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Socioeconomic position indicators and periodontitis: Examining the evidence

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Abstract

Disparities in the prevalence and severity of periodontal disease are associated with socioeconomic factors, such as education and income, and have been recognized since the1960s. Epidemiologic reports have consistently shown that i) periodontal disease is inversely related to education and income after controlling for age and gender, and ii) differences in education and income explain mode if not all of the observed disparities in periodontal disease between blacks and whites. Although race/ethnicity has been the main focus of differences in periodontal diseases in the U.S., disparities in socioeconomic position (SEP) indicators (i.e., education, income, poverty-income ratio) have remained pervasive in the U.S. over the years. SEP indicators, as used in the epidemiologic literature, allocate assignment of socioeconomic measures as a proxy for one's place, position and power in society. Thus, understanding these disparities in periodontal health status may provide insight and context more generally into why racial/ethnic disparities persist. In this paper, we review recent prevalence estimates of periodontitis, according to SEP indicators, and critically assess the importance of SEP factors in periodontal epidemiolgy. The majority of the data available for review comes from the U.S. However, data from other countries is included where available. Specifically, we aim to identify the advantages and disadvantages of the most commonly used SEP indicators in studying periodontal disease; summarize existing evidence on the association between SEP indicators and periodontitis; discuss the analytical issues associated with SEP indicators; and finally, discuss and present, future and alternative research directions on examining the association between SEP indicators and periodontitis.

Introduction

Existing disparities in the prevalence and severity of periodontal disease by education and income have been reported since the early 1960s[48]. Albeit scant, statistical reports have consistently shown that i) periodontal disease is inversely related to education and income after controlling for age and gender, and ii) differences in education and income explain most if not all of the observed disparities in periodontal disease between blacks and whites. Although race/ethnicity has been the main focus of differences in periodontal diseases in the U.S., disparities in socioeconomic position (SEP) indicators (i.e., education, income, poverty-income ratio) have remained pervasive in the U.S. over the years. Thus, understanding these disparities may provide insight and context of why racial/ethnic disparities persist [6-9, 11, 24, 31, 37, 62, 63].

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SEP indicators used in epidemiologic literature allocate assignment of socioeconomic measures to proxy one's place, position and power in society [55]. These measures have implications not only for health outcomes, health behaviors and access but for life experiences in general. Therefore, critical assessment of these measures is needed to understand what they mean for oral health, particularly periodontitis, a disease that is progressive over the life course and exacerbated by other systemic stressors. Most studies have provided unadjusted associations between periodontitis and categories for each SEP indicator [37, 61-63] or have included these indicators as covariates in multivariable analysis approaches to adjust for effects of SEP [9-11, 13, 15, 19, 20, 64]. However, few studies have focused on the independent effect of SEP indicators on periodontal diseases [12, 14, 16, 17, 33, 69-71]. Nevertheless, differences in periodontitis according to SEP indicators are consistent regardless how SEP indicators are examined: Those with low SEP exhibited higher prevalence or greater odds of periodontitis than their peers with high SEP. In the U.S., attention to these disparities was underscored by the first Surgeon General's Report on Oral Health[4] to parallel Healthy People 2010's goal of eliminating health disparities across segments of the population, including differences that occur by education or income [5].

Given the lack of critical and comprehensive assessment of SEP on periodontitis, this paper aims to provide recent prevalence estimates of periodontitis according to SEP indicators. The majority of the data is available from the U.S.; however, data from other countries will be included where available. Specifically, we will identify the advantages and disadvantages of the most commonly used SEP indicators in studying periodontal disease; summarize existing evidence on the association between SEP indicators and periodontitis; discuss the analytical issues associated with SEP indicators; and finally, discuss and present, future and alternative research directions on examining the association between SEP indicators and periodontitis.

Prevalence of periodontitis by SEP indicators

Data from the most recent U.S. national surveys show a social gradient for education and poverty status for the means of pocket depth and loss of attachment[34]. Specifically, data from the National Health and Nutrition Examination Survey 1999-2004 suggest that those with less than a high school education or living 100% below federal poverty level exhibited higher means of pocket depth and loss of attachment than their counterparts with more than a high school education or living 200% above the federal poverty level (Table 1). This finding was also observed for periodontitis defined as the combination of at least one site with 3 mm or more of loss of attachment and 4 mm or more of pocket depth. These findings were consistent for adults aged 20 to 64 years and those 65 years and older. For instance, when compared to adults aged 20 to 64 years with more than a high school education (5.8%), the prevalence of periodontitis was almost three times higher among those with less than a high school education (17.3%). These estimates were similar for adults 65 years of age and older (16.6% for those with less than a high school education versus 8.3% for those with more than a high school education). Although there was no a clear gradient for poverty status among adults 20 to 64 years of age, adults aged 65 years and older living 100% below the federal poverty level exhibited a higher prevalence of periodontitis (17.5%) than their counterparts living 200% above the federal poverty level (8.6%).

