

The Relationship between Income and Oral Health: A Critical Review

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Published

2019

Journal Title

Journal of Dental Research

Version

Accepted Manuscript (AM)

DOI

[10.1177/0022034519849557](https://doi.org/10.1177/0022034519849557)

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1 The relationship between income and
2 oral health – A critical review
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21 Invited Critical Review: Journal of Dental Research

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23 Word count: 3995 words

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25 Abstract

26 In this critical review, we summarized the evidence on associations between individual/household
27 income and oral health, between income inequality and oral health, and on income-related
28 inequalities in oral health. Meta-analyses of mainly cross-sectional studies confirm that low
29 individual/household income is associated with oral cancer (odds ratio: 2.41 (95%CI: 1.59, 3.65)),
30 dental caries prevalence (prevalence ratio: 1.29 (95% CI: 1.18, 1.41)), any caries experience (odds
31 ratio: 1.40 (95% CI: 1.19, 1.65)), tooth loss (odds ratio: 1.66 (95% CI: 1.48-1.86) and traumatic dental
32 injuries (odds ratio: 0.76 (95% CI: 0.65–0.89)). Reviews also confirm qualitatively that low income is
33 associated with periodontal disease and poor oral health related quality of life. Limited evidence
34 from the U.S. shows that psychosocial and behavioural explanations only partially explain
35 associations between low individual/household income and oral health. Few country-level studies
36 and a handful of sub-national studies from the U.S, Japan and Brazil show associations between
37 area-level income inequality and poor oral health. However, this evidence is conflicting given that
38 the association between area-level income inequality and oral health outcomes varies considerably
39 by contexts and by oral health outcomes. Evidence also shows cross-national variations in income-
40 related inequalities in oral health outcomes of self-rated oral health, dental care, oral health related
41 quality of life, outcomes of dental caries and outcomes of tooth loss. There is a lack of discussion in
42 oral health literature about limitations of using income as a measure of social position. Future
43 studies on the relationship between income and oral health can benefit substantially from recent
44 theoretical and methodological advancements in social epidemiology that include application of an
45 intersectionality framework, improvements in reporting of inequality and causal modelling
46 approaches. Theoretically well-informed studies, that apply robust epidemiological methods, are
47 required to address knowledge gaps for designing relevant policy interventions to reduce income-
48 related inequalities in oral health.

49

50 **Keywords:** Social determinants, Health inequalities, Epidemiology, Review, Dental, Theory

51 Introduction

52 Oral conditions affect nearly half of the global population, and unfairly more so among socially
53 disadvantaged individuals and populations (Kassebaum et al. 2017; Watt et al. 2016). Understanding
54 the drivers of population-levels of poor oral health and oral health inequalities is fundamental for
55 formulating an adequate policy response. Social determinants of health are conditions in which
56 people are born, grow, live, work and age ((CSDH) 2007). Among them, income has received ample
57 attention and is noted as the best single indicator of material living standards in health research
58 (Galobardes et al. 2006). Income is indicative of the standard of living and of life chances that
59 individuals and households experience through sharing goods and services (Daly et al. 2002). The
60 aetiology of commonly prevalent oral conditions include behavioural risk factors such as inadequate
61 diet, tobacco use and high levels of stress, all of which are known to vary by income (Laaksonen et
62 al. 2003; Lynch 1997). Income is also recognized as an enabling factor for access to healthcare (van
63 Doorslaer et al. 2006). Therefore, it is vital to understand income's role as a societal driver of oral
64 health.

