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Social disparities in periodontitis among United States adults 1999–2004

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Abstract – *Objectives:* To investigate whether race/ethnicity, income, and education are independently associated with periodontitis; and to investigate the effect of adjusting for income and education on the association between race/ethnicity and periodontitis in the National Health and Examination Nutrition Surveys 1999–2004. *Methods:* Analyses were limited to records of non-Hispanic black, non-Hispanic white or Mexican-American adults (n = 10 648). SUDAAN was used to estimate the strength of the association of race/ethnicity, education, and income with the prevalence of periodontitis before and after adjusting for selected characteristics and risk factors. *Results:* The prevalence of periodontitis was 3.6%, with Black people (7.2%) exhibiting significantly higher prevalence than Mexican Americans (4.4%) and White people (3.0%, $P < 0.01$). After adjusting for selected sociodemographic characteristics, black adults, those with less than a high school education and those with low income were 1.94 (95% CI 1.46–2.58), 2.06 (95% CI 1.47–2.89) and 1.89 (95% CI 1.18–3.04) times more likely to have periodontitis than White people, those with more than a high school diploma and those with high income, respectively. *Conclusions:* This study indicates that inequalities in periodontitis associated with race/ethnicity, education and income continue to be pervasive in the US over the years.

Key words: disparities; inequalities; periodontitis; race/ethnicity; socioeconomic position indicators

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Disparities in the prevalence of periodontitis by race/ethnicity and socioeconomic position (SEP) in the US have been pervasive for years (1–18). Specifically, African Americans exhibit a higher prevalence of periodontitis than non-Hispanic White people. Mexican Americans, on the other hand, have a prevalence of periodontitis similar to that observed in non-Hispanic White people despite their low income and education (10–17). Moreover, people with lower SEP regardless of their race/ethnicity are more likely to have higher prevalence of periodontitis than their higher SEP peers (11, 12, 16, 17). These findings have been observed in studies using a variety of case definitions for periodontitis. However, although many studies have evaluated bivariable relationships, the independent associations of race/ethnicity, education and income with periodontitis have seldom been examined simultaneously in the same population (11, 17).

The relationship among race/ethnicity and SEP (i.e. education and income) and health outcomes, including periodontitis is complex. Evidence suggests that race/ethnicity is a major determinant of one's education and income (19, 20), and therefore, the latter are mediators of the association between race/ethnicity and periodontitis rather than confounders. However, because of the limitations of multivariable adjustment to estimate direct and indirect effects in the presence of mediators (21), adjustment for mediators only allows the estimation of the net effect of an independent variable. Moreover, in the case of education and income as mediators of the association between race/ethnicity and periodontitis, the net estimation may not hold because differences in education and income may

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reflect the pervasiveness of the implementation of previous discriminatory policies in US society such as residential segregation (19, 20, 22). Thus, adjustment for education and income of the association between race/ethnicity and periodontitis may reduce but would not eliminate racial/ethnic disparities because of the unequal meaning of education and income across racial/ethnic groups (19, 23). This unequal meaning would lead to residual confounding (24, 25).

The availability of the National Health and Nutrition Examination Survey 1999–2004 (NHANES 1999–2004) data affords the opportunity to (i) examine whether race/ethnicity, income, and education are independently associated with periodontitis before and after adjusting for selected characteristics; and (ii) investigate the effect of adjusting for income and education on the association between race/ethnicity and periodontitis in non-Hispanic black, Mexican-American and non-Hispanic white adult population. Moreover, we investigated whether the association between race/ethnicity and periodontitis varies with sex and the different levels of income and education. Finally, because the NHANES data were collected in three 2-year surveys, interaction terms between 'race/ethnicity and survey year', 'education and survey year', and 'income and survey year' are tested to rule out the possibility of differences on periodontitis by sampling error as a result of the three 2-year NHANES data used during analyses.

Methods

The NHANES 1999–2000, NHANES 2001–2002 and NHANES 2003–2004 (Demographic Questionnaire and Examination files) public-use data files were used for this study. The data for NHANES 1999–2000 were collected between March 1999 and December 2000; for NHANES 2001–2002 between January 2001 and December 2002; and for NHANES 2003–2004 between January 2003 and December 2004. These surveys assessed the health status of a nationally representative sample of the civilian non-institutionalized US population, selected through a stratified multistage probability sampling design. The sampling design and methods used in NHANES 1999–2000 were very similar to those used in NHANES 2001–2002 and NHANES 2003–2004. Full descriptions of the sample design in NHANES 1999–2000, NHANES 2001–2002 and NHANES 2003–2004 have been reported elsewhere (26, 27). NHANES 1999–2000, NHANES 2001–2002 and NHANES 2003–2004 examined a total of 9965, 11 039 and 10 122 persons 1 month of age to 85 years of age (85 years of age was adjudicated to persons 85 years of age or older), respectively. Of these, 5733, 6327, and 5926 persons were 17 years of age or older in the NHANES 1999–2000, NHANES 2001–2002, and NHANES 2003–2004, respectively, for a total of 17 986.