Commonly used SEP indicators in the U.S.

Although several reviews [52, 54, 55, 66, 74] and empirical papers[22, 23] have focused on measurements of social class and SEP and their complexities in health research, most studies on periodontal diseases have focused on education, income and poverty-income ratio. This

is true regardless of whether SEP indicators are considered as independent predictors [12, 14, 16, 17, 33, 69-71] or covariates[9-11, 13, 15, 19, 20, 64]. More often than not the use of SEP indicators is a function of the data available in large-scale U.S. national surveys as most of the literature examining the relationship between SEP and periodontitis have used such data. For instance, the only data sources where SEP information and periodontitis measures are available are the data from the National Health and Nutrition Examination Survey. It is worth noting that terms such as socioeconomic status and social class are also used to refer to SEP. Consistent with others [38, 52, 55], we used SEP to indicate how socioeconomic factors determine an individual or groups position within the structure of a society. We do not intend to present a detail description of all SEP indicators. However, we will discuss indicators (education, occupation, income, and poverty-income ratio) commonly used when examining periodontitis. More extensive discussions on SEP indicators can be found in previous reviews on this issue [32, 38-40, 52, 54, 55].

Individual-level Indicators

Education, which remains stable over the life course, is the most frequently used and the easiest to measure SEP in epidemiological studies and indicates the knowledge-related assets of an individual [38, 39, 52]. It can be measured and used as continuous (i.e., years of education) or categorical (i.e., less than a high school, high school, and more than a high school). The former assumes that every year of education makes the same contribution to SEP, whereas the latter assumes that specific achievements or credentials are important in determining SEP [39, 54]. Education could have direct (i.e., determines a person's employment status, job position and earned income) and indirect (i.e., affects individuals' behaviors that could lead to health enhancing opportunities [36] and could have a spillover effect across generations[55]) effects for health. However, several limitations could be attributed to education: its meaning changes across birth cohorts, does not account for education outside the host country and does not convey information on quality of the educational attainment or experience [39].

Although not commonly used in the U.S., occupation represents the bridge between education and income. Occupation can be measured as the occupation of the head of the household or as employment status (i.e., full or part time). As with education, occupation could have direct (i.e., monetary reward or income, access to health care [39]) and indirect (i.e., stress, hazard environmental exposures [55]) effects on health. Occupation, which changes over time causing income fluctuations, cannot be assigned to people unemployed and its meaning changes for birth cohorts and countries [39].

Finally, income is the SEP indicator that directly relates to the material goods, resources and conditions of an individual [55]. It is usually measured as the absolute income, earning value or as predefined categories within the past year determined on the individual, family or household level. However, in order to make income equivalent across households or families, the family size should be considered. While income is easy to measure, it may be difficult to collect as people may not want to disclose their actual income. As with education, income could have a cumulative effect over the life course [56] and may have a ‘dose-response’ effect on health [35, 39]. Unlike education, income can be dynamic and change on a short time basis - an issue that is seldom accounted for in epidemiological studies. Income can influence health because of what money can buy (i.e., foods, shelter, access to care, education, leisure activities) [39, 55]. While income is less sensitive to the birth cohort limitations than education and occupation, attention must be paid to income across the life course (i.e., early earning years and older adults) [38, 39]. Poverty-income ratio is a commonly used income-related indicator in the U.S. and represents the ratio of income to the family's appropriate poverty threshold [2]. This measure is usually calculated and provided in large-scale national surveys such as the National Health and Nutrition Examination Surveys [1, 3].

Poverty-income ratio is provided as a continuous variable from 0 to 5 with values above 1.00 indicating income above the poverty level.

Area-level indicators

Area-level SEP measures are used to capture whether the socioeconomic conditions or circumstances of place where people live, above and beyond individual SEP, affects people's health. Although most studies have found small area effects on health, the vast evidence supports such effects [28, 51, 65]. While there is no consensus regarding how to define the most meaningful geographic area associated with health outcomes in the U.S.,[41, 42, 49, 50, 77] most studies investigating the effects of area of residence on health have used census-defined geographical areas such as census tracts, block groups and zip codes in some cases. Several studies have shown little or no difference on how socioeconomic indicators affects health outcomes when comparing census tract and block group areas[41, 42, 49-51, 77]. Furthermore, neighborhood research from a more sociological perspective has mostly used census tracts (or clusters of census tracts) as neighborhood proxies[72, 73]. Outside the U.S., geographic areas commonly used are postcode sector (Scotland, Australia), electoral ward (England), enumeration districts (England and Scotland), and municipality (Finland)[32, 65].