65 Despite their interdependence, the individual/household income, the average income of the
66 population, the income below a certain threshold (poverty line), and the distribution of income
67 within an area (area-level income inequality) are all treated as separate exposures in relation to
68 health. Although area-level measures of income are applied as proxies of income when the data at
69 individual/household level is not available; treating them identically is inappropriate (Subramanian
70 et al. 2009) and inconsistent with multiple hypotheses proposed to explain how income across levels
71 of social organization impact health outcomes (see (Wagstaff 2000) for description of absolute
72 income hypothesis, relative income hypothesis, deprivation hypothesis, relative position hypothesis
73 and income inequality hypothesis). We show multiple hypotheses between different measures of
74 income and across many oral health outcomes in Figure 1. Income is a preferred measure among
75 studies comparing social inequalities in health (Galobardes et al. 2006). In this critical review, we
76 summarize the evidence on the relationship between income and oral health, therefore, from three
77 different perspectives:

78 *Is low individual/ household-level income related to worse oral health outcomes?*

79 *Is area-level income inequality related to worse oral health outcomes?*

80 *What is the extent of income-related oral health inequalities within and between*
81 *countries?*

82 In the final section (Conclusion and Perspectives) we highlight theoretical and methodological
83 advancements in social epidemiology that offer opportunities to fill current knowledge gaps on the
84 relationship between income and oral health.

85 Is low individual/ household-level income related to worse oral health 86 outcomes?

87 Theoretical pathways and explanations

88 Materialist explanations and behavioral/cultural explanations are widely adopted explanations for
89 the relationship between low income and worse oral health outcomes (Sisson 2007; Townsend et al.
90 1982). The material explanation emphasizes the role of material disadvantage due to lack of income
91 such as inability to afford preventive and regular dental care due to treatment costs and accessing
92 healthy diets. Alternatively, behavioral/cultural explanations stress on the role of poor health

93 behaviors (tobacco use, high sugar consumption, infrequent and symptomatic dental visits, and poor
94 oral hygiene practices) that may arise due to low income. The underlying reasons for such behavior
95 include lack of education, knowledge, and attitudes towards healthy behavior. Another explanation
96 for poor behaviour is the 'culture of poverty thesis'. At lower levels of income, a structure of norms,
97 ideas, and behaviors can get established over as a process of biological and social adaptation over
98 time leading to persistent poor health behaviors (Townsend et al. 1982).

99 Sabbah et al. (2009a) examined whether oral health behaviors (smoking, dental visits, frequency of
100 eating fresh fruits and vegetables, and oral hygiene) explained the observed associations between
101 income and multiple oral health outcomes (gingival bleeding, loss of periodontal attachment, tooth
102 loss and perceived oral health) among adults in the U.S. population. Despite adjusting for the oral
103 health behaviors, income related inequalities in all the outcomes remained (higher income vs lower
104 income: gingival bleeding (regression coefficient) -0.6(95% CI: -0.9, -0.4); loss of periodontal
105 attachment (regression coefficient) -0.3 (95%CI: -0.6, -0.1) poor/fair perceived oral health (odds
106 ratio) 0.9 (95%CI: 0.8, 0.9); number of missing tooth surfaces (count rate ratio) 0.9 (95%CI: 0.9, 0.9)).

107 A psychosocial theory emphasizing the role of stress in leading to worse oral health outcomes due to
108 relative disadvantage among individuals is also proposed (Sisson 2007). Sabbah et al. (2009b)
109 examined the role of cognitive ability in income related oral health inequalities measured and found
110 that income inequality persisted after accounting for cognitive ability (gingival bleeding (regression
111 coefficient) -0.9(95% CI: -1.3, -0.6); loss of periodontal attachment (regression coefficient) -1.1
112 (95%CI: -1.5, -0.6); number of missing tooth surfaces (count rate ratio: 0.9 (95%CI: 0.8, 0.9)).

113 A life-course framework theorizes how exposures throughout life, especially during biologically or
114 socially vulnerable periods, influence health at later ages (Ben-Shlomo and Kuh 2002). Using data
115 from the Pelotas birth cohort study in Brazil, several studies showed later on impact on oral health
116 of income earlier in life. Upwardly mobile income between childhood and adolescence improved
117 dental care (Peres et al. 2007). Later on, when 31 years old, Schuch et al. (2018b) showed that adults
118 belonging to low- and fluctuating-income trajectories from childhood to adulthood had twice as
119 much the prevalence of periodontitis than in participants from stable high-income trajectories. The
120 direct effect of early-life poverty on periodontitis in adulthood was also confirmed (Schuch et al.
121 2018a). Another study showed that participants with stable-low and upward income group
122 trajectories had more unsound teeth than those in the stable high-income group (Peres et al. 2018).

