

1 ***Oral diseases: a global public health challenge***

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45 *Abstract*

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

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73 **Key messages**

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

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103 ***Introduction***

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

119
120 Oral diseases are chronic and progressive in nature – for example dental caries affects
121 very young children but is a lifelong condition that tracks across adolescence,
122 adulthood and into later life. Oral conditions disproportionately affect poorer and
123 socially disadvantaged members of society. There is a strong and consistent social
124 gradient between socio-economic status and the prevalence and severity of oral
125 diseases. Indeed, oral diseases can be considered as a sensitive clinical marker of
126 social disadvantage, a ‘canary in the coalmine’ with oral diseases being the early
127 indicator of population ill health linked to deprivation.⁵ Oral diseases and oral health
128 inequalities are directly influenced by the wider social and commercial determinants,
129 the underlying drivers of poor population oral health.⁶

130
131 Oral diseases are however a neglected topic, rarely seen as a priority in health policy.⁷
132 Oral health and the dental profession have become somewhat isolated and
133 marginalised from mainstream developments in health policy and health care systems.
134 The current model of dental care delivery and clinical preventive policy has failed to
135 tackle the global burden of oral diseases. The ‘westernised’ model of modern
136 dentistry (high technology and treatment focused) is unaffordable and inappropriate in

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

142

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

152

153 *Clinical overview of oral diseases*

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

159

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

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

181
182 Periodontal diseases are chronic inflammatory conditions that affect the tissues
183 surrounding and supporting teeth. Initially, periodontal disease presents as gingivitis –
184 reversible inflammation of the periodontal soft tissues resulting in gingival bleeding
185 and swelling. In susceptible individuals with a compromised immune response,
186 gingivitis may lead onto periodontitis which progressively destroys the periodontal
187 tissue support including the bone surrounding teeth.¹⁶ Periodontitis is characterised as
188 the loss of periodontal tissue support manifested through clinical attachment loss,
189 presence of periodontal pocketing, gingival bleeding and radiographically assessed
190 alveolar bone loss. The main cause of periodontal disease is poor oral hygiene leading
191 to the accumulation of pathogenic microbial biofilm (plaque) at and below the
192 gingival margin.^{17,18} Tobacco use is also an important independent risk factor for
193 periodontal disease. Through a shared inflammatory pathway, periodontal disease is
194 associated with other chronic diseases including diabetes, cardiovascular diseases and
195 dementia.^{19–22} In older adults, periodontal disease has been causally linked with
196 aspiration pneumonia, that often results in serious morbidity and mortality.²³
197 Periodontitis may ultimately lead to tooth loss and negatively affects chewing
198 function, aesthetics and quality of life.

199
200 Cancer of the lips and oral cavity is a broad category of localisation for neoplasm
201 defined by the International Classification of Disease, 10th revision as cancer of lips,
202 tongue, gum, floor of mouth, palate, cheek mucosa, vestibule of the mouth and
203 retromolar area (C-00 to C06).²⁴ Squamous cell carcinoma is the most common type.
204 The major risk factors for oral cancers are tobacco, alcohol and areca nut (betel

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

210

211

212 *Global epidemiological overview of oral diseases*

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

219

220 *Dental caries*

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

224

225 Evidence on the burden of untreated caries in deciduous teeth stems from 192 studies
226 which included 1,502,260 children aged 1-14 in 74 countries.³ In 2010, untreated
227 caries in deciduous teeth was the 10th most prevalent health condition affecting 9% of
228 the global child population; the global age-standardised prevalence remained
229 unchanged between 1990 and 2010 (9%); the age-standardised global incidence was
230 15,205 cases per 100,000 person-years in 2010 slightly and not significantly fewer
231 than the 15,437 cases per 100,000 cases reported in 1990. In 2015 the GBD study
232 reported the prevalence of untreated caries in deciduous teeth was 7.8%; the age-
233 standardised prevalence rates in 2015 were comparable to 1990 estimates.³ Untreated
234 caries in deciduous teeth peaked amongst children aged 1-4 years.