Area-level socioeconomic indicators are obtained from the US Census as aggregate of individual data. They can be used to characterize the area area-level socioeconomic conditions or as proxies for individual SEP indicators of people living in those areas [50, 51]. However, because the area-level area-level socioeconomic measures have less variability than individual-level SEP indicators (e.g., income or education), the independent effect for individual SEP indicators may be under- or over-estimated when area measures are used as proxies. As with neighborhood or geographic area of residence definition, in general, there is no clear consensus regarding the area-level area-level socioeconomic factors to be used in studies relating area characteristics to health. The most common approach is to use Census data on income, education, occupation, and indicators of wealth and poverty as area-based measures[27, 50, 51]. Other studies have used indicators including crime rates; unemployment levels; housing characteristics; measures of consumption such as percentage of households without a car; family characteristics such as age of head of household or prevalence of separation or divorce; ethnic composition; and community instability as assessed by the time most residents have lived in the area[21, 45, 57, 73, 75, 76, 86]. Furthermore, the variables have been combined into scores or indices based on statistical techniques, arbitrary assignment by the investigator, or, analyzed separately [25, 29, 30, 43, 60].

Regardless of whether area-level area-level socioeconomic measures are used to determine area area-level socioeconomic effects or as proxies for individuals, area-level area-level socioeconomic indicators have several limitations. These shortcomings include the following: Information on residential mobility of the area residents and length of residence in the area is rarely known; these measures do not tell us anything about where individual's spends most of the time; and because the area effect is associated with health policies and services, there is no a one-size fits all when it comes to health outcomes.

Evidence on the independent effects of SEP indicators on periodontitis

Table 2 includes published studies examining the independent effect of SEP indicators (i**.e., SEP indicators were the exposure of interest)** on periodontitis from January 1, 2002 to August 31, 2009 located through a PubMed database search using a combination of the keywords: “periodontitis,” “periodontal disease,” with keywords, “income,” “education,” “socioeconomic status,” “socioeconomic position,” and “race/ ethnicity.” Articles published in language other than English were excluded, and the identified references were saved into a reference manager software. All citations and their abstracts, whenever available, were

printed and screened to determine articles to be included in the review. In addition, to the PubMed search, selected references quoted in a number of articles were evaluated and whenever appropriate included in the review, according to their relevance to the theme in question. Collectively these searches yielded 454 hits with fifteen original research studies that directly assessed the independent effect of area-level socioeconomic indicators on periodontal disease among adults being included in this review. Most of these studies were conducted in the U.S. (12 out of 15). Table 2 presents the summaries of these studies and information on authors, year, SEP indicator (s) used in the analysis, the main findings of each study and location is provided.

For U.S. studies, with the exception of Borrell et al. [12], the data source for these analyses was the National Health and Nutrition Examination Survey, a national large scale data source. The studies consistently show an inverse relationship between periodontitis and the SEP measurement used in the study regardless of the periodontal disease measure or definition used [12, 14, 16, 17, 19, 33, 69-71]. Interestingly, while education, family income and poverty-income ratio are consistently used as individual level predictors, categorizations of these SEP measures are heterogeneous. For example, a study uses high school educational attainment as a cut-point for educational attainment[14] while other studies further delineate the influence of some college experience on periodontitis[12, 16, 19, 33, 69-71]. Regardless of the definition used, a dose-response relationship with increasing levels of education is shown so that more education equates to a lower prevalence or odds of periodontitis after taking confounding factors into account. Similar results are found with income and poverty-income ratio despite heterogeneity in the cut-points used to categorize these measures.

It is important to note that despite the consistency of the relationship with each SEP indicator and periodontitis, each indicator contributes independently to periodontitis even in the presence of other SEP indicators. Further, Borrell et al.[14] showed that the relationship between SEP and periodontitis is closely intertwined to race/ ethnicity: After adjusting for confounding factors, the joint effect of higher education and higher income translated into significantly better periodontal outcomes for non-Hispanic whites and Mexican Americans. However, this was not the case for non-Hispanic blacks where those with high education and high income have similar prevalence of periodontitis as those with low education and low income. These findings suggest that education and income may afford access to services and knowledge differently across racial/ethnic groups in the U.S. with non-Hispanic whites and Mexican Americans having a higher gain out these area-level socioeconomic indicators, and thus, better periodontal outcomes.