123 Theoretical explanations on the relationship between area-level mean income and oral health are
124 not well developed as they are mostly used as proxies for individual/household income.

125 [Brief summary of evidence](#)

126 Numerous studies have examined associations between low individual- and household-level income
127 and oral health outcomes. Using a systematic search strategy on PubMed (Box 1, Appendix 1), we
128 identified at least 16 reviews on this subject that adopted a systematic search strategy (three on
129 periodontal disease, three on dental caries, two on oral cancer, one each on oral health related
130 quality of life (OHRQoL), dental trauma, and tooth loss, and one generally on oral health) (See
131 Appendix 1). The evidence reviewed is largely contributed from cross-sectional and case control
132 studies, and only a few include cohort studies. Qualitatively, all reviews confirmed that low income is
133 associated with poor oral health outcomes examined. Meta-analyses do not exist on the associations
134 between low income and the outcomes of periodontal disease and OHRQoL. But, reviews concluded
135 that low income is associated with higher periodontal disease (Bastos et al. 2011; Borrell and
136 Crawford 2012; Schuch et al. 2017) in adults and low parental income is associated with worse

137 OHRQoL among children(Kumar et al. 2014). Few reviews applied meta-analysis to quantitatively
138 summarise evidence on low income and specific oral health outcomes.

139 Oral cancer

140 A meta-analysis (collective sample size: 905 cases and 1388 controls) of odds ratio estimates of low
141 to high monthly household income associated with increased risk of oral cancer was found to be
142 2.41 (95%CI: 1.59, 3.65) (Conway et al. 2008). Authors also found higher odds among high income
143 than low income countries in a fixed-effects model ($p=0.04$). No significant differences between
144 studies by variations in income categories among selected studies or by adjustment of confounding
145 factors were reported.

146 Dental caries

147 For dental caries, meta-analysis for the association between low income and dental caries
148 prevalence from 31 studies found a pooled prevalence ratio of 1.29 (95% CI: 1.18, 1.41). Separately,
149 pooled odds ratio of 1.40 (95% CI: 1.19, 1.65) was found for the association between low income and
150 any caries experience (DMFT/dmft >0) from 15 studies (Schwendicke et al. 2015). No significant
151 variations were reported by adjustment for confounding factors (Schwendicke et al. 2015).

152 Tooth loss

153 A meta-analysis of 11 studies examined the association between low income and tooth loss (Seerig
154 et al. 2015) and found that low income was associated with 2.52 times (95% CI: 2.11, 3.01) higher
155 odds of tooth loss. However, when only adjusted results were pooled, the odds ratio attenuated to
156 1.66 (95% CI: 1.48-1.86) (Seerig et al. 2015).

157 Traumatic dental injuries

158 Pooled odds ratio from eight cross-sectional studies on the association between income and
159 traumatic dental injuries in primary dentition showed that children from households with income
160 twice of average salary, and thrice of average salary, had 0.77 and 0.76 lower odds of traumatic
161 dental injuries, (95% CI: 0.66–0.90) and (95% CI: 0.65–0.89) respectively (Correa-Faria et al. 2015).

162 Is area-level income inequality related to worse oral health 163 outcomes?

164 Theoretical pathways and explanations

165 Theoretical explanations for the relationship between area-level income inequality and oral health
166 are grounded in social relations and systematic distribution and misallocation of social resources
167 relevant to health arising due to inequality. The relevance of these pathways is discussed
168 extensively in social epidemiology. However, disagreement persists among their proponents.

169 **Materialist explanation:** the materialist explanations stress the role of environmental factors on
170 health which tend to vary according to the degree of income inequality of an area. Macroeconomic
171 factors such as unemployment and levels of economic development lead to hazardous work and
172 living environments that lead to poorer health on an average (MacIntyre 1997).

