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Is there socioeconomic inequality in periodontal disease among adults with optimal behaviours

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ABSTRACT

Objective: To examine if socioeconomic inequalities exist in periodontal disease among adult with optimal oral health behaviours.

Materials and methods: Data were from the Adult Dental Health Survey 2009, a national survey of England, Wales and Northern Ireland. Overall, 4738 participants aged 35 years and older were included in the analysis. Periodontal disease indicated by pocket depth or loss of attachment $\geq$4 mm, and gingival bleeding were used as periodontal outcomes. Education and deprivation indicated socioeconomic position. Behavioural factors were dental visits, toothbrushing and smoking. The subset of adults with and without optimal health related behaviours included 2916 and 1822 participants, respectively. The associations between periodontal disease and socioeconomic position were tested adjusting for demographic and behavioural factors. Additional models stratifying the sample to those with and without optimal behaviour subgroup were constructed.

Results: Education and deprivation were significantly associated with periodontal disease in the partially adjusted models. In the analysis of those with optimal behaviours, only deprivation and highest level of education showed significant association with periodontitis (PD), but not with gingival bleeding. Among those without optimal behaviours, all socioeconomic factors were associated with all outcomes except deprivation and PD.

Conclusions: Oral health behaviours marginally contributed to inequalities in gingival bleeding and periodontal disease. Socioeconomic inequalities were attenuated among those with optimal behaviours and persisted among those without optimal behaviours. Behaviours appeared to be an effect modifier for the relationship between periodontal outcomes and socioeconomic factors.

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Introduction

Socioeconomic inequalities exist in oral health and have been reported consistently in a large body of the literature [1,2]. Clear social gradients in oral health have been reported using different indicators and among different populations [3–5]. Periodontal disease occurrence in populations also follows a social gradient in terms of prevalence, severity and extent [6,7]. Furthermore, the risk factors of periodontal disease, such as smoking, poor oral hygiene and infrequent dental attendance, are more common among the most disadvantaged individuals in the social gradient [8].

The influence of socioeconomic position on periodontal disease has been attributed to the impact of material abilities on health related behaviours [9], and to psychosocial stress and psychological pathways [8,10]. It has also been suggested that social and psychological factors affect health related behaviour which in turn affect periodontal disease [6]. These factors include oral hygiene, dental attendance and smoking and are linked to both socioeconomic conditions and periodontal disease [5,11,12]. Unsurprisingly, many studies have postulated that altering oral health behaviours could eliminate or significantly decrease socioeconomic inequalities in oral health [11,13]. However, the few studies that have explored the role of health behaviours in periodontal disease suggested that accounting for oral health behaviours did not explain socioeconomic inequalities, and had a limited role in eliminating them [14,15]. They argued that psychosocial factors related to socioeconomic inequalities contribute to the variations in periodontal health regardless of health promoting behaviours. Given that most of these studies assessed the mediating role of behaviours in analytical models that included the whole population, it is possible that limiting the assessment of inequalities to those who refrain from established behavioural risk factors such as smoking, inadequate oral hygiene practice and lack of dental attendance could highlight the importance of the role of these behaviours in inequality [16,17].

In this study, we set out to test if socioeconomic inequalities in periodontal disease exist among adults who have optimal oral health related behaviours using data from the Adult Dental Health Survey 2009 of England, Wales and

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Northern Ireland. The objectives of this study are: to examine if socioeconomic inequalities in periodontitis (PD) and gingival bleeding exist; and to explore if there are differences by education and deprivation in PD and bleeding among adults with and without optimal health-related behaviours.

