. Winn D, Lee Y-C, Hashibe M, Boffetta P, INHANCE consortium. The INHANCE consortium:
684 toward a better understanding of the causes and mechanisms of head and neck cancer. *Oral Dis*
685 2015;**21**:685-693.

- 686 28. Mehanna H, Beech T, Nicholson T, et al. Prevalence of human papillomavirus in
687 oropharyngeal and nonoropharyngeal head and neck cancer-systematic review and meta-
688 analysis of trends by time and region. *Head Neck* 2013;**35**:747-755.
- 689 29. Conway DI, Brenner DR, McMahon AD, et al. Estimating and explaining the effect of
690 education and income on head and neck cancer risk: INHANCE consortium pooled analysis of
691 31 case-control studies from 27 countries. *Int J Cancer* 2015;**136**:1125-1139.
- 692 30. Marthaler TM. Changes in Dental Caries 1953–2003. *Caries Res* 2004;**38**:173-181.
- 693 31. Frencken JE, Sharma P, Stenhouse L, Green D, Lavery D, Dietrich T. Global epidemiology of
694 dental caries and severe periodontitis - a comprehensive review. *J Clin Periodontol*
695 2017;**44**:S94-S105.
- 696 32. Kassebaum NJ, Bernabé E, Dahiya M, Bhandari B, Murray CJL, Marcenes W. Global Burden
697 of Untreated Caries. *J Dent Res* 2015;**94**:650-658.
- 698 33. Kassebaum NJ, Bernabé E, Dahiya M, Bhandari B, Murray CJL, Marcenes W. Global Burden
699 of Severe Periodontitis in 1990-2010. *J Dent Res* 2014;**93**:1045-1053.
- 700 34. Kassebaum NJ, Bernabé E, Dahiya M, Bhandari B, Murray CJL, Marcenes W. Global Burden
701 of Severe Tooth Loss. *J Dent Res* 2014;**93**:20S-28S.
- 702 35. Matsuyama Y, Aida J, Tsuboya T, et al. Are Lowered Socioeconomic Circumstances Causally
703 Related to Tooth Loss? A Natural Experiment Involving the 2011 Great East Japan
704 Earthquake. *Am J Epidemiol* 2017;**186**:54-62.
- 705 36. Schwendicke F, Dörfer CE, Schlattmann P, Page LF, Thomson WM, Paris S. Socioeconomic
706 Inequality and Caries. *J Dent Res* 2015;**94**:10-18.
- 707 37. Costa S, Martins C, Pinto M, Vasconcelos M, Abreu M. Socioeconomic Factors and Caries in
708 People between 19 and 60 Years of Age: An Update of a Systematic Review and Meta-
709 Analysis of Observational Studies. *Int J Environ Res Public Health* 2018;**15**:1775.
- 710 38. Klinge B, Norlund A. A socio-economic perspective on periodontal diseases: a systematic
711 review. *J Clin Periodontol* 2005;**32**:314-325.
- 712 39. Conway DI, Petticrew M, Marlborough H, Berthiller J, Hashibe M, Macpherson LMD.
713 Socioeconomic inequalities and oral cancer risk: A systematic review and meta-analysis of
714 case-control studies. *Int J Cancer* 2008;**122**:2811-2819.
- 715 40. Poulton R, Caspi A, Milne BJ, et al. Association between children's experience of
716 socioeconomic disadvantage and adult health: a life-course study. *Lancet* 2002;**360**:1640-1645.