173 **Behavioral:** the behavioral explanations state that compared to more egalitarian, unequal social
174 environments produce more unhealthy behaviors. This is either due to individual choices or
175 presence of social gradients in health behaviors (MacIntyre 1997).

176 **Psychosocial:** When there is high area-level income inequality, there is a greater degree of social-
177 evaluative threats (comparisons between people) added with the lack of control and coping

178 strategies leading to higher levels of persistent stress. Therefore, a greater decrement in power and
179 control across the social hierarchy in presence of more inequality leads to poorer health on average
180 (Bartley 2004).

181 **Social Capital:** social capital explanations branch out from the psychosocial explanation as this
182 theory posits that a more unequal distribution in income undermines trust and damages social
183 relationships at a population level (Kawachi and Kennedy 1999). The lack of trust and social support
184 are the key reasons for poorer population health in places with high inequality.

185 **Neo-material:** in contrast to the psychosocial and the social capital theories, the neo-material theory
186 emphasizes the role of the neo-material cluster through which income inequality leads to worse oral
187 health at the population level. The neo-material cluster consists of both lack of material resources by
188 individuals and populations as well as a systematic underinvestment in social infrastructure such as
189 public policies on health care, transportation, housing and welfare (Lynch et al. 2004).

190 Operationalization of these theories in oral epidemiological literature has been reviewed in the
191 referred scoping review (Singh et al. 2016). The review found dominant use of psychosocial theory,
192 more post-hoc use of theories than their explicit modeling within studies, and a need to
193 acknowledge heterogeneity of aetiologies of oral health conditions and its impact on presumed
194 theories (Singh et al. 2016).

195 [Brief summary of evidence](#)

196 To our knowledge, no systematic review exists on the relationship between area-level income
197 inequality and oral health outcomes. Studies on income inequality and oral health are relatively
198 recent and exist at both country level (Bernabe and Hobdell 2010; Bernabe et al. 2009a; Bhandari et
199 al. 2015a; 2015b; Sabbah et al. 2010b) and at sub-national levels from Japan (Aida et al. 2011), USA
200 (Bernabe and Marcenes 2011; Moeller et al. 2017), Brazil (Celeste et al. 2011a; Celeste and
201 Nadanovsky 2010; Celeste et al. 2009; Chalub et al. 2014; Goulart Mde and Vettore 2016; Pattussi et
202 al. 2001; Peres et al. 2003; Vettore and Aqeeli 2016; Vettore et al. 2013) and Australia (Singh et al.
203 2018).

204 [Outcomes of dental caries](#)

205 Five studies have examined the associations between area-level income inequality and outcomes of
206 dental caries (Bernabe and Hobdell 2010; Bernabe et al. 2009; Celeste et al. 2009; Pattussi et al.
207 2001; Peres et al. 2003). Of these, three were ecological in study design (Bernabe and Hobdell 2010;
208 Bernabe et al. 2009; Peres et al. 2003), and two applied multilevel modelling (Celeste et al. 2009;
209 Pattussi et al. 2001). Two studies were conducted at the country level and the remaining three
210 studies were conducted at the sub-national level in Brazil. Except for the study by Peres et al. (2003),
211 all studies confirmed a positive association between area-level income inequality and at-least one
212 component of DMFT. Bernabe and Hobdell (2010) found a correlation coefficient of 0.44 ($p=0.038$)
213 for the association between Gini coefficient (a widely used measure of income inequality) and DMFT
214 among 5-6 year children among rich nations, but found no association when low and middle income
215 nations were included in the analysis. Bernabe et al. (2009) found a correlation coefficient of -0.82
216 ($p<0.001$) for the association between Gini coefficient and filled teeth, while a correlation of -0.66
217 ($p<0.01$) with DMFT scores. Pattussi et al. (2001) found higher administrative-level Gini coefficient to
218 be associated with higher DMFT scores (beta coefficient: 3.1 (95% CI: 0.77, 5.55) in Brazil.