During the dental examination, dentists trained in the survey examination protocol conducted the periodontal examinations (26, 27). Briefly, periodontal examinations during the NHANES 1999–2000 were conducted in two sites, midbuccal and mesiobuccal for each tooth, in two randomly chosen quadrants, one maxillary and one mandibular, on the assumption that conditions in these two quadrants would represent the mouth. Third molars were excluded because of their frequent extraction in young adulthood, so a maximum of 14 teeth and 28 sites per individual were examined. For the NHANES 2001–2002 and the NHANES 2003–2004, the periodontal examination was conducted in three sites, midbuccal, mesiobuccal and distobuccal for each tooth. Previous studies used several combinations of clinical attachment loss (CAL) and pocket depth (PD) to establish periodontitis case definitions (6, 10, 11, 28, 29). For this study, prior to the selection of any definition, the distributions of CAL and PD were evaluated in the total population as well as in each racial/ethnic group in each survey and in the data for 6 years. For consistency across surveys, we used the two sites measured in NHANES 1999–2000, NHANES 2001–2002, and NHANES 2003–2004 to define periodontitis. Specifically, for these analyses, periodontitis was defined if a person had at least two sites with CAL ≥4 mm and at least one site with PD ≥4 mm. Moreover, we repeated the analyses using a definition for NHANES 2001–2002 and NHANES 2003–2004 accounting for the three sites measured in the periodontal examination. Specifically, when comparing mean values for PD and CAL using data on two and three sites, there was a difference in the mean PD. Although, for the latter analyses, periodontitis was defined if a person had at least two sites with CAL ≥4 mm and at least two sites with PD ≥4 mm. For either definition, CAL and PD did not have to be present in the same site or tooth.

This analysis was limited to the records of adults aged 18 to 85 years who identified themselves as non-Hispanic black, non-Hispanic white or Mexican-American and had a complete periodontal

examination during NHANES 1999–2000 (n = 3263), NHANES 20001–2002 (n = 3883), or NHANES 2003–2004 (n = 3502) for a final sample of 10 648. The main independent variables of interest were race/ethnicity, education, and income. Race/ethnicity was specified as collected in the surveys, non-Hispanic black, Mexican-American, and non-Hispanic white. Hereafter, non-Hispanic black and non-Hispanic white will be referred to as black and white, respectively. Education was included in the analyses as collected as <12 years, 12 years, and >12 years of education for each survey. Total family 12-month income during the previous year was recorded as a categorical variable as a range value in increments of $5000 from $0 to $74 999 and $75 000 and above. For this analysis, income was categorized as ≤$19 999; $20 000 to $34 999; and ≥$35 000.

To estimate the association of race/ethnicity, education and income with the odds of having periodontitis adjusting for other factors, the following variables were included in the analysis: age at interview, sex, marital status, place of birth, presence of health insurance, time since last dental visit, history of diabetes and tobacco use. NHANES 1999–2000, NHANES 2001–2002, and NHANES 2003–2004 used the same or very similar questions to record these covariates. Age was collected as continuous in the surveys and categorized into three age groups: 18–34, 35–59 and 60–85 years. Sex and presence of health insurance were included in the analyses as collected in the surveys. Among participants who have health insurance, a follow-up question (yes/no) regarding dental coverage was asked. Categories in the marital status question originally included married, living together with someone as married, widowed, divorced, separated, or never married. These categories were grouped into married (married or living together with someone as married), single, divorced (separated or divorced), and widowed. Place of birth was recoded as being born in the US or elsewhere. Time since last dental visit was categorized in both surveys as follows: ≤1 year; >1 year but ≤2 years; >2 years but ≤5 years; and >5 years. Because the use of three 2-year surveys (NHANES 1999–2000, NHANES 2001–2002 and NHANES 2003–2004), a variable was created for survey year to account for any sampling error across the three 2-year of NHANES data used during analyses.

The question 'Have you ever been told by a doctor that you have diabetes?' was used to assess the history of diagnosed diabetes in the surveys. Diabetes that manifested in women only during pregnancy was excluded. Smoking status was derived from two questions in both surveys, 'Do you smoke cigarettes now?' and 'Have you smoked at least 100 cigarettes in your entire life?' Smokers were stratified as 'current smokers' (subjects who answered 'Yes' to both questions), 'former smokers' (subjects who answered 'No' to the first question and 'Yes' to the second question), and 'never smokers' (subjects who answered 'No' to both questions).