- 717 41. Peres MA, Peres KG, de Barros AJD, Victora CG. The relation between family socioeconomic
718 trajectories from childhood to adolescence and dental caries and associated oral behaviours. *J*
719 *Epidemiol Community Heal* 2007;**61**:141-145.
- 720 42. Peres MA, Peres KG, Thomson WM, Broadbent JM, Gigante DP, Horta BL. The Influence of
721 Family Income Trajectories From Birth to Adulthood on Adult Oral Health: Findings From the
722 1982 Pelotas Birth Cohort. *Am J Public Health* 2011;**101**:730-736.
- 723 43. Celeste RK, Fritzell J. Do socioeconomic inequalities in pain, psychological distress and oral
724 health increase or decrease over the life course? Evidence from Sweden over 43 years of
725 follow-up. *J Epidemiol Community Health* 2018;**72**:160-167.
- 726 44. Aldridge RW, Story A, Hwang SW, et al. Morbidity and mortality in homeless individuals,
727 prisoners, sex workers, and individuals with substance use disorders in high-income countries:
728 a systematic review and meta-analysis. *Lancet* 2018;**391**:241-250.
- 729 45. Daly B, Newton T, Batchelor P, Jones K. Oral health care needs and oral health-related quality
730 of life (OHIP-14) in homeless people. *Community Dent Oral Epidemiol* 2010;**38**:136-144.
- 731 46. Fukuda H, Kuroda K, Ohsaka T, Takatorige T, Nakura I, Saito T. Oral health status among
732 low-income people admitted to Osaka Socio-Medical Center in Japan. *Int Dent J* 2009;**59**:96-
733 102.
- 734 47. Parker E, Jamieson L, Steffens M, Cathro P, Logan R. Self-reported oral health of a
735 metropolitan homeless population in Australia: comparisons with population-level data. *Aust*
736 *Dent J* 2011;**56**:272-277.
- 737 48. Gibson G, Rosenheck R, Tullner JB, et al. A national survey of the oral health status of
738 homeless veterans. *J Public Health Dent* 2003;**63**:30-37.
- 739 49. Groundswell. *Healthy Mouths Report 1 Healthy Mouths*. London. 2016. Available from:
740 [http://groundswell.org.uk/wp-content/uploads/2017/10/Groundswell-Healthy-Mouths-Report-](http://groundswell.org.uk/wp-content/uploads/2017/10/Groundswell-Healthy-Mouths-Report-Final.pdf)
741 [Final.pdf](http://groundswell.org.uk/wp-content/uploads/2017/10/Groundswell-Healthy-Mouths-Report-Final.pdf) (accessed Aug 21, 2018).
- 742 50. Vainionpää R, Peltokangas A, Leinonen J, Pesonen P, Laitala M-L, Anttonen V. Oral health
743 and oral health-related habits of Finnish prisoners. *BDJ open* 2017;**3**:17006.
- 744 51. Marshman Z, Baker SR, Robinson PG. Does dental indifference influence the oral health-
745 related quality of life of prisoners? *Community Dent Oral Epidemiol* 2014;**42**:470-480.
- 746 52. Rouxel P, Duijster D, Tsakos G, Watt RG. Oral health of female prisoners in HMP Holloway:
747 implications for oral health promotion in UK prisons. *Br Dent J* 2013;**214**:627-632.
- 748 53. Walsh T, Tickle M, Milsom K, Buchanan K, Zoitopoulos L. An investigation of the nature of

- 749 research into dental health in prisons: a systematic review. *Br Dent J* 2008;**204**:683-689.
- 750 54. Jones CM, Woods K, Neville J, Whittle JG. Dental health of prisoners in the north west of
751 England in 2000: literature review and dental health survey results. *Community Dent Health*
752 2005;**22**:113-117.
- 753 55. Priwe C, Carlsson P. Oral Health Status of Male Swedish Citizens at Admission to Prison. *J*
754 *Correct Heal Care* 2018;**24**:382-394.
- 755 56. Boyer EM, Nielsen-Thompson NJ, Hill TJ. A comparison of dental caries and tooth loss for
756 Iowa prisoners with other prison populations and dentate U.S. adults. *J Dent Hyg* 2002;**76**:141-
757 150.
- 758 57. Faulks D, Hennequin M. Defining the population requiring special care dentistry using the
759 International Classification of Functioning, Disability and Health – a personal view. *J Disabil*
760 *Oral Heal* 2006;**7**:143-152.
- 761 58. Faulks D, Freedman L, Thompson S, Sagheri D, Dougall A. The value of education in special
762 care dentistry as a means of reducing inequalities in oral health. *Eur J Dent Educ* 2012;**16**:195-
763 201.
- 764 59. Parker EJ, Jamieson LM, Broughton J, Albino J, Lawrence HP, Roberts-Thomson K. The oral
765 health of Indigenous children: A review of four nations. *J Paediatr Child Health* 2010;**46**:483-
766 486.
- 767 60. Schroth RJ, Harrison RL, Moffatt MEK. Oral Health of Indigenous Children and the Influence
768 of Early Childhood Caries on Childhood Health and Well-being. *Pediatr Clin North Am*
769 2009;**56**:1481-1499.
- 770 61. First Nations Information Governance Centre. *Report on the Findings of the First Nations Oral*
771 *Health Survey (FNOHS) 2009-2010*. Ottawa; 2012. Available from:
772 https://fnigc.ca/sites/default/files/docs/fn_oral_health_survey_national_report_2010.pdf
773 (accessed Nov 5, 2018).
- 774 62. Indian Health Services. *The 1999 Oral Health Survey of American Indian and Alaska Native*
775 *Dental Patients: Findings, Regional Differences and National Comparisons*. Rockville; 2000.
776 Available from:
777 http://dhss.alaska.gov/dph/wcfh/documents/oralhealth/docs/oral_health_1999_ihs_survey.pdf
778 (accessed Nov 2, 2018).
- 779 63. Mejia GC, Parker EJ, Jamieson LM. An introduction to oral health inequalities among
780 Indigenous and non-Indigenous populations. *Int Dent J* 2010;**60**:212-215.
- 781 64. Australian Institute of Health and Welfare. Australia's Dental Generations: The National