Materials and methods

Data source

The data used for this study were from the Adult Dental Health Survey 2009, a cross-sectional national survey on a representative sample of adults aged 16 years and older living in England, Wales and Northern Ireland. Given the low level of periodontal diseases among younger adults, basic periodontal assessment was only conducted for participants aged 35 and older. The survey included a questionnaire-based interview and clinical examination. Overall 11,380 participated in the home interview. The number of the participants who were clinically examined was 6469 (61%). Only 4895 participants who were 35 years and older had basic periodontal examination (BPE) (75.6% of those who had clinical examination). After exclusion of participants with missing data, edentate, and those with less than two teeth, 4738 participants were included in the analysis (96.8% of those who had BPE). Detailed information and description of the survey have been reported elsewhere [18].

Outcome variables

Periodontal status was assessed using the BPE for those aged 35 and over. The examination assessed calculus, gingival bleeding and pocket depth on six sites on each tooth for the whole mouth. Finally, loss of attachment (LoA) was only measured for participants aged 55 and older. A mirror and CPI probe type C were used for examination. The worst score in each sextant was recorded using the following codes: up to 3.5 mm, 4–5.5 mm, 6–8.5 mm and more than 9 mm. Periodontitis was defined as having one or more sites with pocket or LoA of 4 mm or more [19]. Two periodontal variables were used for this study, the first variable was composite measure PD for dentate adults, and it consisted of periodontal pocketing depth (PD) or LoA of 4 mm or more. It is worth noting that this variable reflects pocket depth or LoAs for those aged 55 and over, and only pocket depth for those aged 35 and under 55. This variable was created in the original survey [18]. The second periodontal variable was gingival bleeding.

Socioeconomic variables

Education and deprivation were selected as indicators for socioeconomic position. Education was selected as it is a more common indicator of socioeconomic condition throughout the life span, and for better comparison with international studies. Deprivation is commonly used in the analysis of health surveys in UK as it reflects area level factors. Furthermore, the other two indicators of socioeconomic position, income and job classification, showed weaker or no association with PD in a previous study [20], and had more missing cases related to income [20]. Educational attainment was calculated from three questions related to education, the first question indicated whether any educational qualification has been obtained by the participant (yes or no), the second question asked whether any technical or specialized qualification has been obtained (yes or no), and if the participants answered yes to either of the two questions, another question was asked to indicate whether the qualification was above or below a degree level. The calculated education variable included three groups: university degree, educational qualification, but no degree and no educational qualification. The index multiple of deprivation (IMD) which is linked to UK postal code was used to indicate deprivation level. This index includes seven domains covering income, employment, education, health, housing, crime and living environment [21].

Behavioural variables

The three-main oral health behaviours indicators were smoking, dental attendance and regular toothbrushing. Smoking indicated whether participants were current, former smokers or never smoked. Dental attendance indicated whether participants visit the dentist at least once every six months, at least once every year, or less than once every year/never. Toothbrushing included two groups: brushing twice a day or more, and once a day or less up to no regular patter. The behavioural variables were also used to select a subset of adults with and without optimal oral health related behaviours from the whole sample. The variables indicating optimal behaviours were: non-smokers (never or former smokers), regular dental attendance (at least once a year) and regular toothbrushing (twice a day). These groups were based on previous studies that examined the role of behaviours and Public Health England's guidelines [14,22].

Confounders

These include age (35–44, 45–54, 55–64 and 65–74, 75+), sex and country of residence (England, Northern Ireland and Wales).

Statistical analysis

The analysis was conducted using STATA version 14 (StataCorp LP, College Station, TX). Survey command was used throughout the analysis accounting for examination weights. Only participants with complete data were included in the analysis. Participants who had less than two teeth were excluded from the analysis ($n = 9$), 0.1. Among eligible participants groups, 3% were excluded from the analysis due to missing data on periodontal disease measured by PD or LoA ($n = 57$), 1.2%, gingival bleeding ($n = 12$), 0.2%, education ($n = 5$), 0.1% and dental visits ($n = 49$) 1.0%. Accordingly, data analysis for this study only included 4738 participants.

Table 1. Demographic and socioeconomic characteristics of study participants and the distribution of the periodontal outcomes within study variables (percentages/means, 95%CI) England Wales and Northern Ireland 2009 N (4738).