Statistical analysis

Descriptive statistics for the characteristics of the population and prevalence of periodontitis were calculated by race/ethnicity. To determine significant differences, chi-squared (discrete variables) and t-tests (continuous variables) were used. Cochran–Mantel–Haenszel chi-squared tests were used to assess independence of the prevalence of periodontitis by race/ethnicity stratified by each covariate.

Logistic regression was used to estimate the strength of the association of race/ethnicity, education, and income with the prevalence of periodontitis before and after adjusting for selected characteristics and risk factors. Specifically, five sets of analyses were performed for race/ethnicity: (i) crude odds ratios (crude OR); (ii) ORs adjusted for age, sex, marital status, and place of birth (model 1); (iii) ORs additionally adjusted for health insurance and time since last dental visit (model 2); (iv) ORs additionally adjusted for smoking and diabetes (model 3); and (v) finally, additionally adjusted income and education (model 4). For income and education, similar analyses were repeated to obtain the crude OR; the ORs for models 1 to 4 additionally adjusting for race/ethnicity; and finally, the ORs for model 4 for education was adjusted for income and vice versa. Tests for trend were performed for education and income. Interaction terms between race/ethnicity and income, race/ethnicity and education, and race/ethnicity and sex were tested. In addition, an interaction term was tested between survey year and race/ethnicity, survey year and income, and survey year and education to determine any change in the strength of the association among groups over time. The number of records included in the analyses varied, depending on the covariates included in the model.

Data management procedures were carried out with SAS (30) and statistical analyses were conducted using SUDAAN (31). SUDAAN takes into

account the complex sampling design yielding unbiased standard error estimates. In the tables, the sample sizes were unweighted. However, estimates for means, proportions, standard errors, and ORs with their 95% confidence intervals (CI) were weighted.

Results

The study population characteristics show that Mexican Americans and Black people exhibit worse sociodemographic characteristics than White people (Table 1). Mexican Americans and Black

Table 1. Selected characteristics and prevalence of periodontitis among Black, Mexican-American and White adults: NHANES 1999–2004[a]