- 782 Survey of Adult Oral Health 2004-06. Canberra; AIHW. 2007.
- 783 65. Vargas CM, Dye BA, Hayes KL. Oral health status of rural adults in the United States. *J Am*
784 *Dent Assoc* 2002;**133**:1672-1681.
- 785 66. Listl S, Galloway J, Mossey PA, Marcenes W. Global Economic Impact of Dental Diseases. *J*
786 *Dent Res* 2015;**94**:1355-1361.
- 787 67. Righolt AJ, Jevdjevic M, Marcenes W, Listl S. Global-, Regional-, and Country-Level
788 Economic Impacts of Dental Diseases in 2015. *J Dent Res* 2018;**97**:501-507.
- 789 68. Nasseh K, Vujicic M, Glick M. The Relationship between Periodontal Interventions and
790 Healthcare Costs and Utilization. Evidence from an Integrated Dental, Medical, and Pharmacy
791 Commercial Claims Database. *Health Econ* 2017;**26**:519-527.
- 792 69. Slade GD. Epidemiology of dental pain and dental caries among children and adolescents.
793 *Community Dent Health* 2001;**18**:219-227.
- 794 70. Bastos JL, Gigante DP, Peres KG. Toothache prevalence and associated factors: a population
795 based study in southern Brazil. *Oral Dis* 2008;**14**:320-326.
- 796 71. Tickle M, Blinkhorn AS, Milsom KM. The occurrence of dental pain and extractions over a 3-
797 year period in a cohort of children aged 3-6 years. *J Public Health Dent* 2008;**68**:63-69.
- 798 72. Antunes JLF, Peres MA, Mello TR de C, Waldman EA. Multilevel assessment of determinants
799 of dental caries experience in Brazil. *Community Dent Oral Epidemiol* 2006;**34**:146-152.
- 800 73. Feitosa S, Colares V, Pinkham J. The psychosocial effects of severe caries in 4-year-old
801 children in Recife, Pernambuco, Brazil. *Cad Saude Publica* **21**:1550-1556.
- 802 74. Ratnayake N, Ekanayake L. Prevalence and impact of oral pain in 8-year-old children in Sri
803 Lanka. *Int J Paediatr Dent* 2005;**15**:105-112.
- 804 75. Shepherd MA, Nadanovsky P, Sheiham A. The prevalence and impact of dental pain in 8-year-
805 old school children in Harrow, England. *Br Dent J* 1999;**187**:38-41.
- 806 76. Bastos JL, Celeste RK, Paradies YC. Racial Inequalities in Oral Health. *J Dent Res*
807 2018;**97**:878-886.
- 808 77. Barrêto EPR, Ferreira EF e, Pordeus IA. Determinant factors of toothache in 8- and 9-year-old
809 schoolchildren, Belo Horizonte, MG, Brazil. *Braz Oral Res* 2009;**23**:124-130.
- 810 78. Blumenshine SL, Vann WF, Gizlice Z, Lee JY. Children's School Performance: Impact of
811 General and Oral Health. *J Public Health Dent* 2008;**68**:82-87.