			Periodontal outcomes			
Characteristics	*N* (4736)	Percentage/mean	Bleeding	*p* Value	Periodontitis	*p* Value*
Age						
35–44	1242	29.3% (27.8–30.9)	52.5% (49.3–55.7)	<.001	42.9% (39.7–46.1)	<.001
45–54	1162	24.8% (23.4–26.2)	59.7% (56.4–62.9)		52.9% (49.6–56.1)	
55–64	1113	22.1% (20.9–23.4)	57.9% (54.7–61.1)		61.6% (58.4–64.7)	
65–74	770	14.0% (13.0–15.1)	49.7% (45.9–53.6)		60.7% (56.9–64.4)	
75 and over	451	9.7% (8.8–10.7)	50.3% (45.2–55.4)		58.9% (53.7–63.8)	
Country of residence						
England	4117	91.6% (90.9–92.3)	54.3% (52.6–56.0)	.001	53.6% (51.9–55.3)	.093
Wales	315	5.4% (4.8–6.1)	58.4% (52.6–64.0)		55.1% (49.3–60.8)	
Northern Ireland	306	3.0% (2.6–3.3)	66.9% (61.1–72.2)		48.5% (42.6–54.4)	
Sex						
Male	2191	48.4% (46.8–50.2)	57.1%(54.8–59.5)	.008	56.8% (54.5, 59.2)	<.001
Female	2547	51.6% (50.0–53.2)	52.8%(50.6–55.0)		50.5% (48.3–52.7)	
Education						
No qualification	833	17.3% (16.1–18.5)	59.5% (55.7–63.2)	<.001	63.6% (59.9–67.2)	<.001
Qualification bellow degree	2725	57.1% (55.5–58.7)	55.7% (53.6–57.8)		53.8% (51.7–55.9)	
Qualification with a degree	1180	25.6% (24.2–27.1)	49.9% (46.6–53.2)		46.3% (42.9–49.5)	
Index of Multiple Deprivation (Mean)		6.1 (5.9–6.2)	5.8[a] (5.7–5.9) 6.3[b] (6.2–6.5)		5.9[a] (5.8–6.0) 6.2[b] (6.1–6.4)	
Smoking status						
Current smoker	802	17.8% (16.6–19.1)	59.7% (55.7–63.5)	.002	62.4% (58.5–66.2)	.001
Former smoker	1809	37.7% (36.1–39.3)	51.5% (48.9–54.1)		52.4% (49.9–55.0)	
Never smoked	2127	44.5% (42.9–46.1)	55.8% (53.4–58.2)		50.9% (48.5–53.4)	
Frequency of dental visit						
At least every 6 months	2762	55.6% (54.0–57.2)	51.8% (49.7–53.9)	<.001	53.3% (51.2–55.4)	.06
At least once every year	1013	21.8% (20.5–23.1)	52.5% (49.0–56.0)		50.0% (46.5–53.5)	
Less than once every year	963	22.6% (21.2–24.0)	64.7% (61.2–68.0)		57.5% (53.9–61.0)	
Teeth cleaning						
Twice a day and more	3536	74.5% (73.0–75.8)	52.9% (51.1–54.8)	<.001	51.6% (49.8–53.5)	<.001
once a day or less	1202	25.5% (24.1–27.0)	60.4% (57.2–63.6)		59.2% (55.9–62.3)	

*p Value for chi square.
[a]Mean IMD among participants with periodontitis or gingival bleeding.
[b]Mean IMD among healthy participants.