	Distribution of characteristics				Prevalence of periodontitis			
Characteristics	Black people (n = 2363)	Mexican American (n = 2977)	White people (n = 5308)	P-value[b]	Black people (n = 2363)	Mexican American (n = 2977)	White people (n = 5308)	P-value[b,c]
Overall prevalence	–	–	–	–	7.2 (0.55)	4.4 (0.67)	3.0 (0.27)	<0.01
Age group (years)								
18–34	42.1 (1.05)	54.0 (1.94)	33.1 (1.19)	<0.01	1.3 (0.48)	1.2 (0.30)	0.7 (0.26)	<0.01
35–59	47.0 (1.18)	39.7 (1.50)	50.8 (0.98)		10.7 (0.93)	7.5 (1.43)	3.6 (0.44)	
60–85	10.9 (0.74)	6.3 (0.73)	16.2 (0.60)		15.3 (2.23)	13.5 (2.18)	5.6 (0.60)	
Sex								
Male	46.8 (1.07)	53.0 (0.87)	50.0 (0.72)	<0.01	9.4 (1.03)	6.3 (1.03)	4.3 (0.46)	<0.01
Female	53.3 (1.07)	47.0 (0.87)	50.0 (0.72)		5.3 (0.67)	2.2 (0.52)	1.7 (0.28)	
Country of birth								
USA	–	41.4 (2.87)	–	<0.01	–	3.6 (0.83)	–	0.10
Mexico	–	58.6 (2.87)	–		–	4.9 (0.76)	–	
Marital status								
Married	41.3 (1.53)	66.1 (1.38)	66.8 (0.84)	<0.01	8.3 (0.88)	5.2 (0.88)	3.1 (0.42)	<0.01
Divorced	17.4 (1.01)	7.3 (0.67)	10.1 (0.58)		8.4 (1.79)	6.5 (1.36)	3.1 (0.84)	
Single	36.9 (1.48)	24.6 (1.13)	19.2 (0.79)		4.5 (0.74)	1.8 (0.53)	1.5 (0.43)	
Widow	4.5 (0.32)	2.0 (0.24)	3.9 (0.28)		13.4 (3.09)	5.7 (1.94)	4.6 (1.31)	
Education								
<12 years	30.3 (1.40)	52.3 (1.60)	11.1 (0.68)	<0.01	11.7 (1.06)	6.4 (1.04)	8.6 (1.15)	<0.01
12 years	26.4 (0.96)	21.9 (1.16)	27.5 (1.05)		5.6 (1.01)	2.3 (0.65)	2.6 (0.46)	
>12 years	43.6 (1.42)	25.9 (1.84)	61.5 (1.49)		5.1 (0.68)	2.3 (0.56)	2.2 (0.27)	
Income								
Low	38.9 (1.68)	37.5 (2.12)	17.6 (1.40)	<0.01	8.9 (1.02)	5.5 (0.94)	5.8 (0.93)	<0.01
Medium	22.6 (1.12)	27.7 (1.74)	17.9 (0.86)		7.0 (1.43)	5.5 (1.09)	3.3 (0.59)	
High	38.6 (1.83)	34.8 (2.53)	64.5 (1.73)		4.7 (0.83)	2.8 (0.75)	2.1 (0.32)	
Time since last dental visit								
≤1 year	51.0 (1.41)	47.3 (2.08)	68.4 (1.08)	<0.01	5.5 (0.62)	2.8 (0.60)	2.0 (0.27)	<0.01
> 1 but ≤ 2 years	16.9 (0.85)	17.0 (0.97)	12.1 (0.44)		7.9 (1.62)	3.9 (1.01)	3.5 (0.86)	
> 2 but ≤ 5 years	18.2 (0.74)	19.3 (1.06)	11.4 (0.48)		7.1 (1.37)	6.0 (1.24)	4.8 (1.03)	
> 5 years	13.9 (1.11)	16.4 (1.34)	8.1 (0.78)		10.8 (1.84)	5.1 (1.09)	7.0 (0.85)	
Health insurance								
Yes	75.2 (1.20)	52.7 (2.08)	85.9 (0.81)	<0.01	6.9 (0.66)	4.1 (0.80)	2.8 (0.29)	0.08
No	24.8 (1.20)	47.4 (2.08)	14.1 (0.81)		8.4 (0.98)	4.9 (0.76)	4.3 (1.08)	
Dental insurance[d]								
Yes	81.2 (1.50)	68.9 (2.25)	68.1 (1.03)	<0.01	5.7 (0.68)	3.2 (0.67)	2.5 (0.32)	0.11
No	18.8 (1.50)	31.1 (2.25)	31.9 (1.03)		11.5 (1.99)	5.9 (1.79)	3.3 (0.71)	
Diabetes								
Yes	8.5 (0.77)	5.8 (0.37)	5.2 (0.38)	<0.01	15.7 (3.27)	13.8 (3.28)	7.1 (1.51)	<0.01
No	91.5 (0.77)	94.2 (0.37)	94.8 (0.38)		6.4 (0.58)	3.9 (0.57)	2.8 (0.29)	
Smoking status								
Current smokers	26.2 (1.42)	23.0 (1.06)	24.5 (1.01)	<0.01	13.0 (1.33)	6.8 (1.23)	5.7 (0.91)	<0.01
Former smokers	14.0 (0.95)	19.4 (1.04)	25. 9 (1.02)		11.6 (2.52)	5.7 (1.07)	3.6 (0.68)	
Never smokers	59.8 (1.73)	57.7 (1.33)	49.7 (1.18)		4.3 (0.46)	2.3 (0.56)	1.5 (0.24)	

[a]All sample sizes are unweighted; while mean values, proportions and P-values are weighted to take into account the sample design.
[b]P-value for chi-square of homogeneity.
[c]All Cochran–Mantel–Haenszel chi-squared tests for each covariate were significant at <0.0001 with the exception of country of birth (0.13), health insurance (0.10) and dental health insurance (0.10).
[d]Among participants with health insurance a follow-up question regarding dental coverage was asked.

people were more likely to have less than a high school education, be in the lower income category, be less likely to have a dental visit within the past year, less likely to have health insurance and dental insurance than White people (all $P < 0.01$). However, these conditions are worst for Mexican Americans. Black people were more likely to report being told by a doctor that they have diabetes and report being a current smoker (all $P < 0.01$).

The overall prevalence of periodontal disease was 3.6% (data not shown), with Black people (7.2%) exhibiting significantly higher prevalence than Mexican Americans (4.4%) and White people (3.0%, $P < 0.01$; Table 1). Higher prevalences of periodontal disease were found in people aged 60–85 years, men, people who were widowed, those having less educational attainment and lower income, and those lacking health insurance regardless of their race/ethnicity (all $P < 0.01$). In addition, the prevalence of periodontitis was higher among those reporting diabetes and being a current smoker ($P < 0.01$). Although this difference did not reach significance, Mexican Americans born in Mexico were more likely to have periodontal disease.

