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Associations Between Socioeconomic, Spatial and Educational Factors and Midlife Periodontal Disease Risk: Evidence From 'High School and Beyond'

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ABSTRACT

Background: Periodontal disease (PD) is a prevalent, preventable and treatable oral infection associated with substantial morbidity globally. There is little information from population-representative cohort studies about the sociodemographic, educational and other early life factors that stratify PD risk.

Methods: We used data from the U.S. 'High School and Beyond' (HS&B:80) study, which has followed a nationally representative sample of 26,820 people from high school in 1980 through midlife in 2021. Data from the 1980s include information about education, early life circumstances, spatial location and demographic attributes. Data from 13,080 sample members who responded in 2021 include indicators of self-reported PD diagnosis.

Results: People with higher degrees and course grades have a lower risk of midlife PD. Rural adolescents and those who attended private schools are also at lower risk. We find little evidence of heterogeneity in correlates of midlife PD by gender or race/ethnicity.

Conclusions: The quantity and characteristics of people's schooling and their location of residence are associated with midlife PD.

1 | Introduction

Periodontal diseases (PD), including gingivitis and periodontitis, are characterized by an imbalanced or 'dysbiotic' oral microbial ecology which elicits chronic gingival inflammation, leading to progressive loss of tooth-supporting structures and tooth loss in susceptible hosts. There is mounting evidence that PDs are a cause of—or is at least associated with risk of—systemic inflammation (Behle et al. 2009; Demmer et al. 2013; Lockhart et al. 2012), chronic inflammatory diseases such as insulin resistance (Demmer et al. 2012, 2017), diabetes (Arora et al. 2014; Winning et al. 2017), cardiovascular disease (Naderi

Abbreviations: ADRD, Alzheimer's disease and related dementias; AME, average marginal effect; BMI, body mass index; HS&B:80, High School and Beyond; IE, interaction effect; IES, Institute for Education Sciences; PD, periodontal disease; SES, socioeconomic status.

and Merchant 2020; Sanz et al. 2020; Zardawi et al. 2021; Zhou et al. 2021), stroke (Beck et al. 2018; Kebschull, Demmer, and Papapanou 2010; Sen et al. 2018), pneumonia (Müller 2015) rheumatoid arthritis (Renvert et al. 2020; Rivas, Creazzo, and Vargas 2023), select cancers (Nwizu, Wactawski-Wende, and Genco 2020; Sobocki et al. 2022; Verma, Singh, and Verma 2023) and Alzheimer's disease and related dementias (ADRD) (Choi et al. 2019; Demmer et al. 2020; Lee et al. 2017a, 2017b; Stewart et al. 2015; Yamamoto et al. 2012).

PDs are highly *preventable* and are caused by—among other things—modifiable social and behavioural factors such as diet, smoking and oral health. They are also readily *treatable* through surgical and non-surgical oral healthcare procedures. There is good evidence that oral healthcare therapies designed to treat PD by reconfiguring the oral microbiome can reverse these processes and improve chronic disease outcomes (Müller 2015; Rivas, Creazzo, and Vargas 2023; Chen et al. 2023; Nguyen et al. 2021; Orlandi, Graziani, and D'Aiuto 2020; Sun et al. 2021). Given that PDs are largely preventable and treatable and linked to a range of subsequent chronic diseases, it may be possible to intervene on it—for example, through oral health care, encouraging desistance from tobacco use or improvements in access to nutritious food—in such a way that reduces the incidence of several serious chronic conditions later in life.

For all these reasons, it is important to understand the forces that might condition PD risk in adults. As reviewed below, however, there is surprisingly little evidence—at least from prospective, nationally representative cohort studies—about the degree to which early life social, economic, spatial, demographic and educational factors are associated with adults' risk of PD. To this end, we ask: How are family socioeconomic origins, educational contexts, opportunities and outcomes, spatial location and demographic group memberships associated with adults' risk of reporting PD at midlife?

1.1 | Disparities in Periodontal Disease Risk

Effective efforts to reduce PD risk—either to reduce suffering from PD or to reduce the risk of subsequent chronic conditions—should be informed by knowledge about social, economic, spatial and demographic disparities in the incidence of PD. Unfortunately, in the United States, what we know about these disparities is limited in important ways; most of these limitations stem from limited surveillance by public health systems and an overreliance on data from smaller, geographically limited cross-sectional and/or non-representative samples.