First, the distribution of all variables included in the analysis was assessed for the whole population and for those with and without periodontal disease. A set of logistic regression analyses were used to assess socioeconomic inequality in periodontal diseases using the two indicators, namely pocketing and LoA, and gingival bleeding. Two logistic regression models were constructed for each analysis. The first model was adjusted for age, sex and country of residence. The second model was additionally adjusted for behavioural factors, smoking, dental visits and tooth brushing. We tested interaction between each of the behavioural factors and each of education and deprivation. Finally, we used logistic regression analyses stratified for those with and without optimal oral health behaviours (non-smokers, regular dental attendance, regular toothbrushing) adjusting for age, sex, country, education and deprivation. It is worth noting that IMD as an area level indicator of socioeconomic position should ideally be used in multilevel model; however, the variable was used in accordance with the survey recommendations for consistency with previous studies [18,20].

Results

The study population demographic, socioeconomic and behavioural characteristics are shown in Table 1. No major differences have been found between the study sample included in the analysis and participants who were excluded because of missing values or not fitting the inclusion criteria (Supplementary Table 5).

The majority of the study sample analysed were from England and in the age group from 35 to 54 years and had educational qualification below degree level (57.1%). Most of the study sample reported visiting the dentist every 6 months (55.6%), had never smoked (44.5%), and reported brushing their teeth twice a day or more (74.5%) (Table 1).

Periodontal disease and bleeding were higher among males and adults with no educational qualifications. Bleeding and periodontal diseases were highest among current smokers, participants who reported visiting the dentist less than once a year and those reported brushing their teeth once a day or less (Table 1).

Table 2 shows results of logistic regression analysis for factors associated with periodontal disease and gingival bleeding in the whole sample. There were significant education gradients in PD and gingival bleeding with those with a degree having the lowest odds ratios followed by those with qualification below a degree compared to those without educational qualification. These relationships persisted after adjusting for behavioural factors (Table 2). On the other hand, the significant deprivation inequalities observed in periodontal disease in Model 1 were attenuated and lost significance after adjusting for behavioural factors in Model 2 (Table 2). Toothbrushing and dental visits were significantly associated with gingival bleeding. Former and never smokers

Table 2. Logistic regression analysis showing the associations between socioeconomic position and bleeding and periodontal disease, England Wales and Northern Ireland 2009 ($N = 4738$).

	Bleeding		Periodontitis	
	Odds ratio (95%CI)			
	Model 1	Model 2	Model 1	Model 2
Age groups				
35–44	Reference			
45–54	1.31**	1.34**	1.44***	1.45***
	(1.09–1.57)	(1.11–1.61)	(1.20–1.74)	(1.20–1.74)
55–64	1.20	1.27*	2.02***	2.09***
	(0.99–1.44)	(1.05–1.53)	(1.67–2.44)	(1.73–2.53)
65–74	0.84	0.91	1.88***	2.4***
	(0.68–1.04)	(0.73–1.12)	(1.53–2.32)	(1.65–2.53)
75 and over	0.85	0.90	1.68***	1.84***
	(0.66–1.09)	(0.70–1.17)	(1.30–2.17)	(1.42–2.38)
Sex				
Male	Reference			
Female	0.83**	0.87*	0.76***	0.78***
	(0.73–0.95)	(0.76–0.99)	(0.66–0.86)	(0.68–0.89)
Country				
England	Reference			
Wales	1.13	1.13	0.98	0.98
	(0.88–1.44)	(0.88–1.46)	(0.77–1.25)	(0.76–1.25)
Northern Ireland	1.64***	1.63***	0.82	0.80
	(1.26–2.14)	(1.25–2.13)	(0.63–1.06)	(0.62–1.04)
Education				
No Qualification	Reference			
Qualification, below degree	0.82*	0.86	0.75**	0.77**
	(0.68–0.98)	(0.71–1.04)	(0.62–0.90)	(0.64–0.93)
Qualification, at degree level	0.68**	0.72**	0.59***	0.64***
	(0.55–0.85)	(0.58–0.91)	(0.47–0.74)	(0.51–0.79)
Deprivation				
IMD	0.95***	0.96**	0.97**	0.98
	(0.92–0.98)	(0.94–0.98)	(0.94–0.99)	(0.95–1.01)
Teeth cleaning				
Once a day or less	Reference			
Twice a day or more		0.84*		0.91
		(0.72–0.98)		(0.77–1.06)
Dental visit frequency				
Less than once/year	Reference			
At least once/year		0.67***		0.81
		(0.55–0.83)		(0.66–1.01)
At least once/6 months		0.65***		0.91
		(0.54–0.77)		(0.76–1.09)
Smoking				
Current smoker	Reference			
Former smoker		0.88		0.62***
		(0.72–1.07)		(0.51–0.77)
Never smoked		1.09		0.68***
		(0.89–1.32)		(0.56–0.83)