Table 2 shows the crude and adjusted associations between periodontal disease and race/ethnicity, education and income. Race/ethnicity, education and income were independently associated with periodontal disease. These associations remain significant after adjustment for selected covariates. Specifically, Black adults are 2.66 times (95% CI 2.03–3.47) more likely to have periodontitis than White adults. When education and income were included in the model, Black adults remain 1.94 times (95% CI 1.46–2.58) more likely to have periodontitis than White adults (model 4). Thus, the adjustment of education and income reduces the association between race/ethnicity and periodontitis for Black adults by 43% but the association remains significant. For education when adjusting for selected covariates including race/ethnicity and income, those with less than a high school education are 2.06 (95% CI 1.47–2.89) times more likely to have periodontitis than those with more than a high school education. Finally, in the fully adjusted model, individuals with low income are 1.89 (95% CI 1.18–3.04) times more likely to have periodontitis than their counterparts with higher income.

No interactions were observed between race/ethnicity and sex, race/ethnicity and education, and race/ethnicity and income. Moreover, interactions were not found between race/ethnicity and age group; income and age group or education and age group. Finally, the strengths of the association of race/ethnicity, education and income with periodontitis were not different across survey years.

When using a definition accounting for the use of three sites in NHANES 2001–2002 and NHANES

Table 2. Odds ratios[a] and 95% confidence limits for periodontitis prevalence by race/ethnicity, household income and education among US adults 18 years or older: NHANES 1999–2004

	Odds ratios for periodontitis prevalence				
Characteristics	Crude [b]	Model 1[c]	Model 2	Model 3	Model 4
Race/ethnicity					
White adults	1.00	1.00	1.00	1.00	1.00
Black adults	2.52 (2.01–3.16)	3.23 (2.48–4.21)	2.74 (2.13–3.53)	2.66 (2.03–3.47)	1.94 (1.46–2.58)
Mexican-American	1.51 (1.06–2.14)	1.80 (1.02–3.18)	1.35 (0.77–2.37)	1.43 (0.82–2.48)	1.08 (0.63–1.86)
Education (years)					
<12	3.36 (2.70–4.17)	3.46 (2.58–4.63)	2.54 (1.81–3.57)	2.17 (1.52–3.09)	2.06 (1.47–2.89)
12	1.17 (0.91–1.52)	1.21 (0.90–1.64)	0.98 (0.72–1.34)	0.87 (0.65–1.17)	0.81 (0.61–1.09)
>12	1.00	1.00	1.00	1.00	1.00
P-trend	<0.0001	<0.0001	<0.0001	<0.0002	<0.0002
Income					
≤$19 999	2.63 (2.04, 3.37)	3.62 (2.38, 5.52)	2.53 (1.57, 4.08)	2.22 (1.39, 3.56)	1.89 (1.18, 3.04)
$20 000–$34 999	1.61 (1.12, 2.32)	1.96 (1.26, 3.05)	1.59 (1.00, 2.55)	1.41 (0.88, 2.27)	1.30 (0.84, 2.00)
≥$35 000	1.00	1.00	1.00	1.00	1.00
P-trend	<0.0001	0.0001	0.001	0.004	0.03

[a]Odds ratios (ORs) are obtained from separate models using race/ethnicity, education and income as the predictor variable.
[b]Crude ORs calculated in separate models for race/ethnicity, education and income.
[c]ORs adjusted for age, sex, marital status, place of birth and survey year (model 1); ORs additionally adjusted for health insurance and time since last dental visit (model 2); additionally smoking and diabetes were added to the model (model 3); and finally, ORs for race/ethnicity additionally adjusted for education and income while the model for education is adjusted for income and vice versa (model 4). All models for education and income are adjusted for race/ethnicity.

2003–2004, the overall prevalence of periodontitis was slightly higher (3.8%) than when using two sites (3.6%). However, the results for the prevalence of periodontitis presented the same pattern across the covariates included in Table 1. Although the OR for Black people (2.36; 95% CI 1.74–3.21) was higher than when using the two site definitions, the ORs for the least educated (2.10; 95% CI 1.39–3.17) and low income (1.92; 95% CI 1.23–2.99) were similar to those presented in Table 2 for model 4.

Discussion

Our findings suggest that racial/ethnic and socioeconomic disparities in periodontitis continue to be pervasive, and that in fact, the racial/ethnic disparities have remained the same over the past decade. Specifically, these analyses show that Black people are twice as likely to have periodontitis as White people, a finding previously reported by NHANES III (10, 11, 17). This finding was also true for income (17). However, the difference in periodontitis between the least and the most educated appears to have increased over the past 10 years (17).