1.1.1 | Demographic Characteristics

Among U.S. adults, PD is more common among men, people racialized as Black, Mexican Americans and older people (Eke et al. 2018; Eke, Borgnakke, and Genco 2020). As described below, however, it is unclear how much these demographic group differences in prevalence rates are due to group differences in education, family socioeconomic conditions and/or spatial location.

1.1.2 | Education

As reviewed by Watson and Nilam (2017), people with more years of completed schooling are at reduced risk of PD (Boillot et al. 2011; Borrell, Beck, and Heiss 2006; Borrell et al. 2008; Gundala and Chava 2010; Niskanen et al. 2020; Renson et al. 2019). Prior research universally operationalizes education as 'highest degree earned' or 'years of schooling completed'—partly because these can be reliably measured retrospectively in surveys. However, this single measure fails to capture rich differences in schooling experiences that contribute not only to educational attainment but also to differences in human capital among those with the same level of educational attainment. Schools differ in their social and academic contexts and in the learning opportunities they provide. These, in turn, contribute to outcomes such as grades, achievement test scores and coursework completion, which reflect knowledge and skills (Carroll and Muller 2018) that may independently shape PD risk.

Also, nearly all prior research documenting educational gradients in PD risk has used data from cross-sectional surveys (Borrell et al. 2008; Gundala and Chava 2010; Niskanen et al. 2020; Renson et al. 2019). Because details of adults' adolescent educational contexts, opportunities and (non-degree attainment) outcomes are very difficult to measure retrospectively, they have been left out of previous research.

1.1.3 | Childhood Socioeconomic Circumstances

In the United States and elsewhere, adults with socioeconomic advantages—such as higher incomes and better jobs—are less likely to experience PD (Eke et al. 2018). Tadakamadla et al.'s (2020) recent review article showed that higher *childhood* socioeconomic status (SES) is associated with reduced *childhood* PD risk. There is—to our knowledge—no existing evidence about how people's *childhood* SES—typically measured in terms of parental education, parental occupation and family income—is related to their *later-life* risk of PD. However, to understand the independent roles of race/ethnicity, education, early life spatial location and other early life factors in stratifying PD risk, it is important to consider *childhood* SES. This is partly because these early life factors shape adult SES—perhaps mainly because they shape educational contexts, opportunities and outcomes—and partly because adult SES and PD status may have a complex bidirectional causal relationship.

1.1.4 | Spatial Location

There is suggestive international evidence that the composition of oral microbiomes—and thus, presumably, risk of PD—varies across urban and rural areas (Flies et al. 2020; Widyarman et al. 2021). Urban and rural dwellers face different environmental exposures, may have dissimilar diets and experience differential access to oral health care. There is little published evidence about rural–urban or regional variation in rates of PD in the United States; exceptions use data from the Behavioural Risk Factor Surveillance System (Eke, Borgnakke, and Genco 2020) and show higher rates in rural areas and in the American South and Southwest.

However, to our knowledge, there is no published evidence about how those rates vary across adults' locations of *birth* (as opposed to their location of residence as *adults*); if early life spatial location is formative of the composition of the microbiome, then this is an important omission. What is more, it is not clear from published evidence how much spatial variation there is net of other individual-level characteristics such as those described above.

1.2 | Summary

PDs are preventable and treatable conditions that may play a role in several subsequent chronic diseases. However, what we know about disparities in PD risk is quite limited. Few studies on this subject use data from large, nationally representative samples; nearly all consider single covariates in isolation (e.g., racial/ethnic group membership) instead of considering adjusted, conditional associations in a multivariable model; none considers anything about education besides attainment, thereby limiting the potential for intervention, none considers the role of childhood SES in shaping adult disease outcomes and none considers associations between childhood spatial location adults' outcomes. We improve on all these limitations in our own research.

2 | Materials and Methods

2.1 | Study Sample

We use data from 'High School and Beyond' (HS&B:80), which began in 1980 as a nationally representative probability sample of 30,030 high school sophomores and 28,240 high school seniors from 1020 randomly selected U.S. public and private high schools (Grodsky et al. 2022). From the initial sample of 58,270 students, a random subset of 14,830 sophomores and 12,000 seniors have been re-interviewed multiple times. Panellists were born between 1962 and 1965 (and were thus between 57 and 60 when last contacted in 2021). Note that all sample sizes in this article are rounded to the nearest 10 in accordance with restricted data use protocols.