Neighborhood area-level socioeconomic findings related to periodontitis are less consistent than individual level findings. While one study[12] showed that neighborhood area-level socioeconomic disadvantage was not significantly associated with periodontitis, another study found that it was [16]. This may be a result of data sources where neighborhood measures may lack sufficient variability to detect an effect.

For the international studies, two studies evaluated education and income separately[53, 80] while one study examined a summary score of education and income[79]. In general, these studies show that low socioeconomic position was positively associated with periodontal diseases regardless of the case definition used in the study. However, the studies examining education and income separately show that after adjustment for selected characteristics, education seems to be more important than income. Specifically, low education was associated with increase probability of periodontitis after controlling for selected covariates including income[53, 80].

Analytical issues of SEP indicators

Several issues must be considered when examining the effect of SEP indicators on health outcomes and these issues apply regardless of whether the indicator is examined as an independent variable or as a covariate. First, there is the misconception that SEP indicators are highly correlated, and therefore, they should not be included together in the analytical model or that including one indicator can be used as a proxy for (an)other SEP indicator(s). Second, adjustment for any covariate usually implies that categories within the covariate are homogenous, and thus, the effect associated with that particular category on the health outcome of interest is uniform across the population studied. Finally, and related to the last issue, when adjusting the effect of race/ethnicity for SEP indicators, if a significant effect is observed for race/ethnicity on the outcome of interest, this effect is usually attributed to some unique biological or genetic effect of race/ethnicity.

Most studies of periodontitis tend to include education and income (or poverty-income ratio) either in combination or alone (See Table 2). When the latter situation occurs, the rationale for it is that these indicators are highly correlated and including an indicator may be sufficient to account for the effect of SEP in general. However, research shows that in general the correlation coefficients for education and income are less than 0.50 suggesting that these indicators are capturing related but distinct constructs, and therefore, should not be used as proxies for each other [22, 23]. The latter applies when SEP indicators are used as independent variables or covariates. For example, Braveman et al. found that conclusions inferred from the association of race/ethnicity with fair/poor health or delayed or no prenatal care depend on whether education and income (or poverty level) are included individually or together in the model [23] showing that education and income cannot be used interchangeably as each indicator contributes uniquely important information about one's area-level socioeconomic circumstance. Further, while the magnitude of the estimates for the associations between race/ethnicity and each outcome somewhat decreases when adjusting for either education or income (or poverty level), a large decrease was observed when both indicators were accounted for in the analyses. The findings suggest that the correlations between SEP indicators are not strong enough to justify using one indicator as a proxy for the other at best and for SEP in its entirety at worst. Thus, while these indicators are correlated and used interchangeably, they are not completely equivalent: each of them has a very different relationship with the health status of individuals.

Another common misconception is to use income as a proxy for wealth. Table 3 shows data on mean annual income[26] and net worth[44] in dollars from a nationally representative sample of US adults. The mean annual income represents the disposable cash an individual has to spend during the year while the net worth could be seen as an indicator of security or economic stability in time of loss of income due to unemployment or illness [66]. These data show that wealth can be very different across racial/ethnic groups in similar quintile of monthly household incomes. Although wealth is not commonly used as a SEP indicator, a recent review of the literature found 29 articles examining wealth as an independent variable with a wide range of outcomes (i.e., mortality, self-rated health, chronic conditions, functional status and mental health among others) published between 1990 and 2006[66]. While the definition and terminology for wealth varied among studies, most of these studies (15 out of 29) reported a positive association between wealth and health outcomes[66]. To the best of our knowledge, no study has examined the association between wealth and periodontitis.

Multivariable analysis allows the adjustment of the effect of selected covariates on the association of interest by making things ‘equal’ in the study population[68, 85]. The rationale behind adjusting for a covariate during multivariable analysis is that each category or level

of the covariate will render a uniform effect across all individuals in the study population. This is also expected when adjusting or accounting for the effect of SEP indicators. However, SEP indicators are not equivalent across racial/ethnic groups, the covariate mostly examined in the U.S. regardless of the health outcome studied. For instance, Table 3 shows the mean annual income for the overall population according to race/ethnicity[26]. The data suggest that non-Hispanic blacks and Hispanics had on average lower mean annual income than their non-Hispanic white and Asian counterparts. In fact, these data show an unexpected and complex pattern when the mean annual income is presented by level of education in each racial/ethnic group. The latter underscores the assumption of homogeneity across category or level of a covariate. Moreover, it clearly calls attention to the issue of using a SEP indicator for another. In this instance, using education as a proxy for income would not only violate the homogeneity assumption but also underscore the issue that SEP indicators do not carry the same meaning for each racial/ethnic group. Thus, the persistent racial/ethnic disparities in periodontitis or any health outcome when adjusting for SEP indicators could reflect residual confounding associated with the lack of commensurability of SEP indicators for each racial/ethnic group. Finally, because race/ethnicity precedes SEP indicators on the causal pathway, the effect of race/ethnicity after adjustment for SEP on health outcomes could underscore that SEP indicators do not fully mediate or explain the effect of race/ethnicity.