219 [Periodontal disease](#)

220 One country-level ecological study (Sabbah et al. 2010b) and two sub-national multilevel studies
221 (Celeste et al. 2011a; Vettore et al. 2013) from Brazil have tested associations between income

222 inequality and periodontal disease. Except Celeste et al. (2011a), both confirmed a positive
223 association between income inequality and periodontal disease. Sabbah et al. (2010a) found a
224 correlation coefficient of 0.50 ($p=0.013$) for ≥ 4 mm periodontal pockets and 0.62 ($p=0.008$) for ≥ 6
225 mm periodontal pockets, respectively. Vettore et al. (2013) found that individuals living in Brazilian
226 state capitals and federal districts within the highest tertile of income inequality had 3.0 times (95%
227 CI: 1.5, 5.9) times higher odds of severe periodontal disease.

228 Outcomes of tooth loss

229 Only sub-national studies from Brazil, USA, Japan and Australia exist on the associations between
230 income inequality and tooth loss (Aida et al. 2011; Bernabe and Marcenes 2011; Celeste et al. 2011a;
231 Celeste and Nadanovsky 2010; Celeste et al. 2009; Chalub et al. 2016; Goulart Mde and Vettore
232 2016; Singh et al. 2018). Out of the eight studies, five studies reported a positive association
233 between area-level income inequality and tooth loss (Aida et al. 2011; Bernabe and Marcenes 2011;
234 Celeste and Nadanovsky 2010; Celeste et al. 2009; Goulart Mde and Vettore 2016), with effect
235 estimates ranging from odds ratio of 1.17 (95% CI: 1.05, 1.30) associated with 5% change in income
236 inequality to 1.67 (95% CI: 1.26, 2.29; having 19 or less teeth vs having 20 or more teeth as
237 reference). Two reported no associations (Celeste et al. 2011a; Chalub et al. 2016), and one found
238 high-income inequality to be associated with lower inadequate dentition among Australian adults
239 (odds ratio of 0.64; 95% CI: 0.48, 0.87 for having less than 21 teeth) (Singh et al. 2018).

240 Subjective oral health outcomes

241 One study each from the U.S.A, Australia, and Brazil have tested associations between income
242 inequality and subjective oral health outcomes (Moeller et al. 2017; Singh et al. 2018; Vettore and
243 Aqeeli 2016). No association was reported in one study (Singh et al. 2018), while the other two
244 studies found high-income inequality to be associated with worse subjective oral health.

245 Dental care utilization

246 Three country-level studies have investigated the associations between income inequality and
247 dental care utilization (Bernabe et al. 2009; Bhandari et al. 2015a; 2015b). All confirmed an inverse
248 association between income inequality and dental care utilization.

249 Other oral disorders

250 One sub-national study reported no association between income inequality and malocclusion
251 (Celeste and Nadanovsky 2010).

252 What is the extent of income-related oral health inequalities within 253 and between countries?

254 Theoretical pathways and explanation

255 Based on the reviewed theoretical pathways and the evidence for the relationship between income,
256 poverty and income inequality and oral health above; one can speculate that income-related oral
257 health inequalities between countries will differ depending on the underlying historical, political,
258 economic and social environment that shape income inequality within countries. Proposing a
259 conceptual model that can capture the influence of income across different levels of social
260 organization, at different life stages, through multiple theorized pathways and that is relevant to all
261 oral health outcomes can be ambitious. However, mapping the key aspects that connect income and
262 income inequality to oral health outcomes is important to understand and address the societal
263 drivers of income-related oral health inequalities. Conceptual models elucidate specific intervention
264 points for reducing income-related oral health inequalities within and between countries. We

265 propose a theoretical framework in Figure 2, adapted from a previous model proposed for explaining
266 population-level causation of dental caries (Holst et al. 2001), and existing models to explain social
267 inequalities in health ((CSDH) 2007) and oral health (Watt and Sheiham 2012).