Student, teacher and school administrator questionnaires fielded in 1980 gathered data on students' educational experiences, school curricular offerings, school structure and control, student-level outcomes (e.g., grades, course progression), family socioeconomic background (e.g., parental education and occupation, family composition, siblings, parenting practices and parents' educational and occupational expectations for their children) and spatial location. Both the sophomore and senior cohorts completed standardized multiple-choice assessments of reading, vocabulary and math.

All panel members were re-surveyed in 1982, 1984 and 1986; sophomores were re-surveyed in 1992 and 2014, and seniors were re-surveyed in 2015. HS&B:80 surveys have had remarkably high response rates—ranging from ~90% in the 1980s to ~65% in the 2013–2015 follow-ups. In 2021, we again contacted all surviving members of the HS&B:80 cohort. Fieldwork included a multimode survey that assessed a variety of health and cognition outcomes (among other topics), including PD status, smoking behaviours, diabetes status, body mass index (BMI) and midlife occupation. Of the ~24,330 surviving HS&B:80 sample members, ~13,770 completed surveys in 2021—a response rate of 58%. For more details about the design and contents of HS&B:80 and about data access, see Grodsky et al. (2022). Of the ~13,770 completing surveys in 2021, only ~13,080 provided sufficient information to be included in the analysis; most excluded respondents elected not to report their periodontal disease status.

2.2 | Measures

2.2.1 | Periodontal Disease

In the 2021 HS&B:80 survey, participants were asked: 'Have you EVER been told by a doctor or other health professional that you had periodontal or gum disease?' Those answering affirmatively were then asked the year in which they were first diagnosed with the disease. For our purposes, we classify sample members according to whether they have ever been diagnosed with PD.

Prior research has demonstrated that self-reported measures of PD have high specificity but lower sensitivity (Genco et al. 2007; Lertpimonchai et al. 2023).

2.2.2 | Early Life Covariates

2.2.2.1 | Education. Educational attainment has been ascertained from survey and transcript records since 1980, but we use a measure collected in 2021 that captures the highest level of schooling completed. Measures from high school of highest mathematics course taken, grade point average, curricular track, type of school attended, school social context and cognitive skills are derived from student and school administrator surveys in the 1980s. School social context includes—in reference to HS&B:80 participants' high schools—indicators of the percentage of recent graduates going to college, a measure of each schools' contribution to positive changes in mathematics test scores across 10th and 12th grades, the percentage of students who are White, the average socioeconomic background of students in the schools and the percentage of students who are in an academic curricular track. Cognitive skills in high school are measured using standardized achievement test scores in reading, vocabulary and mathematics.

2.2.2.2 | Demographics. The 1980 student and school administrator surveys collected information about each student's gender, racial/ethnic group, urban/rural residence, region of the country and family socioeconomic background. Indicators of family socioeconomic background include the highest level of education attained by either parent, the log of childhood family income, father's occupational prestige, number of siblings and a measure of whether sample members' families owned or rented their homes in 1980. We also include indicators of whether sample members were sophomore or seniors in 1980 and of whether they were disabled in 1980.

TABLE 1 | Descriptive statistics, by beriodontal disease status at midlife.

	Full sample			No periodontal disease			Periodontal disease			% Ever diagnosed
	%/Avg	(SD)	*n*[a]	%/Avg	(SD)	*n*[a]	%/Avg	(SD)	*n*[a]	
Educational attainment										
High school or less	17.9%		2340	17.6%		1950	19.5%		390	16.3%
Some college	38.0%		4980	37.3%		4140	42.0%		840	16.9%
Bachelor's degree	25.8%		3380	26.3%		2920	23.0%		460	12.6%
Graduate/ professional	18.3%		2390	18.8%		2080	15.5%		310	12.8%
Highest mathematics course										
Less than algebra I	19.6%		2500	19.3%		2090	21.6%		420	16.3%
Algebra I or geometry	25.3%		3220	24.8%		2680	27.8%		540	16.1%
Algebra II	24.0%		3050	24.0%		2590	23.7%		460	15.3%
Trigonometry or calculus	31.1%		3960	31.9%		3450	26.8%		520	13.1%
Grades in senior year	2.824	(0.73)	11,790	2.84	(0.73)	10,050	2.76	(0.71)	1740	—
Curricular track										
Vocational	21.1%		2650	20.8%		2220	22.6%		430	17.0%
General	33.7%		4220	33.3%		3550	35.3%		670	15.1%
College preparatory	45.2%		5670	45.8%		4880	42.1%		800	14.1%
School type										
Public	81.7%		10,680	81.4%		9030	82.9%		1650	15.5%
Catholic	15.2%		1990	15.4%		1710	14.6%		290	13.6%
Private	3.1%		410	3.2%		360	2.5%		50	12.2%
School social context										
% of grads going to college	47.71	(20.94)	12,580	47.66	(21.00)	10,660	47.98	(20.61)	1920	—
Math value added	0.02	(0.75)	12,680	0.03	(0.74)	10,760	−0.02	(0.78)	1920	—
% of students who are White	78.71	(26.50)	12,380	78.86	(26.56)	10,480	77.89	(26.17)	1890	—
School average soc. status	−0.08	(0.41)	13,080	−0.08	(0.41)	11,090	−0.08	(0.40)	1990	—
% in academic track, grade 10	44.96	(28.49)	11,930	44.78	(28.58)	10,110	45.95	(27.99)	1820	—
Cognitive skills										
Reading achievement	−0.07	(0.95)	11,700	−0.07	(0.96)	9930	−0.09	(0.92)	1770	—