Model 1: adjusted for age, country, sex, education and deprivation. Model 2: additionally, adjusted for teeth cleaning dental visits and smoking.
*$p<.05$.
**$p<.01$.
***$p<.001$.

were significantly less likely to have periodontal disease than current smokers (Table 2). There was no interaction between socioeconomic indicators and health behaviours with the exception of education and smoking in the model pertaining to PD (LoA >4 mm).

Table 3 shows the distribution of sociodemographic factors and periodontal diseases among the subsample with and without optimal oral health behaviours. Males, older adults, the least educated and most deprived had higher levels of PD and gingival bleeding (Table 3).

Table 4 exhibits the association of each of PD and gingival bleeding with socioeconomic factors for those with and without optimal oral health behaviour (non-smokers, regular dental attendance, regular toothbrushing) (*N*: 2916 and 1822, respectively). The model was adjusted for age, country, sex, education and deprivation. Among those with optimal behaviours, statistically significant association between highest level of education and PD persisted. Similarly, the least deprived were significantly less likely to have PD (LoA >4 mm). On the other hand, statistically significant inequalities in gingival bleeding disappeared (Table 4). Among those without optimal behaviours, education gradients persisted in both gingival bleeding and PD with those with a degree having the lowest odds, while deprivation was only associated with gingival bleeding.

Table 3. Demographic and socioeconomic characteristics and the distribution of the periodontal outcomes among adults with and without optimal health related behaviours (percentages/means, 95%CI), England Wales and Northern Ireland 2009.