268 [Brief summary of evidence](#)

269 No systematic reviews exist on the extent of variations in income-related oral health inequalities.
270 Social gradients and differences in oral health status according to income are confirmed by
271 numerous studies. Few and relatively recent studies quantified income-related oral health
272 inequalities using composite inequality measures and compared between populations by time or
273 geography and/or oral health outcomes (Borrell and Taliq 2012; Celeste et al. 2011b; Do et al. 2010;
274 Farmer et al. 2017; Guarnizo-Herreno et al. 2015; Kramer et al. 2015; Manski et al. 2016; Mejia et al.
275 2014; Peres et al. 2015; Ravaghi et al. 2013a; 2013b; Roncalli et al. 2015; Sanders et al. 2009; Shen et
276 al. 2013; Slade et al. 2014; Tchicaya and Lorentz 2014). Cross-national variations in income-related
277 inequalities are confirmed from cross-sectional studies on self-rated oral health (Guarnizo-Herreno
278 et al. 2015), oral health-related quality of life (Sanders et al. 2009) and dental care (Manski et al.
279 2016; Tchicaya and Lorentz 2014). Cross-national variations in trends in income-related inequalities
280 are also confirmed in outcomes of dental caries, edentulousness, number of filled teeth (Farmer et
281 al. 2016) and inadequate dentition (Peres et al. 2015). Within-countries variations in income-related
282 oral health inequalities by time are also confirmed (Borrell and Taliq 2012; Do et al. 2010; Kramer et
283 al. 2015; Roncalli et al. 2015; Slade et al. 2014). Finally, some studies have confirmed variations in
284 income-related oral health inequalities according to oral health outcomes within the same
285 population (Farmer et al. 2017; Mejia et al. 2014; Ravaghi et al. 2013b). Only two studies have
286 compared income-related inequalities between oral and general health outcomes in the same
287 population and found higher in oral health outcomes rather than general health (Ravaghi et al.
288 2013a; Sabbah et al. 2007).

289 [Conclusions and perspectives](#)

290 [Summary of evidence](#)

291 The evidence on the relationship between income and oral health is multifaceted, and unclear on
292 certain specific aspects. For example, while the evidence on the relationship between
293 individual/household income and oral health outcomes is more developed (tested across large
294 number of oral health outcomes and many nations), the evidence is limited and inconclusive on the
295 relationship between area-level income inequality as an exposure and oral health outcomes.
296 Variations of temporal and geographic nature in income-related inequalities in oral health within
297 and between countries is also less evidenced.

298 [Gaps in evidence](#)

299 Some knowledge gaps persist on the relationship between income, income inequality and oral
300 health outcomes. For instance, it is less likely that low income affects all oral health outcomes with
301 the same intensity or through identical pathways. Oral diseases differ in their aetiology and low
302 income, or high-income inequality, may lead to different material stressors relevant to each of them
303 (for example: accessing preventive dental healthcare for dental caries and accessing tobacco
304 cessation services and nicotine replacement therapies for the periodontal disease). There is limited
305 discussion on the use of income as a measure of social position despite its known limitations related
306 to misreporting and its reliability for young and older adults and its relevance as measure of social
307 disadvantage among population sub-groups such as among those with disabilities, ethnic minorities,
308 indigenous people and diverse gender or sexual identities. There is lack of clarity and consensus on
309 causal pathways through which income, or income inequality, impacts oral health outcomes.

310 Increased knowledge of causal pathways is tantamount to better understand and address issues
311 around confounding by other measures of social position such as occupation, employment and
312 education. Finally, evidence on the relationship between income and oral health is derived mainly
313 from cross-sectional studies where the temporal sequence between low income and poor oral
314 health cannot be established. We do not summarize evidence on poverty and oral health in this
315 critical review as poverty cannot be solely defined and measured by income and must include
316 aspects of low wealth and low consumption (Headey 2008) and should be examined in future
317 reviews.