235

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

239 The global age-standardised prevalence remained stable between 1990 and 2010 at
240 35%. The age-standardised incidence was 27,257 cases per 100,000 person-years in
241 2010, not significantly different from the 1990 estimates of 28,689 cases per 100,000
242 person-years. Prevalence reached two peaks, the first at age 25 years and another later
243 in life at around 70 years, the latter probably explained by root caries. The most recent
244 data from 2015 confirmed that untreated caries in the permanent dentition remains the
245 most common condition (34.1%). In contrast to earlier data, the peak of untreated
246 dental caries in the permanent dentition is now seen in the younger 15-19 years old
247 group.³ Figure 1 shows the latest estimates of the prevalent cases of untreated dental
248 caries in permanent teeth per 100,000 population. There has only been a 4% decrease
249 in number of prevalent cases of untreated dental caries globally from 1990 (31,407
250 cases per 100,000) to 2017 (30,129 cases per 100,000). The global distribution and
251 inter-country variations in prevalence have also remained the same during this period.
252 Overall, the burden of untreated dental caries for primary and permanent dentition
253 remained relatively unchanged over the last 30 years challenging the conventional
254 view that dental caries burden has generally improved.

255

256 *Figure 1 here*

257

258 *Periodontal diseases*

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

266

267 *Tooth loss*

268 Tooth loss reflects the end-point of a life-time of dental diseases - mainly dental
269 caries and periodontal diseases- and the history, or a lack of, dental treatment. In
270 2010, 158 million people or 2.3 % of the global population was completely
271 edentulous (no natural teeth). Figures of the prevalence of severe tooth loss revealed a
272 significant improvement between 1990 and 2010, a fall from 4.4% to 2.4%. Incidence

273 rate also declined from 374 cases per 100,000 person-years in 1990 to 205 cases per
274 100,000 person-years in 2010. ³⁴

275

276 *Oral cancer*

277 Lip and oral cavity cancers are among the top 15 most common cancers in the world
278 with 500,550 incident cases in 2018. The total number of deaths due to cancer of lip
279 and oral cavity accounts for 177,384 (67% in males) in 2018 or an ASR of 2.8 per
280 100,000 males and 1.2 per 100,000 females. Oral cancer has the highest incidence
281 among all cancers in Melanesia and South Asia among males and it is the leading
282 cause of cancer mortality among males in India and Sri Lanka. The age-standardized
283 rate per 100,000 males is the fourth highest of all cancers among males living in
284 countries with a low and medium Human Development Index (8.7 per 100,000
285 males).²⁴

286

287 *Socioeconomic inequalities in oral health*

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

306 in both low and high-income countries, even after adjustment for behavioural
307 confounders.³⁹
308
309 Studies testing socioeconomic inequalities in dental caries over the life course are rare
310 and mostly come from population-based birth cohorts from New Zealand (Dunedin)
311 and Brazil (Pelotas). Findings from the Dunedin study showed that untreated dental
312 caries in adulthood were negatively associated with childhood SES. With increasing
313 socioeconomic status, the amount of poor oral health indicators decreased, even after
314 controlling for childhood health and adult socioeconomic position. Moreover, low
315 adult SES had a significant effect on poor adult dental health after controlling for low
316 childhood SES.⁴⁰ Findings from the 1982 Pelotas birth cohort study showed that
317 poverty in at least one stage of early life had an effect on adolescent's dental caries
318 experience, oral health-related behaviours, and dental service use.⁴¹ At 24 years of
319 age, the study findings revealed that poverty experienced in early life was associated
320 with unsound teeth.⁴² In Sweden, most of the socioeconomic inequalities were already
321 set early in life and remained even at old age.⁴³

322

323 *Marginalised groups and disability*

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

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

348

349 Figure 2 here

350

351 ***Impact of oral diseases on individuals, families and society***

352 *Economic burden of oral diseases*

353 Dental diseases impose a substantial economic burden to society.⁶⁶ The economic
354 burden is due to direct costs (treatment expenditures), indirect costs (productivity
355 losses due to absence from work and school), and intangible costs (such as pain,
356 problems with biting/chewing/eating, speaking, tasting, expression of emotions such
357 as smiling, involved in social activities and finding a partner). Worldwide, in 2015
358 dental diseases accounted for direct costs of US-\$356.80 billion and indirect costs of
359 US-\$187.61 billion.⁶⁷ In a comparison of expenditures on various diseases in the EU-
360 2018 in 2015 (see Appendix), dental diseases (EUR 90 billion) ranked third behind
361 diabetes (EUR 119 billion), and cardiovascular diseases (EUR 111 billion).