It is possible that the residual effect observed for race/ethnicity may not be mediated by SEP, and in fact, may reflect the multidimensionality of race/ethnicity in the U.S. 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 U.S. society that may act directly or indirectly on periodontal diseases[82]. Moreover, evidence suggests that race/ethnicity is a major determinant of one's education and income (i.e., race/ethnicity determines the education individual's receive in the U.S., and further, may influence their income),[81, 82, 84] 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,[67] adjustment for mediators only allows the estimation of the net effect of an independent variable. For instance, in the case of education and income as mediators of the association between race/ethnicity and periodontitis, the net estimation may not hold because education and income carry different meaning across racial/ethnic groups as a result of the pervasiveness of the implementation of previous discriminatory policies in U.S. society such as residential segregation [81-83]. Thus, adjustment for education and income of the association between race/ethnicity and periodontitis may reduce but would not eliminate racial/ethnic disparities due to the unequal meaning of education and income across racial/ethnic groups[52, 81, 82]. This unequal meaning would lead to residual confounding[46, 47].

Conclusions and future directions

- Current studies show that persons who are socioeconomically disadvantaged regardless of the SEP indicator used consistently have poorer periodontal outcomes.
- Investigation of the influence of SEP indicators on the etiologic pathway of periodontitis is needed to better understand SEP and its contribution to health.
- SEP and race/ ethnicity are inextricably linked in U.S. society and each are independently associated with periodontitis[16, 17]. Moreover, socioeconomic disadvantage and racial discrimination may lead to stress. The cumulative exposure of this stress may disrupt an individual's allostatis[78] or his/her ability to achieve

stability through change and lead to allostatic load[58, 59]. Thus, allostatic load may help to explain some of the differential burden of stress experienced by low socioeconomic and racial/ethnic minority groups. These groups are the ones driving the existing disparities in periodontitis and other health outcomes. In fact, a recent study found that U.S. adults with a high allostatic load were 55% more likely to have periodontitis than their counterparts with low allostatic load with this association being stronger in Mexican Americans [18]. Mexican Americans with a high allostatic load were almost five times more likely to have periodontitis than their counterparts with low allostatic load. Thus, an understanding of the role of stress measured through allostatic load will help us tailor interventions to selected groups (e.g., poor persons and racial/ethnic minorities) to buffer stress that may increase the probability of periodontitis and other chronic diseases.

- Structural interventions targeting cultural traditions such as religious organizations that have strong ties in racial/ethnic communities may also help to reduce stress that may have a negative impact on health. Additionally, educational awareness could be implemented in religious organizations to help disseminate information about improving periodontal outcomes within economically disadvantaged communities and to their social networks.

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Table 1

Mean pocket depth, mean loss of attachment and prevalence of periodontitis for race/ethnicity, education and poverty status among US adults 20 years and older: National Health and Nutrition Examination Survey, 1999-2004[34]

	20-64 years of age			65 years of age and older		
Characteristics	**Pocket depth in mm**[a]	**Loss of attachment in mm**	**Periodontitis**[b]	**Pocket depth in mm**	**Loss of attachment in mm**	**Periodontitis**
Race/ethnicity						
Non-Hispanic white	0.96 (0.02)	0.67 (0.02)	5.8 (0.58)	1.04 (0.03)	1.47 (0.05)	9.0 (0.94)
Non-Hispanic Black	1.19 (0.03)	0.84 (0.04)	16.8 (0.95)	1.27 (0.07)	1.93 (0.12)	23.9 (3.55)
Mexican American	1.16 (0.04)	0.81 (0.05)	13.8 (1.53)	1.17 (0.06)	1.90 (0.11)	17.2 (2.90)
Education (years)						
< 12	1.25 (0.03)	1.05 (0.05)	17.3 (1.65)	1.23 (0.04)	2.10 (0.09)	16.6 (1.98)
12	1.04 (0.03)	0.77 (0.03)	9.3 (0.98)	0.98 (0.04)	1.41 (0.06)	8.3 (1.26)
>12	0.95 (0.03)	0.62 (0.02)	5.8 (0.52)	1.06 (0.03)	1.36 (0.05)	8.3 (1.41)
Poverty Status[c]						
< 100%	1.16 (0.03)	0.97 (0.04)	13.9 (1.85)	1.27 (0.06)	2.30 (0.24)	17.5 (4.05)
100%-199%	1.14 (0.03)	0.97 (0.04)	15.3 (1.22)	1.10 (0.04)	1.65 (0.08)	11.6 (1.72)
≥ 200%	0.96 (0.02)	0.64 (0.02)	6.0 (0.56)	1.03 (0.03)	1.39 (0.05)	8.6 (1.11)