Racial/ethnic and socioeconomic differences in periodontal diseases have been reported since data have been collected in the US, with most studies reporting higher prevalence of periodontal diseases for Black people and those with low income and less education (2, 5, 12, 18, 32–34). These findings persisted even after accounting for neighborhood socioeconomic characteristics (11, 35). For example, evidence suggests that race/ethnicity and education were associated with periodontitis before and after controlling for selected covariates including neighborhood socioeconomic conditions (11). Specifically, non-Hispanic Black people and those with less than a high school diploma were twice as likely to have periodontitis compared with non-Hispanic White people and those with more than a high school education, respectively. The results of our study, consistent with those of previous studies (2, 9, 11, 17, 18), showed an association between race/ethnicity, education and income with periodontitis, with Black people, those with less education and those with low income exhibiting higher odds of having periodontitis than their white or Mexican American, more educated and high-income counterparts.

Despite having the lowest educational attainment, lowest income and lowest insurance coverage, Mexican Americans exhibited a prevalence of periodontitis similar to that of White people. This finding has been reported before using NHANES III data (17). Specifically, the authors call attention to the assumption of homogeneity in health status on groups sharing minority status. This assumption may lead to an inaccurate picture and may lead to erroneous and faulty public health strategies to prevent and control disease. This study shows that although Mexican Americans and Black people had more sociodemographic characteristics in common than either group did with their white counterparts, Mexican Americans exhibited prevalence of periodontitis similar to that in White people while Black people exhibited higher prevalence than White people. The paradox of better health outcomes in Mexican Americans holds for mortality rates (infants and adults) and some morbidity and health-related conditions (cancer, cardiovascular disease, high blood pressure and high cholesterol levels) (36–39). As our study did not find interactions between race/ethnicity and income or race/ethnicity and education our findings indicate that the higher prevalence in Black people, those with low income and less education are independent.

The persistence of these findings over time begs us to go beyond just the repetition of the findings as an expected fact and to ask the question: What is it about race/ethnicity, education, and income as social constructs that affect individual health in the US? Race is a proxy for an array of unmeasured exposures (i.e. racial discrimination, segregation, environmental exposure, unequal opportunities for social mobility, access to quality of care) in US society that may act directly or indirectly on periodontal diseases (20). Education, on the other hand, seems to have an effect on health independent of other economic resources and can be passed on through generations (23, 40). Moreover, because race conveys people some advantages or disadvantages, it determines the education individuals receive in the US, and further, may influence their income (20, 41). Thus, race/ethnicity precedes education and income, which are part of the causal pathway by which race/ethnicity affects health outcomes (20), including periodontitis. Because multivariable techniques are unable to separate indirect and direct effects of race/ethnicity after adjusting for mediators (21) and race/ethnicity channels people into different socioeconomic opportunities (19, 20, 22), the adjustment for education and income may reduce but would not

eliminate the racial/ethnic disparities. Our findings suggest that the existence of racial/ethnic disparities in periodontitis remains after adjusting for education and income and vice versa. These disparities could be the net effect of race/ethnicity or could reflect a residual confounding after the adjustment of education and income, constructs that reflect unmeasured inequalities, and thus, are unequal across racial/ethnic groups.

Among the strengths of our study are the use of a nationally representative data and the large sample size, which allow to control for several potential confounders and to examine interactions. The cross-sectional nature of the data and the lack of information on the length of time individuals have been disadvantaged prevent us from making inferences regarding temporal ordering with regard to exposure and disease. Finally, a limitation inherent in national surveys collecting periodontal data is the use of partial-mouth recording examining only two sites (mesiobuccal and midfacial) or three sites (midbuccal, mesiobuccal, and disto-buccal) in two randomly selected quadrants under the assumption that these measurements are representative of the full mouth (42–44). We repeated the analyses using definitions accounting for the use of three sites in NHANES 2001–2002 and NHANES 2003–2004 and the results remain the same as the results presented here. Therefore, the prevalence estimates using partial mouth recording are likely to be underestimates of the true prevalence of periodontitis. This suggests that our results may underestimate the prevalence of periodontitis in the population. Moreover, if the underestimation occurs, the lack of interactions of race/ethnicity, education and income with survey year underscored the consistencies across definitions among survey years. Finally, the lack of genetic information in our study could raise questions regarding our findings of the existing racial/ethnic disparities. However, despite the changes in the population composition mixture, and therefore, genetic pool of the racial categories over time, racial differences in periodontal health have persisted. Thus, genetic characteristics alone cannot explain these differences. Moreover, individual genetic characteristics are unlikely to explain persistent socioeconomic differences in periodontal health within and across racial/ethnic groups.