- 812 79. Jackson SL, Vann WF, Kotch JB, Pahel BT, Lee JY. Impact of Poor Oral Health on Children's
813 School Attendance and Performance. *Am J Public Health* 2011;**101**:1900-1906.
- 814 80. Pourat N, Nicholson G. Unaffordable dental care is linked to frequent school absences. *Policy*
815 *Brief UCLA Cent Health Policy Res* 2009:1-6.
- 816 81. Guarnizo-Herreño CC, Wehby GL. Children's dental health, school performance, and
817 psychosocial well-being. *J Pediatr* 2012;**161**:1153-1159.
- 818 82. Rebelo MAB, Rebelo Vieira JM, Pereira JV, Quadros LN, Vettore MV. Does oral health
819 influence school performance and school attendance? A systematic review and meta-analysis.
820 *Int J Paediatr Dent* October 2018. DOI: 10.1111/ipd.12441
- 821 83. Piovesan C, Antunes JLF, Mendes FM, Guedes RS, Ardenghi TM. Influence of children's oral
822 health-related quality of life on school performance and school absenteeism. *J Public Health*
823 *Dent* 2012;**72**:156-163.
- 824 84. Seirawan H, Faust S, Mulligan R. The impact of oral health on the academic performance of
825 disadvantaged children. *Am J Public Health* 2012;**102**:1729-1734.
- 826 85. Chaffee BW, Rodrigues PH, Kramer PF, Vítolo MR, Feldens CA. Oral health-related quality-
827 of-life scores differ by socioeconomic status and caries experience. *Community Dent Oral*
828 *Epidemiol* 2017;**45**:216-224.
- 829 86. Kramer PF, Feldens CA, Helena Ferreira S, Bervian J, Rodrigues PH, Peres MA. Exploring the
830 impact of oral diseases and disorders on quality of life of preschool children. *Community Dent*
831 *Oral Epidemiol* 2013;**41**:327-335.
- 832 87. Wong HM, McGrath CPJ, King NM, Lo ECM. Oral Health-Related Quality of Life in Hong
833 Kong Preschool Children. *Caries Res* 2011;**45**:370-376.
- 834 88. Do LG, Spencer A. Oral Health-Related Quality of Life of Children by Dental Caries and
835 Fluorosis Experience. *J Public Health Dent* 2007;**67**:132-139.
- 836 89. Krisdapong S, Sheiham A, Tsakos G. Oral health-related quality of life of 12- and 15-year-old
837 Thai children: findings from a national survey. *Community Dent Oral Epidemiol* 2009;**37**:509-
838 517.
- 839 90. Filstrup SL, Briskie D, da Fonseca M, Lawrence L, Wandera A, Inglehart MR. Early childhood
840 caries and quality of life: child and parent perspectives. *Pediatr Dent* **25**:431-440.
- 841 91. Nagarkar SR, Kumar J V, Moss ME. Early childhood caries-related visits to emergency
842 departments and ambulatory surgery facilities and associated charges in New York state. *J Am*
843 *Dent Assoc* 2012;**143**:59-65.

