**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, 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.

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 disproportionally 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. Oral diseases and oral health inequalities are directly influenced by the wider social and commercial determinants, the underlying drivers of poor population oral health.

Oral diseases are however a neglected topic, rarely seen as a priority in health policy. 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. 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. 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. 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. 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. 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). 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. 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. 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. In older adults, periodontal disease has been causally linked with aspiration pneumonia, that often results in serious morbidity and mortality. 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). Squamous cell carcinoma is the most common type. The major risk factors for oral cancers are tobacco, alcohol and areca nut (betel
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. 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.

**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).

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.

**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.

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. 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. 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. 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. 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.

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.  

*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).  

*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. 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. Costa and colleagues identified associations between poor socioeconomic status (SES) and severe dental caries among adults; 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. 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 inequality\(^{44}\) (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%.\textsuperscript{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.\textsuperscript{60}

Adults and older people from indigenous populations also experience very poor oral health and high treatment needs,\textsuperscript{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.\textsuperscript{64,65}

Impact of oral diseases on individuals, families and society

Economic burden of oral diseases

Dental diseases impose a substantial economic burden to society.\textsuperscript{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.\textsuperscript{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.\textsuperscript{68}

Children

The toothache that follows from untreated caries is persistent and often severe.\textsuperscript{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. People from LMIC and indigenous populations in high income countries, have a lifetime history of dental pain that generally exceeded 50% of children. Dental problems can result in lost time from school and to negatively impact on school performance possibly exacerbating social inequalities. 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.

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. 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. 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. Population-based studies of 4-week prevalence of all cause oro-facial pain was 26% in the UK, and 53% in Canada. A 2012 report from Brazil estimated that nearly 25% of the adult population had experienced dental pain within the previous six months.

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.\textsuperscript{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.\textsuperscript{97–103} In adults, oro-facial pain is common and is the most consistent contributor to decreased quality of life.\textsuperscript{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.\textsuperscript{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 CanS1 billion in lost productivity.\textsuperscript{106} A study from the U.S. suggests gender-specific effects of oral health on earning capacities in the labor market.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{110}

\textit{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.\textsuperscript{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.\textsuperscript{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,\textsuperscript{112} associated problems with pain, eating, oral comfort\textsuperscript{113} as well as problems with the use of dentures.\textsuperscript{114} Poor oral health in later life has also been shown to affect social relationships and loneliness\textsuperscript{115,116} and poor nutrition.\textsuperscript{117}

\textit{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.\textsuperscript{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,\textsuperscript{119} oral health care and approaches to disease prevention still operate to a large extent in a non-integrated dental ‘silos’. 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.\textsuperscript{6,120,121} Additionally, there is growing recognition,\textsuperscript{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.\textsuperscript{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\textsuperscript{3,4,124} including sugary drinks.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{128}

Hastings has argued that equal concern now needs to be focused upon both the commercial, as well as the social determinants of health.\textsuperscript{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”.\textsuperscript{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”.\textsuperscript{130} It is recognised that the profit margins for trans-global corporations are immense compared with the
public finances available for health improvement interventions. 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. A recent scoping review 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. 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. 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. 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. 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.

Knai and colleagues have proposed a systems approach for analysing the commercial determinants of health. 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 industries. 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. 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. 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 disproportionally 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 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)
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
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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 sales with accumulated revenues in excess of US$100 billion in 2014, a sum that exceeds the GDP of Slovakia and another 125 countries around the globe. Commercial economic power readily translates into political power and policy influence. Between 2009 and 2015 Coca-Cola, PepsiCo and the American Beverage Association spent US$114 million lobbying at the US federal level. In 2003, after a joint expert committee recommended limiting free sugars to less than 10% of total energy in an advisory report 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. Among other tactics, the US Sugar Association, working through two US senators, threatened to get US funding for the WHO withdrawn (US$406 million).

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. 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.
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.\textsuperscript{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.\textsuperscript{142} In contrast, the WHO’s total budget for 2017 was US$4.4 billion.\textsuperscript{149}
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