This study indicates that social constructs, race/ethnicity, education, and income are associated with periodontal health. These findings have been consistently reported in the US over the years. Thus, the pathways by which race/ethnicity and socioeconomic indicators, separately or combined, lead to health or disease should be investigated. Although in the US, the debate of differences on health has been centered around 'disparities', our findings clearly underscored the role of social inequalities in which social constructs commonly used in US society may be determining and shaping disparities in health for disadvantaged groups, namely racial/ethnic or socioeconomic groups. Thus, if the causes of health disparities are to some extent created in the social milieu in which we live and interact with each other, in order to reduce and eventually eliminate health disparities, awareness of the social determinants of health disparities needs to be raised at the higher level of society to change the focus of the health policy agenda from an individual model (i.e. individual's race) to a population health approach (i.e. the political, social and economic forces behind an individual's racial membership). This approach will lead to improving the health of the entire population, and eventually, to eliminating health disparities. Finally, in order to eliminate health disparities in the US, the continuous collection of quality data on the indicators driving the disparities at the national level is crucial. While NHANES is limited to inferences on non-Hispanic Black people, Mexican Americans and non-Hispanic White people, which ignores the diversity of the American population (i.e. Asians and other Hispanic subgroups), the availability of its periodontal data has contributed to our understanding and documentation of the existing disparities in periodontal health in the US since the 1960s. However, the next NHANES data collection, 2005–2006, has changed the dental examination from a comprehensive examination to a simplified oral health screening. This change, if permanent could have important policy and public health implications for the measurement, monitoring and tracking of periodontal health disparities according to race/ethnicity and socioeconomic position. The unavailability of these data would not decrease these disparities but would hide them leading to an increase over time.