- 844 92. Breckons M, Bissett SM, Exley C, Araujo-Soares V, Durham J. Care Pathways in Persistent
845 Orofacial Pain. *JDR Clin Transl Res* 2017;**2**:48-57.
- 846 93. Macfarlane T V, Blinkhorn AS, Davies RM, Ryan P, Worthington H V, Macfarlane GJ.
847 Orofacial pain: Just another chronic pain? Results from a population-based survey. *Pain*
848 2002;**99**:453-458.
- 849 94. Locker D, Grushka M. The Impact of Dental and Facial Pain. *J Dent Res* 1987;**66**:1414-1417.
- 850 95. de Pinho Silva AM, Campos AC, Ferreira E, Duarte Vargas AM. Toothaches in the daily lives
851 of Brazilian adults. *Int J Environ Res Public Health* 2012;**9**:2587-2600.
- 852 96. Allareddy V, Rampa S, Lee MK, Allareddy V, Nalliah RP. Hospital-based emergency
853 department visits involving dental conditions: Profile and predictors of poor outcomes and
854 resource utilization. *J Am Dent Assoc* 2014;**145**:331-337.
- 855 97. Calado R, Ferreira S, Nogueira P, Mella P. *III Estudo Nacional de Prevalência Das Doenças*
856 *Orais*. Lisboa; 2015. Available from: [https://www.dgs.pt/documentos-e-publicacoes/iii-estudo-](https://www.dgs.pt/documentos-e-publicacoes/iii-estudo-nacional-de-prevalencia-das-doencas-orais.aspx)
857 [nacional-de-prevalencia-das-doencas-orais.aspx](https://www.dgs.pt/documentos-e-publicacoes/iii-estudo-nacional-de-prevalencia-das-doencas-orais.aspx) (accessed Aug 31, 2018).
- 858 98. Schuller A, Kempen I va., Vermaire E, et al. *Gebit Fit : Een Onderzoek Naar de*
859 *Mondgezondheid En Het Tandheelkundig Preventief Gedrag van Volwassenen in Nederland in*
860 *2013*. Leiden; 2014. Available from: [https://repository.tudelft.nl/view/tno/uuid:c776997e-93f8-](https://repository.tudelft.nl/view/tno/uuid:c776997e-93f8-4fd8-a317-15fade31925b)
861 [4fd8-a317-15fade31925b](https://repository.tudelft.nl/view/tno/uuid:c776997e-93f8-4fd8-a317-15fade31925b) (accessed Sept 05, 2018).
- 862 99. Carter KD, Stewart JF. *National Dental Telephone Interview Survey 2002. AIHW Cat. No.*
863 *DEN 128*. Adelaide; 2003. Available from:
864 <https://www.adelaide.edu.au/arc poh/downloads/publications/reports/working-papers/2002.pdf>
865 (accessed Sept 18, 2018).
- 866 100. Nuttall N, Steele J, Pine C, White D, Pitts N. The impact of oral health on people in the UK in
867 1998. *Br Dent J* 2001;**190**:121-126.
- 868 101. Llodra Calvo J. Encuesta de salud oral de España. *RCOE* 2012;**17**:13-41.
- 869 102. Sanders AE, Slade GD, Lim S, Reisine ST. Impact of oral disease on quality of life in the US
870 and Australian populations. *Community Dent Oral Epidemiol* 2009;**37**:171-181.
- 871 103. Savolainen J, Suominen-Taipale A-L, Hausen H, et al. Sense of coherence as a determinant of
872 the oral health-related quality of life: a national study in Finnish adults. *Eur J Oral Sci*
873 2005;**113**:121-127.
- 874 104. Slade GD, Strauss RP, Atchison KA, Kressin NR, Locker D, Reisine ST. Conference
875 summary: assessing oral health outcomes--measuring health status and quality of life.