[a] **Weighted** means (Standard error) for pocket depth and loss of attachment; **weighted** prevalence (Standard error) for periodontitis

[b] Periodontitis defined as at least one site with ≥3 mm of loss of attachment and ≥4 mm of pocket depth

[c] Poverty status defined as below the federal poverty level

Table 2

Studies focusing on the independent effect of socioeconomic position (SEP) indicators on periodontitis

Study	Study Design and Data Source(s)	Periodontitis Measurement(s)	SEP measurement(s)	Main Finding related to Periodontitis
	United States			
Borrell et al. 2002[19]	Cross-sectional National Health and Nutrition Examination Survey III n=12,399 adults aged 17 years and older	Periodontitis defined as at least 3 sites with clinical attachment loss of ≥4mm and at least two sites with pocket depth of ≥4mm.	Education (<12years, 12 years and >12 years); total family ncome (<$16,999, $17,000-$34,999, and ≥$35,000) and Poverty- income ratio (0-1.85, 1.851-3.5 and 3.501 and above).	Prevalence of periodontitis inversely associated with education, income and poverty-income ratio across all racial/ethnic groups (non-Hispanic blacks, Mexican Americans and non-Hispanic whites). Education and income were significantly inversely associated with periodontitis after adjustment for age, gender, race/ethnicity country of birth, marital status, time since last dental visit, health insurance, self-reported diabetes and smoking status. Adjustment for education included income and vice versa. These findings were consistent for the overall population and for racial/ethnic-specific analyses.
Borrell et al. 2004[14]	Cross-sectional National Health and Nutrition Examination Survey III n=3,406 adults aged 50 years and older	At least 4 sites with clinical attachment loss ≥5mm and one site with pocket depth ≥4mm. Conditions did not have to be present in same site nor same tooth.	Education (<12 and ≥12 years) and total family income (<$20,000 and ≥$20,000).	Education and income independently associated with periodontitis with a significant inverse relationship for each racial/ethnic group. These findings were observed after controlling for age, gender, time since last dental visit, health insurance, self-reported diabetes and smoking status. Adjustment for education included income and vice versa. After adjustment for variables listed above, the joint effect of high education and high income resulted in significantly better periodontitis outcomes for non-Hispanic whites and Mexican-Americans, but not for non-Hispanic blacks. Non-Hispanic blacks with high education and high income have similar prevalence of periodontitis as their peers with low education and low income.
Dye & Selwitz	Cross-sectional National Health and Nutrition Examination Survey III n= 11,347 adults aged	Attachment loss extent index (ratio # of sites with attachment loss divided by the number of sites examined per person); Mean attachment loss (# of sites with attachment loss divided by the	Education (did not completed high school, completed high school and at least some	Education was inversely associated with all periodontal measures: Those without high school education and those who completed high school had worst periodontal scores than those with at least some college before and after adjusting for gender, age, race/ethnicity, smoking status and dental