318 [Way forward for research](#)

319 Despite knowing that social exposures such as gender, ethnicity, age, education as well as income
320 are shaped by societal systems of oppression and privilege (Kapilashrami and Hankivsky 2018; Merlo
321 2018), studies treat these measures as independent to each other in relation to health. Such an
322 exercise risks considering these exposures as measures of individual risk and ignores intersection
323 between different forms of social identities (Evans et al. 2018). An intersectionality approach, that
324 can examine interactions between income and multiple social exposures when studying
325 determinants of oral health and oral health inequalities will be valuable (Kapilashrami and Hankivsky
326 2018; Merlo 2018).

327 Often studies on income-related oral health inequalities selectively choose scales (absolute or
328 relative) to report inequality. The choice between the scales are value-laden and sometimes driven
329 by either preferred conclusions or selective exclusion of measures (Kjellsson et al. 2015). To avoid
330 such suspicions, inequalities should be presented on both scales (Mackenbach et al. 2016). Choosing
331 a reference group when estimating inequalities is an additional issue of concern. Particularly, when
332 inequalities are measured on a relative scale for oral health outcomes that have an upper and lower
333 bound when outcomes can be expressed as either health attainments or shortfalls (example:
334 presence or absence of periodontitis). It is advised that income-related oral health inequalities are
335 presented using all three measures: attainment-relative, absolute, and shortfall-relative, to avoid
336 risks of suspecting preferential reporting of shortfall or attainment perspective (Kjellsson et al.
337 2015). Inequality plots are now developed that can simultaneously present changes in income-
338 related oral health inequalities over time on both relative and absolute scales (Blakely et al. 2017).

339 Causal approaches based on the 'potential outcome approach' framework are gaining momentum in
340 epidemiology to address pertinent research questions related to health inequalities but lags in oral
341 health literature. Examples include the estimation of causal effects of social disadvantage on health
342 (Nandi et al. 2012) or modeling utility of interventions in reducing existing socioeconomic
343 inequalities in health (Blakely et al. 2018). These techniques offer substantial opportunities to
344 improve the current understanding of income and oral health relationship (VanderWeele 2015). Rich
345 observational data can be utilized using these methods that mimic randomized controlled trials to
346 examine causal relationships between income and health. By employing mediation analysis, the total
347 causal effects of income on oral health outcome can be decomposed into a portion of the total
348 effect that is not transmitted through measured pathways (natural direct effect), and a portion
349 transmitted through measured mediators (natural indirect effect). It must be noted that causal
350 modeling approaches have strong assumptions of no confounding among others. Therefore, the
351 selection of confounding factors must be carefully thought through and theoretically informed
352 (Fleischer and Diez Roux 2008). Well-designed longitudinal studies with sufficiently large
353 representative sample sizes, long-term follow up, and rich baseline covariate data can help in
354 minimizing bias. Long-term follow-up studies, for instance birth cohorts, also offer unique
355 opportunities to examine the oral health impact of early life exposures to low parental income

356 across the life-course. Furthermore, longitudinal studies have the capacity to inform lagged and
357 period effects of low income on oral health, of which cross-sectional and intervention studies with
358 short-term follow-up may not.

359 Conclusion

360 The studies on oral health effects of individual/household income and of societal income inequality
361 need to enhance their theoretical and methodological rigor. Well-designed epidemiological studies
362 that exploit ongoing methodological advances in epidemiology and statistics, as well as theoretical
363 developments in social epidemiology, are likely to address current knowledge gaps on income-
364 related inequalities in oral health. Robust evidence generated from studies that capitalize on these
365 advancements can help design policy interventions to reduce the pervasive oral health effects of low
366 income and income inequality. Meta-analyses confirm that low individual/household income is
367 associated with several adverse oral health outcomes. Limited evidence shows that psychosocial and
368 behavioural explanations only partially explain associations between low individual/household
369 income and oral health. The evidence on area-level income inequality and poor oral health is
370 conflicting given that the associations varies considerably by contexts and by oral health outcomes.

371 Acknowledgments

372 No funding was obtained from grant funds, commercial sources, and from a contributors'
373 institutions for this work.

374 Conflicts of Interest

375 None to declare

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377

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Figure 1 Relationship between income and oral health outcomes at different levels of social organisation

Figure 2 Conceptual framework for income and oral health relationship