	Adults with optimal health related behaviours (*N*: 2916)				Adults without optimal health related behaviours (*N*: 1822)			
	N	Percentage/mean	Gingival bleeding	Periodontitis	*N*	Percentage/mean	Gingival bleeding	Periodontitis
Age groups								
35–44	778	29.2% (27.2–31.2)	46.6% (42.6–50.6)	37.8% (33.9–41.8)	464	29.6% (27.2–32.2)	61.2% (56.1–66.2)	50.4% (45.2–55.5)
45–54	700	24.3% (22.6–26.2)	54.5% (50.3–58.8)	49.6% (45.3–53.8)	462	25.5% (23.2–27.8)	67.1% (61.9–71.8)	57.6% (52.4–62.6)
55–64	697	22.7% (21.2–24.5)	52.3% (48.2–56.4)	59.3% (55.2–63.3)	416	21.1% (19.2–23.3)	67.1% (61.9–71.8)	65.4% (60.1–70.3)
65–74	481	14.2% (12.9–15.6)	48.9% (44.2–53.8)	60.8% (56.9–65.4)	289	13.7% (12.1–15.5)	50.7% (44.3–57.7)	60.6% (54.2–66.6)
75 and over	260	9.5% (8.4–10.8)	51.6% (44.9–58.3)	62.1% (55.5–68.3)	191	10.1% (8.7–11.7)	48.2% (40.5–56.0)	54.3% (46.3–61.9)
Country								
England	2550	92.0% (91.0–92.9)	49.9% (47.7–52.0)	51.3% (49.1–53.5)	1567	90.9% (89.6–92.1)	61.0% (58.3–63.7)	57.1% (54.4–59.9)
Wales	191	5.2% (4.5–6.1)	57.5% (50.1–64.6)	50.7% (43.3–58.1)	124	5.8% (4.8–6.9)	59.2% (49.9–67.9)	61.1% (51.9–69.6)
Northern Ireland	175	2.8% (2.3–3.2)	64.2% (56.4–71.2)	46.4% (38.7–54.3)	131	3.3% (2.7–3.9)	70.4% (61.5–77.9)	51.1% (42.2–59.9)
Sex								
Males	1111	39.8% (37.8–41.8)	51.9% (48.7–55.3)	54.9% (51.6, 58.2)	1080	61.4% (58.8–63.8)	62.1% (58.8–65.3)	58.7% (55.3–61.9)
Females	1805	60.1% (58.1–62.1)	49.8% (47.2–52.4)	48.6% (46.0–51.2)	742	38.6% (36.1–41.2)	59.8% (55.7–63.7)	54.8% (50.7–58.8)
Education								
No qualification	422	14.2% (12.9–15.7)	55.4% (50.0–60.6)	61.9% (56.7–66.9)	411	21.9% (19.9–24.2)	63.3% (57.9–68.4)	65.2% (59.9–70.2)
Qualification, below degree	1649	56.2% (54.1–58.2)	51.3% (48.6–53.9)	50.9% (48.1–53.6)	1076	58.4% (55.8–80.9)	62.2% (58.8–65.4)	58.0% (54.7–61.3)
Qualification, at degree level	845	29.6% (27.7–31.5)	47.2% (43.4–51.0)	46.5% (42.7–50.3)	335	19.6% (17.6–21.9)	56.1% (49.8–62.1)	45.6% (39.5–51.8)
Mean index of multiple deprivation (IMD)	2916	6.5 (6.3–6.6)	6.3[a] (6.2–6.5) 6.6[b] (6.4–6.7)	6.3[a] (6.2–6.5) 6.6[b] (6.4–6.7)	1822	5.47 (5.3–5.6)	5.2[a] (5.1–5.4) 5.8[b] (5.6–6.1)	5.3[a] (5.1–5.5) 5.6[b] (5.4–5.9)

[a]Mean IMD among participants with periodontitis or gingival bleeding.
[b]Mean IMD among healthy participants.

Discussion

In this study, we have shown that in a nationally representative sample of England, Wales and Northern Ireland adults, education and deprivation gradients in periodontal disease exist, and persisted even after adjusting for demographic, social and behavioural factors. However, education inequalities in PD only persisted between those with highest and lowest education among those with optimal oral health behaviours. On the other hand, there was clear and steep education gradients in all outcomes among those without optimal behaviours. The findings suggest that health-related behaviours modify inequality in periodontal diseases, particularly gingival bleeding, among adults in England, Wales and Northern Ireland.

Socioeconomic inequalities in periodontal outcomes observed in this study and the effect of adjusting for oral health-related behaviour are in line with previous studies, in which accounting for oral health related behaviour only attenuated inequalities in oral health but did not eliminate them [14,15]. Interestingly, when we limited the analysis to individuals with optimal oral health behaviours, the significant associations of education and deprivation with gingival bleeding, and of the second level of education and PD disappeared. On the other hand, education inequalities in PD and gingival bleeding persisted among those without optimal behaviours. It is worth noting that a previous study that examined inequalities in periodontal diseases using the same data, found persistent education inequalities after adjusting for different socioeconomic indicators and argued that education is a proxy for behaviours [20]. To the best of our knowledge, this is the first study that examined the presence of socioeconomic inequalities in oral health among subsets of individuals with and without optimal oral health-related behaviours using a nationally representative sample.