Study	Study Design and Data Source(s)	Periodontitis Measurement(s)	SEP measurement(s)	Main Finding related to Periodontitis
2005[33]	20–79 years	number of sites examined per person); periodontal status measure (Worst tooth condition in the mouth for bleeding or attachment loss); and derived community periodontal index (dCPI; Worst tooth condition in the mouth for bleeding, calculus or probing depth ≥ 4mm).	college).	visit in the past 12 months.
Borrell et al. 2006[12]	Cross-sectional Atherosclerosis risk in communities (ARIC) study n= 5,677 African American and whites aged 45 to 64 years	Severe periodontitis: at least 2 interproximal sites with clinical attachment loss of ≥6mm and one interproximal site with pocket depths of ≥5mm.	Neighborhood area-level socioeconomic Score tertiles: Wealth or income (log of median household income, log of median value of owner-occupied housing units and percentage of households receiving interest, dividends or net rental income); Education (% of adults 25 years and older with completed high school and % of adults 25 years and older who had completed college) Occupation (% of employed individuals 16 years and older in executive, managerial or professional specialty occupations). Individual level socioeconomic status measures: Education (<high school, high school/ general equivalency diploma or vocational school , and some college, college or professional school); Family income in past 12 months (<$35,000, $35,000-$74,999 and ≥75,000 for whites and <$16,000, $16,000-$49,999 and ≥$50,000 for blacks).	Individual SEP measures: Low income was significantly associated with a higher odds of periodontitis whites; Lower education and low income were associated with greater odds of periodontitis in blacks. Neighborhood socioeconomic status measure: There was no association between neighborhood area-level socioeconomic score and periodontitis in neither whites nor blacks. Joint effects of neighborhood and individual SEP: The odds of periodontitis was greater in whites with low income and living in the worse neighborhood than in their counterparts with high income and living in the best neighborhoods. This finding was not observed for blacks.
Borrell et al. 2006[16]	Cross-sectional National Health and Nutrition Examination Survey III and 1990 U.S. Census data n=13,090 non-Hispanic black, non-Hispanic white, and Mexican-American adults aged 18+ yrs	At least 2 sites with clinical attachment loss ≥4mm and one sites with pocket depth ≥4mm. Conditions did not have to be present in same site nor same tooth.	Neighborhood area-level socioeconomic Score tertiles: Wealth or income (log of median household income, log of median value of owner-occupied housing units and percentage of households receiving interest, dividends or net rental income); Education (% of adults 25 years and older with completed high school and % of adults 25 years and older who had completed college) Occupation (% of employed individuals 16 years and older in executive, managerial or professional specialty occupations).	After controlling for age, gender, race/ethnicity, income, self-reported diabetes and smoking status, education and neighborhood area-level socioeconomic score were associated with greater odds of periodontitis. These models were also adjusted for neighborhood area-level socioeconomic score and vice versa. Income was not associated with periodontitis. It is worth noting that race/ethnicity was also evaluated as an independent variable in this analysis. Blacks and Mexican Americans exhibited greater odds of periodontitis than whites after controlling for age, gender,

Study	Study Design and Data Source(s)	Periodontitis Measurement(s)	SEP measurement(s)	Main Finding related to Periodontitis
				education, income, neighborhood area-level socioeconomic, self-reported diabetes and smoking status.
			Individual level socioeconomic status measures: Education (<12, 12 and >12 years of education); and total family income (≤$14,999, $15,000-$24,999 and ≥$25,000).	
Sabbah et al. 2007[69]	Cross-sectional National Health and Nutrition and Examination Survey III n=13,925 adults age 17 and older 17641	Ratio of sites with extent of pockets ≥4mm, extent of loss of periodontal attachment ≥3mm, extent of gingival bleeding to total number of examined sites. Periodontitis defined as presence of at least one sire with loss of attachment ≥3mm and one site with gingival bleeding.	Education (<12 years, 12 years and >12 years) and poverty- income ratio; quartiles)	Education and poverty-income ratio were inversely associated with periodontal disease measures after adjusting for age, sex, ethnicity, diabetes, smoking, dental insurance, education (the model for poverty-income ratio) and poverty-income ratio (the model for education). A dose-response was observed for education on periodontitis.
Borrell & Crawford 2008[17]	Cross-sectional National Health and Examination Nutrition 1999-2004	At least 2 sites with clinical attachment loss ≥4mm and one site with pocket depth ≥4mm. Conditions did not have to be present in same site nor same tooth.	Education (<12 years, 12 years and >12 years) and total family income (≤$19,999, $20,000-$34,999 and ≥$35,000).	Education and income were inversely associated with periodontitis after adjusting for age, sex, race/ ethnicity, marital status, place of birth, survey year, health insurance, time since last dental visit, smoking, diabetes, education (the model for income) and income (the model for education).
	n=10,648 non-Hispanic black, non-Hispanic white, and Mexican-American adults aged 18 to 85 years of age			It is worth noting that race/ethnicity was also evaluated as an independent variable in this analysis. Blacks had greater odds of periodontitis than whites after controlling for age, sex, race/ ethnicity, marital status, place of birth, survey year, health insurance, time since last dental visit, smoking, diabetes, education and income.
Sabbah et al. 2008[71]	Cross-sectional National Health and Nutrition Examination Survey III n=4,295 adults age 17 years and older	Extent of pockets of ≥ 4mm; extent attachment loss of ≥3mm; extent of gingival bleeding. These variables were calculated as the ratio of # of sites with the conditions to the total # of sites examined. A dichotomous periodontal disease	Education (<12, 12 and >12 years) and poverty-income ratio (continuous).	Education was inversely associated with all periodontal measures before and after adjusting age, sex, ethnicity, diabetes, smoking, dental insurance, poverty-income ratio and allostatic load Poverty-income ratio was significantly associated with periodontitis, extent of periodontal pockets and extent of attachment los before and after adjusting for