- 876 *Community Dent Health* 1998;**15**:3-7.
- 877 105. Macfarlane T V, Blinkhorn AS, Davies RM, Kincey J, Worthington H V. Oro-facial pain in the
878 community: prevalence and associated impact. *Community Dent Oral Epidemiol* 2002;**30**:52-
879 60.
- 880 106. Hayes A, Azarpazhooh A, Dempster L, Ravaghi V, Quiñonez C. Time loss due to dental
881 problems and treatment in the Canadian population: analysis of a nationwide cross-sectional
882 survey. *BMC Oral Health* 2013;**13**:17.
- 883 107. Glied S, Neidell M. The Economic Value of Teeth. *J Hum Resour* 2010;**45**:468-498.
- 884 108. Australian Research Centre for Population Oral Health. Productivity losses from dental
885 problems. *Aust Dent J* 2012;**57**:393-397.
- 886 109. Nardi A, Michel-Crosato E, Haye Biazevic MG, Crosato E, Pizzatto E, de Paula Queluz D.
887 Relationship between orofacial pain and absenteeism among workers in Southern Brazil.
888 *Brazilian J Oral Sci* 2009;**8**:50-54.
- 889 110. Hyde S, Satariano WA, Weintraub JA. Welfare dental intervention improves employment and
890 quality of life. *J Dent Res* 2006;**85**:79-84.
- 891 111. Dolan TA, Atchison K, Huynh TN. Access to dental care among older adults in the United
892 States. *J Dent Educ* 2005;**69**:961-974.
- 893 112. Jensen PM, Saunders RL, Thierer T, Friedman B. Factors Associated with Oral Health Related
894 Quality of Life in Community-Dwelling Elderly Persons with Disabilities. *J Am Geriatr Soc*
895 2008;**56**:711-717.
- 896 113. McGrath C, Bedi R. A study of the impact of oral health on the quality of life of older people
897 in the UK--findings from a national survey. *Gerodontology* 1998;**15**:93-98.
- 898 114. John MT, LeResche L, Koepsell TD, Hujoel P, Miglioretti DL, Micheelis W. Oral health-
899 related quality of life in Germany. *Eur J Oral Sci* 2003;**111**:483-491.
- 900 115. Tsakos G, Sabbah W, Chandola T, et al. Social Relationships and Oral Health Among Adults
901 Aged 60 Years or Older. *Psychosom Med* 2013;**75**:178-186.
- 902 116. Rouxel P, Heilmann A, Demakakos P, Aida J, Tsakos G, Watt RG. Oral health-related quality
903 of life and loneliness among older adults. *Eur J Ageing* 2016;**14**:101-109
- 904 117. Nowjack-Raymer RE, Sheiham A. Numbers of Natural Teeth, Diet, and Nutritional Status in
905 US Adults. *J Dent Res* 2007;**86**:1171-1175.
- 906 118. Solar O, Irwin A. *A Conceptual Framework for Action on the Social Determinants of Health*.

907 *Social Determinants of Health Discussion Paper 2 (Policy and Practice)*. Geneva; WHO.
908 2010. Available from:
909 https://www.who.int/sdhconference/resources/ConceptualframeworkforactiononSDH_eng.pdf
910 (accessed Oct 15, 2018)

911 119. Watt RG. From victim blaming to upstream action: Tackling the social determinants of oral
912 health inequalities. *Community Dent Oral Epidemiol* 2007;**35**:1-11.

913 120. Lee JY, Divaris K. The Ethical Imperative of Addressing Oral Health Disparities. *J Dent Res*
914 2014;**93**:224-230.

915 121. Newton JT, Bower EJ. The social determinants of oral health: new approaches to
916 conceptualizing and researching complex causal networks. *Community Dent Oral Epidemiol*
917 2005;**33**:25-34.

918 122. Bedos C, Apelian N, Vergnes JN. Time to Develop Social Dentistry. *JDR Clin Transl Res*
919 2017;**3**:109-110.

920 123. da Fonseca MA, Avenetti D. Social Determinants of Pediatric Oral Health. *Dent Clin North Am*
921 2017;**61**:519-532.

922 124. Kearney J. Food consumption trends and drivers. *Philos Trans R Soc* 2010;**365**:2793-2807.

923 125. Popkin BM, Hawkes C. Sweetening of the global diet, particularly beverages: patterns, trends,
924 and policy responses. *Lancet Diabetes Endocrinol* 2016;**4**:174-186.

925 126. World Cancer Research Fund International. Building Momentum: Lessons on Implementing a
926 Robust Sugar Sweetened Beverage Tax. London; WCRF. 2018.

927 127. Kickbusch I, Allen L, Franz C. The commercial determinants of health. *Lancet Glob Heal*
928 2016;**4**:e895-e896.

929 128. Buse K, Tanaka S, Hawkes S. Healthy people and healthy profits? Elaborating a conceptual
930 framework for governing the commercial determinants of non-communicable diseases and
931 identifying options for reducing risk exposure. *Global Health* 2017;**13**:34.

932 129. Hastings G. Why corporate power is a public health priority. *BMJ* 2012;**345**:e5124-e5124.

933 130. Chan M. Opening address at the 8th Global Conference on Health Promotion Helsinki,
934 Finland. WHO. Published 2013. Available from:
935 https://www.who.int/healthpromotion/conferences/8gchp/statement_2013/en/ (accessed Sept
936 25, 2018).