The relationship of education and deprivation with health related behaviours could be attributed to the fact that individuals with better education and who live in good areas have better opportunities to adopt healthy behaviours, use health services, and benefit from health promoting activities than less educated groups and those who live in deprived areas [23]. Interestingly, interaction between behaviours and socioeconomic indicators was only observed between smoking and education, given the strong association between smoking and each of PD and socioeconomic factors. The lack of interaction between each of oral hygiene and dental visits with socioeconomic status could be attributed to adjusting for several other factors in the models, and to the availability of dental services through the National Health Services (NHS) which reduces inequalities in access to services. It is also important to note that there are some considerations regarding interpreting deprivation inequalities, as IMD is a composite area level index made up of seven different domains related to neighbourhoods and households, and it does not necessarily reflect the level of deprivation each participant is experiencing [24].

Differences found in the analysis between gingival bleeding and PD based on PD and LoA could be attributed to the fact that gingival bleeding is an indicator of gingival

Table 4. Logistic regression analysis showing the associations between socioeconomic position and periodontal outcomes among adults with optimal health related behaviours, England Wales and Northern Ireland 2009.

	Adults with optimal health related behaviours (*N*: 2916)		Adults without optimal health related behaviours (*N*: 1822)	
	Odds ratio (95%CI)			
	Gingival bleeding	Periodontitis	Gingival bleeding	Periodontitis
Age groups				
35–44	Reference			
45–54	1.36* (1.08–1.72)	1.59** (1.26–2.03)	1.24 (0.91–1.68)	1.24 (0.93–1.67)
55–64	1.24 (0.98–1.56)	2.32*** (1.82–2.94)	1.21 (0.88–1.66)	1.67** (1.22–2.28)
65–74	1.06 (0.82–1.37)	2.44*** (1.86–3.18)	0.60** (0.43–0.85)	1.30 (0.92–1.83)
75 and over	1.16 (0.84–1.60)	2.50*** (1.79–3.48)	0.54** (0.36–0.81)	0.92 (0.62–1.37)
Sex				
Male	Reference			
Female	0.89 (0.76–1.06)	0.77** (0.64–0.91)	0.88 (0.91–1.1)	0.81 (0.65–1.00)
Country				
England	Reference			
Wales	1.33 (0.97–1.83)	0.92 (0.67–1.25)	0.87 (0.89–1.29)	1.07 (0.72–1.59)
Northern Ireland	1.79** (1.26–2.52)	0.90 (0.64–0.1.27)	1.48 (0.97–2.26)	0.72 (0.49–1.07)
Education				
No qualification	Reference			
Qualification, below degree	0.86 (0.67–1.11)	0.79 (0.60–1.02)	0.81 (0.61–1.08)	0.69** (0.53–0.93)
Qualification, at degree level	0.76 (0.57–1.01)	0.71* (0.53–0.95)	0.66* (0.45–0.96)	0.44*** (0.30–0.63)
Index of multiple deprivation (IMD)	0.97 (0.94–1.00)	0.96* (0.93–0.99)	0.95* (0.91–0.98)	0.99 (0.95–1.02)

Adjusted for age, country, sex, education and deprivation.
*$p<.05$.
**$p<.01$.
***$p< .001$.

inflammation and active disease, while PD and LoA reflect the history of periodontal disease [25,26]. These differences are clearly demonstrated with age groups associations, as all older age groups had consistent and significant higher odds of PD than the lowest age group, while the relationships between gingival bleeding and age were less consistent. On the other hand, when the analysis was stratified by optimal behaviours, strong and consistent age gradients were observed among those with optimal behaviours in PD, but not among those without optimal behaviour. This observation suggests that adopting unhealthy behaviours probably accelerates PD at a relatively younger age.

The analysis of the whole sample demonstrated that smoking was associated with PD but not with gingival bleeding, a relationship consistent with the literatures [27–29]. On the other hand, oral hygiene (toothbrushing) and dental visits were significantly and negatively associated with gingival bleeding, but not with PD; although, the associations were in the expected direction [30].