Study	Study Design and Data Source(s)	Periodontitis Measurement(s)	SEP measurement(s)	Main Finding related to Periodontitis
		variable defined as at least one gingival bleeding site and one site with attachment loss of ≥3mm.		all characteristics including education.
Sabbah et al. 2009[70]	Cross-sectional National Health and Nutrition Examination Survey III n=12,051 adults age 17 years and older	Extent of sites with gingival bleeding and extent of attachment loss of ≥3mm. These measures were calculated as the ratio of # of sites with the condition to the total # of sites examined.	Education (<12 years, 12 years and >12 years) and poverty-income ratio (continuous).	Education and poverty-income ratio were inversely associated with percent teeth gingival bleeding and periodontal attachment before and after adjusting for demographic characteristics and health-related behaviors.
			International	
Susin and Albandar 2005[79]	Cross-sectional Representative sample of Porto Alegre, Rio Grande do Sul, Brazil n=612 young people age 14-29	Aggressive periodontitis was defined as 4 or more teeth with attachment loss ≥4mm for persons age 14-19 and 4 or more teeth with attachment loss of ≥5mm for persons age 20-29.	Socioeconomic status (defined by the Brazilian economy classification (CCEB) – High: ≥9 years education and upper two tertiles of CCEB or 5-8 years of education and high tertile of CCEB; Low: 1-4 years of education and lower two tertiles of CCEB or 5-8 years of education and lowest tertile of CCEB; Middle: those who have higher economy and education than the low socioeconomic group, but less than the high group.	Aggressive periodontitis significantly higher among those with low socioeconomic status compared to those with high socioeconomic status before and after adjusting for age, smoking status and supragingival calculus.
Torrungruang et al. 2005[80]	Cross-sectional Baseline assessment in a longitudinal study, Bangkok, Thailand n=2,005 adults aged 50-73	Periodontitis defined as mild, moderate or severe which corresponded to clinical attachment loss of <2.5mm, 2.5-3.9mm or ≥4.0mm, respectively.	Education (≤ high school and > high school); and annual income (<$6,000, $6,000-14,999 and ≥$15,000).	In the crude analysis, those with more than a high school education were significantly less likely to have moderate or severe periodontitis compared to those with less than a high school education. Also those with income between $6000-14,999 were significantly less likely to have severe periodontitis compared to those with income <$6,000 while those with income ≥ $15,000 were significantly less likely to have moderate and severe periodontitis. After adjusting for age, gender, plaque, smoking and diabetes status, only education remained significant associated with lower odds of having moderate or severe periodontitis.
Krustrup and Petersen 2006[53]	Cross-sectional Nation-wide household based survey, National Institute of Public Health, Denmark	Periodontal disease was defined using the Community Periodontal Index: Presence or absence of gingival bleeding (CPI 1); pocket depth 4-	Education (low: <10 years, medium: 11-12 years, high: 13-14 years, very high: ≥15 years) and income defined as <100,00DKK, 100,000-199,999DKK, 200,000-299,999DKK and ≥300,000DKK for persons age	After controlling for gender, age, area of residence, income and regular dental visits, education was associated with presence of bleeding, pocket depth 4-5 mm and pocket

Study	Study Design and Data Source(s)	Periodontitis Measurement(s)	SEP measurement(s)	Main Finding related to Periodontitis
	n=1,115 adults age 35-44	5mm (CPI 3); and pocket depth ≥6mm (CPI 4).	65-74 and for persons age 35-44 years income was categorized as <200,000DKK, 200,000-299,999DKK, 300,000-399,999DKK and ≥400,000DKK.	depth ≥6mm. This association was seeing among those with low and medium education relative to those with very high education.

Table 3

Mean annual income by educational attainment[26] and net worth[44] by monthly household income quintile according to race/ethnicity

	Non- Hispanic White	Black[a]	Asian	Hispanic	Total
Income (Dollars)					
All workers	36,763	28,071	37,940	24,602	33,452
Less than a high school	21,311	16,163	19,640	18,804	19,405
High school	29,052	23,322	24,539	23,836	26,894
Some college or associate's degree	34,663	30,034	32,160	30,801	32,874
Bachelor's degree	48,667	41,972	46,857	40,068	46,805
Advanced degree	61,682	54,527	70,280	52,268	61,287
Net worth (Dollars)					
All households	87,056	5,446	59,292	7,950	58,905
Lowest Quintile	21,558	NA[b]	1,600	1,229	5,466
Second	55,892	4,348	9,600	4,400	29,517
Third	67,392	13,026	34,386	9,826	48,200
Fourth	102,351	26,953	69,894	37,838	83,127
Highest Quintile	210,298	61,000	195,461	80,600	188,712

[a] Blacks may include Hispanics

[b] Not available