362

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

368

369 *Children*

370 The toothache that follows from untreated caries is persistent and often severe.⁶⁹⁻⁷¹ In
371 a review of seven studies, Slade found the prevalence of dental pain ranged from 5-
372 33% and to increased with child age, caries severity, and decreasing socio-economic

373 status.⁶⁹ People from LMIC and indigenous populations in high income countries,
374 have a lifetime history of dental pain that generally exceeded 50% of children⁷²⁻⁷⁷
375
376 Dental problems can result in lost time from school and to negatively impact on
377 school performance possibly exacerbating social inequalities.^{4,78-84} Numerous studies
378 show that untreated dental caries and associated oral problems substantially decrease
379 quality of life for both the child, as well as their caregivers.⁸⁵⁻⁹⁰
380
381 For young children with extensive dental caries, treatment under general anaesthesia
382 is often the only realistic approach. Such care is expensive and often only viable in
383 high-income countries. Two US studies indicate that the average cost of dental
384 treatment under general anaesthesia varied between over \$5,500 (2008 USD) and
385 \$7,303 (2012 USD) per child.⁹¹ Globally, few data exist to document the use of
386 general anaesthesia to treat dental diseases. Schroth and colleagues reported that day
387 surgery to treat ECC among Canadian children less than 6 years old occurred at a rate
388 of 12.1 per 1,000 children and accounted for 31% of all day surgeries performed in
389 this age group.⁶⁰ In Australia, between 2011 and 2012, the total number of hospital
390 procedures requiring a general anesthetic (GA) due to dental reasons among children
391 under 5 years of age reached 7,890 (8.1% of the total number of GAs).

392

393 *Adults*

394 Many adults have poor access to dental care, which means they also must deal with
395 acute and chronic dental pain and diminished quality of life.⁹² Population-based
396 studies of 4-week prevalence of all cause oro-facial pain was 26% in the UK,⁹³ and
397 53% in Canada.⁹⁴ A 2012 report from Brazil estimated that nearly 25% of the adult
398 population had experienced dental pain within the previous six months.⁹⁵

399

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

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

410

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

415

416 A limited amount of research attests to the social cost of oral conditions in adults as it
417 relates to effects on employment status and work productivity.¹⁰⁵ A nationwide study
418 performed in Canada found that dental-related issues resulted in an average of 3.5
419 hours of lost working time per person per year, adding to a national total of 40 million
420 lost work hours, which they estimated led to over Can\$1 billion in lost productivity.¹⁰⁶

421 A study from the U.S. suggests gender-specific effects of oral health on earning
422 capacities in the labor market.¹⁰⁷ A nationally representative study of employed adults
423 in Australia found that 9% of employed persons missed one or more half days in a
424 year due to dental problems with lost productivity costs of Aus\$660 million.¹⁰⁸ In a
425 regional survey of working adults in Brazil, Nardi and colleagues reported that oro-
426 facial pain led to 15% of respondents being absent from work in the 6 months prior to
427 the survey.¹⁰⁹ In an interventional study in the US Hyde and colleagues found that
428 unemployed welfare recipients who had been unsuccessfully seeking employment for
429 at least 3 months and who completed a course of dental treatment were two times as
430 likely to achieve favourable/neutral employment after the dental care compared to
431 those who did not receive any care.¹¹⁰

432

433 *Older Adults*

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

440

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

457 ***Social and commercial determinants of oral diseases***

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

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

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

478

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

486

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

501

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

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

519

520 *Panel – here*

521

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

530

531 *Figure 3 – here*

532

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

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

547

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

558

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

570

571

572 ***Conclusion***

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

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

583

584 (4,990 words)

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587 **Contributors**

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

596

597 **Declaration of interests**

598 The authors have stated explicitly that there are no conflicts of interest in connection
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606

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610 England, Wales and Northern Ireland

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613

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615 Figure: Global production of sugar between 1980 and 2016 in metric tonnes.

616 **Costs of dental care**

617

618

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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