One of the important findings of this analysis is the lack of statistically significant socioeconomic differences in gingival bleeding and the attenuation of education differences in PD/LoA among those with optimal behaviours. While these findings imply reduction of inequalities in PD and gingival bleeding among those with optimal oral health behaviours, they should be interpreted with caution. First, due to the dual relationship between lower socioeconomic factors on the one hand and each of the health-risk behaviours and poor oral health, one would expect smaller socioeconomic variations between those with optimal health behaviours. Second, given the inclusion of use of dental services among the optimal behaviours, this observation could only be relevant to UK where the National Health System (NHS) still provides relatively affordable and equitable oral health services. It was not surprising that around 77% of the participants visit a dentist once a year. While this undoubtedly contributes to eliminating inequality in periodontal diseases in UK, it also means that the findings are not applicable to countries where dental services are mostly private and subjected to the market rules. Finally, achieving an optimal oral health behaviour in a given population is not a simple or straightforward task. There is evidence that behavioural change intervention might be successful for individuals, but not for a whole population [31]. Policies and interventions at the country/societal level that address the underpinning causes of health risk behaviours are more likely to produce sustainable changes towards achieving optimal behaviours [32].

The findings pertaining to the attenuation of socioeconomic inequalities in periodontal diseases among those with optimal behaviours also highlight the importance of confirming these observations with different longitudinal and large intervention studies. Establishing stronger evidence to support the hypothesis suggested in this analysis of national data from England, Northern Ireland and Wales is an important step to advocate and initiate policies aiming at changing oral health-behaviours by reducing inequalities in such behaviours, as is the case with the use of dental services in the UK. We submit that the focus should not only be on changing individuals' behaviours, but more importantly on developing and adopting policies that tackle underlying and structural determinants of oral health and health-related behaviours and promote healthy environment [33].

There are some limitations in this study that should be mentioned. First, the findings of this study are based on analysis of cross-sectional data, thus the results cannot be used to draw conclusions regarding causal relationships. Second, the data used in this study were collected in 2009, and could be argued to be relatively old; however, it is the latest adult

dental health survey conducted in England, Wales and Northern Ireland. Third, due to the nature of the method of clinical assessment of periodontal disease used in the ADHS 2009, we could not use established case definition of PD, instead we used pragmatic definitions based on the worst score of pocket depth or LoA. Fourth, information about oral health-related behaviours were obtained by self-reported measure, and thus they are prone to information bias, participants might have over reported behaviours like toothbrushing, because it is socially desirable, or under reported other behaviours like smoking. However, objective measures of health-related behaviours could also possess some limitations [34]. Fifth, the variable for dental visits did not indicate whether the visits were for regular check-up or treatment/continuation of treatment, hence it might reflect care-seeking behaviour rather than preventive behaviour. There is also a potential of bias for using IMD as an area level factor in the regression model. Furthermore, periodontal disease is associated with systemic diseases [16]. However, information about systemic diseases were not gathered in the ADHS 2009, and therefore including important systemic conditions like Diabetes mellitus in our analysis was not possible. It is also worth noting that inclusion of additional behaviours and psychosocial factors known to be associated with PD, such as stress [10], could have further explained inequalities in periodontal diseases. Finally, it is important to highlight the challenges of assessing inequality using relative scale, using regression models, rather than reporting absolute inequality in this manuscript.

Our study demonstrated the existence of socioeconomic inequalities in PD and gingival bleeding among British adults. It also showed that accounting for oral health related behaviours namely toothbrushing, dental attendance and smoking have not completely eliminated these inequalities. Despite this, the study also suggested that oral health-related behaviours modify the relationship between periodontal diseases, particularly gingival bleeding and socioeconomic indicators. These findings suggest that inequalities could be significantly modified if optimal health-related behaviours could be achieved for all through social and fiscal policies that enable adopting healthy behaviours by all sectors of the society. However, given the cross-sectional nature of the survey, and the limitations of some of the behavioural variables, the findings should be interpreted with caution.

Disclosure statement

The authors report no conflicts of interest.

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