937 131. Sheiham A, James WPT. Diet and Dental Caries. *J Dent Res* 2015;**94**:1341-1347.

- 938 132. McKee M, Stuckler D. Revisiting the Corporate and Commercial Determinants of Health. *Am J*
939 *Public Health* 2018;**108**:1167-1170.
- 940 133. O'Connor A. Coca-Cola funds scientists who shift blame for obesity away from bad diets. *New*
941 *York Times*. Published 2015. Available from: [https://well.blogs.nytimes.com/2015/08/09/coca-](https://well.blogs.nytimes.com/2015/08/09/coca-cola-funds-scientists-who-shift-blame-for-obesity-away-from-bad-diets/)
942 [cola-funds-scientists-who-shift-blame-for-obesity-away-from-bad-diets/](https://well.blogs.nytimes.com/2015/08/09/coca-cola-funds-scientists-who-shift-blame-for-obesity-away-from-bad-diets/) (accessed Oct 15,
943 2018)
- 944 134. Kearns CE, Glantz SA, Schmidt LA. Sugar Industry Influence on the Scientific Agenda of the
945 National Institute of Dental Research's 1971 National Caries Program: A Historical Analysis
946 of Internal Documents. Capewell S, ed. *PLOS Med* 2015;**12**:e1001798.
- 947 135. Fabbri A, Lai A, Grundy Q, Bero LA. The Influence of Industry Sponsorship on the Research
948 Agenda: A Scoping Review. *Am J Public Health* 2018;**108**:e9-e16.
- 949 136. World Health Organization. Set of Recommendations on the Marketing of Foods and Non-
950 Alcoholic Beverages to Children. Geneva; WHO. 2010.
- 951 137. Birch S, Listl S. The Economics of Oral Health and Health Care. Max Planck Institute for
952 Social Law and Social Policy Discussion Paper No. 07-2015. 2015. Available from:
953 <https://ssrn.com/abstract=2611060> (accessed Oct 20, 2018).
- 954 138. Goldman AS, Yee R, Holmgren CJ, Benzian H, Benzian H. Global affordability of
955 fluoride toothpaste. *Global Health* 2008;**4**:1-8.
- 956 139. Blecher E, Liber AC, Drope JM, Nguyen B, Stoklosa M. Global Trends in the Affordability of
957 Sugar-Sweetened Beverages, 1990–2016. *Prev Chronic Dis* 2017;**14**:160406.
- 958 140. Knai C, Petticrew M, Mays N, et al. Systems Thinking as a Framework for Analyzing
959 Commercial Determinants of Health. *Milbank Q* 2018;**96**:472-498.
- 960 141. Lobstein T, Jackson-Leach R, Moodie ML, et al. Child and adolescent obesity: part of a bigger
961 picture. *Lancet* 2015;**385**:2510-2520.
- 962 142. Nestle M. Soda Politics: Taking on Big Soda (and Winning). USA: Oxford University Press;
963 2015.
- 964 143. The World Bank. GDP (current US\$) - Data. Available from:
965 <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD> (accessed Sept 26, 2018).
- 966 144. Center for Science in the Public Interest. *Big Soda vs. Public Health: How the Industry Opens*
967 *Its Checkbook to Defeat Health Measures*. Washington DC; 2015.
- 968 145. World Health Organization. *Diet, Nutrition and the Prevention of Chronic Diseases*. Geneva;

969 WHO. 2003.

970 146. Norum KR. World Health Organization's Global Strategy on diet, physical activity and health:
971 the process behind the scenes. *Scand J Nutr* 2005;**49**:83-88.

972 147. Boseley S, McMahon J. Political Context of the World Health Organization: Sugar Industry
973 Threatens to Scupper the WHO. *Int J Heal Serv* 2003;**33**:831-833.

974 148. Rudd Center for Food Policy and Obesity. Sugary Drink Facts 2014: Some Progress but Much
975 Room for Improvement in Marketing to Youth. 2014. Available from:
976 http://www.sugarydrinkfacts.org/resources/sugarydrinkfacts_report.pdf (accessed Oct 10,
977 2018).

978 149. The World Health Organization. *Programme Budget 2016-2017*. Geneva; WHO. 2015.

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982