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References

1. Douglass CW, Gillings D, Sollecito W, Gammon M. National trends in the prevalence and severity of the periodontal diseases. J Am Dent Assoc 1983;107:403–12.
2. Nikias MK, Fink R, Sollecito W. Oral health status in relation to socioeconomic and ethnic characteristics of urban adults in the U.S.A. Community Dent Oral Epidemiol 1977;5:200–6.
3. Oliver RC, Brown LJ, Loe H. Variations in the prevalence and extent of periodontitis. J Am Dent Assoc 1991;122:43–8.
4. Oliver RC, Brown LJ, Loe H. Periodontal diseases in the United States population. J Periodontol 1998;69:269–78.
5. Elter JR, Beck JD, Slade GD, Offenbacher S. Etiologic models for incident periodontal attachment loss in older adults. J Clin Periodontol 1999;26:113–23.
6. Locker D, Leake JL. Risk indicators and risk markers for periodontal disease experience in older adults living independently in Ontario, Canada. J Dental Res 1993;72:9–17.
7. White BA, Caplan DJ, Weintraub JA. A quarter century of changes in oral health in the United States. J Dent Educ 1995;59:19–57.
8. Caplan DJ, Weintraub JA. The oral health burden in the United States: a summary of recent epidemiologic studies. J Dent Educ 1993;57:853–62.
9. Albandar JM. Periodontal diseases in North America. Periodontol 2000 2002;29:31–69.
10. Borrell LN, Burt BA, Taylor GW. Prevalence and trends in periodontitis in the USA: the NHANES, 1988 to 2000. J Dent Res 2005;84:924–30.
11. Borrell LN, Burt BA, Warren RC, Neighbors HW. The role of individual and neighborhood social factors on periodontitis: the third National Health and Nutrition Examination Survey. J Periodontol 2006;77:444–53.
12. Borrell LN, Burt BA, Neighbors HW, Taylor GW. Social factors and periodontitis in an older population. Am J Public Health 2004;94:748–54.
13. Albandar JM, Brunelle JA, Kingman A. Destructive periodontal disease in adults 30 years of age and older in the United States, 1988–1994. J Periodontol 1999;70:13–29.
14. Albandar JM, Kingman A, Brown LJ, Loe H. Gingival bleeding and subgingival calculus as determinants of disease progression in early-onset periodontitis. J Clin Periodontol 1998;25:231–7.
15. Hyman JJ, Reid BC. Epidemiologic risk factors for periodontal attachment loss among adults in the United States. J Clin Periodontol 2003;30:230–7.
16. Dye BA, Selwitz RH. The relationship between selected measures of periodontal status and demographic and behavioural risk factors. J Clin Periodontol 2005;32:798–808.
17. Borrell LN, Lynch J, Neighbors H, Burt BA, Gillespie BW. Is there homogeneity in periodontal health between African Americans and Mexican Americans? Ethn Dis 2002;12:97–110.
18. Borrell LN, Burt BA, Gillespie BW, Lynch J, Neighbors H. Periodontitis in the United States: beyond black and white. J Public Health Dent 2002;62:92–101.
19. Williams DR. Race/ethnicity and socioeconomic status: measurement and methodological issues. [Review] [81 refs]. Int J Health Serv 1996;26: 483–505.
20. Williams DR. Race, socioeconomic status, and health. The added effects of racism and discrimination. Ann N Y Acad Sci 1999;896:173–88.
21. Robins JM, Greenland S. Identifiability and exchangeability for direct and indirect effects. Epidemiology 1992;3:143–55.
22. Williams DR, Collins C. US Socioeconomic and Racial-Differences in Health - Patterns and Explanations. Annu Rev Sociol 1995;21:349–86.
23. Krieger N, Williams DR, Moss NE. Measuring social class in US public health research: concepts, methodologies, and guidelines. Annu Rev Public Health 1997;18:341–78.
24. Kauffman JS, Kauffman S. Assessment of structured socioeconomic effects on health. Epidemiology 2001;12:157–67.
25. Kaufman JS, Cooper RS, McGee DL. Socioeconomic status and health in blacks and whites: the problem of residual confounding and the resiliency of race. Epidemiology 1997;8:621–8.
26. National Health and Nutrition Examination Survey. Dental Examiners Procedures Manual. Hyattsville, MD: Centers for Disease Control and Prevention. National Center for Health Statistics; 2001.
27. National Health and Nutrition Examination Survey. Interviewer Procedures Manual I-IV. Hyattsville, MD: Centers for Disease Control and Prevention. National Center for Health Statistics; March 2001.
28. Machtei EE, Christersson LA, Grossi SG, Dunford R, Zambon JJ, Genco RJ. Clinical criteria for the definition of ''established periodontitis''. J Periodontol 1992;63:206–14.
29. Beck JD, Koch GG, Rozier RG, Tudor GE. Prevalence and risk indicators for periodontal attachment loss in a population of older community-dwelling blacks and whites. J Periodontol 1990;61:521–8.
30. SAS Institute Inc. SAS/STAT 9.1 User's Guide. Cary, NC: SAS Institute Inc.; 2004.
31. Research Triangle Institute. SUDAAN Language Manual, Release 9.0. Research Triangle Park, NC: Research Triangle Institute; 2004.
32. Douglass CW, Gillings D, Sollecito W, Gammon M. National trends in the prevalence and severity of the periodontal diseases. J Am Dent Assoc 1983;107:403–12.
33. U.S. Department of Health and Human Services. Oral Health in America: A Report of the Surgeon General. Rockville, MD: U.S. Department of Health and Human Services, National Institute of Dental and Craniofacial Research, National Institutes of Health; 2000.
34. Burt BA, Eklund SA. Dentistry, dental practice and the community. 6th edn. St. Louis, MO: Elsevier Saunders; 2005.
35. Borrell LN, Beck JD, Heiss G. Socioeconomic disadvantage and periodontal disease: the dental atherosclerosis risk in communities study. Am J Public Health 2006;96:332–9.
36. Franzini L, Ribble JC, Keddie AM. Understanding the Hispanic paradox. Ethn Dis 2001;11:496–518.

37. Markides KS, Coreil J. The health of Hispanics in the southwestern United States: an epidemiologic paradox. Public Health Rep 1986;101:253–65.
38. Palloni A, Arias E. Paradox lost: explaining the Hispanic adult mortality advantage. Demography 2004;41:385–415.
39. Patel KV, Eschbach K, Ray LA, Markides KS. Evaluation of mortality data for older Mexican Americans: implications for the Hispanic paradox. Am J Epidemiol 2004;159:707–15.
40. Lynch J, Kaplan G. Socioeconomic position. In: Berkman LF, Kawachi I editors. Social epidemiology. New York: Oxford University Press, Inc; 2000. p. 13–35.
41. Williams DR, Collins C. Racial residential segregation: a fundamental cause of racial disparities in health. Public Health Rep 2001;116:404–16.
42. Kingman A, Albandar JM. Methodological aspects of epidemiological studies of periodontal diseases. Periodontol 2000 2002;29:11–30.
43. Susin C, Kingman A, Albandar JM. Effect of partial recording protocols on estimates of prevalence of periodontal disease. J Periodontol 2005;76:262–7.
44. Beck JD, Caplan DJ, Preisser JS, Moss K. Reducing the bias of probing depth and attachment level estimates using random partial-mouth recording. Community Dent Oral Epidemiol 2006;34:1–10.