(Continues)

TABLE 1 | (Continued)

	Full sample			No periodontal disease			Periodontal disease			% Ever diagnosed
	%/Avg	(SD)	*n*[a]	%/Avg	(SD)	*n*[a]	%/Avg	(SD)	*n*[a]	
Vocabulary achievement	−0.07	(0.96)	11,720	−0.07	(0.96)	9960	−0.11	(0.94)	1760	—
Math achievement	−0.07	(0.95)	11,430	−0.07	(0.96)	9710	−0.04	(0.94)	1720	—
Gender										
Male	44.9%		5870	44.9%		4980	44.7%		890	14.8%
Female	55.1%		7210	55.1%		6110	55.3%		1100	15.6%
Race/ethnicity										
Non-Hispanic Black	16.7%		2190	16.5%		1830	18.1%		360	15.6%
Non-Hispanic White	57.5%		7520	58.3%		6460	53.3%		1060	15.0%
Hispanic	20.6%		2700	20.2%		2240	23.1%		460	15.5%
Other race/ethnicity	5.1%		670	5.0%		560	5.5%		110	18.3%
Region of residence in adolescence										
Northeast	21.6%		2820	21.5%		2380	22.1%		440	15.9%
South	31.4%		4110	31.6%		3500	31.2%		620	15.7%
Midwest	27.1%		3550	27.5%		3050	25.1%		500	13.5%
West	19.9%		2600	19.5%		2160	22.1%		440	16.6%
Urbanicity of residence in adolescence										
Urban	24.4%		3190	24.0%		2660	26.6%		530	17.2%
Suburban	49.5%		6480	49.4%		5480	50.3%		1000	16.0%
Rural	26.1%		3410	26.6%		2950	23.1%		460	13.0%
Parental education (highest of mother, father)										
Less than high school	13.8%		1680	13.4%		1380	16.2%		300	16.8%
High school	28.9%		3520	29.0%		2990	28.1%		520	15.7%
Some college	29.0%		3530	28.7%		2960	30.3%		560	14.9%
Bachelor's degree	13.3%		1620	13.6%		1400	11.9%		220	13.9%
Graduate/professional	15.1%		1840	15.4%		1590	13.5%		250	14.8%
Childhood family income (ln)	3.10	(0.67)	11,850	3.11	(0.67)	10,080	3.07	(0.68)	1770	—
Father's occupational prestige	47.45	(12.71)	9940	47.37	(12.72)	8440	47.85	(12.66)	1500	—
Number of siblings	2.94	(1.69)	5220	2.98	(1.69)	4390	2.73	(1.69)	840	—

(Continues)

TABLE 1 | (Continued)

	Full sample			No periodontal disease			Periodontal disease			% Ever diagnosed
	%/Avg	(SD)	n^a	%/Avg	(SD)	n^a	%/Avg	(SD)	n^a	
Family-owned or rented home in 1980										
Rented	22.5%		2600	22.0%		2160	25.6%		450	16.8%
Owned	77.5%		8960	78.0%		7640	74.4%		1310	14.8%
High school class in 1980										
Sophomore	57.3%		7490	57.6%		6390	55.3%		1100	15.0%
Senior	42.7%		5590	42.4%		4700	44.7%		890	15.7%
Disability status in 12th grade										
Not disabled	87.2%		10,860	87.5%		9240	85.7%		1620	14.8%
Disabled	12.8%		1590	12.5%		1320	14.3%		270	18.2%

Note: Sample restricted to 'High School and Beyond' sample members who participated in the 2021–2022 round of data collection. See text for more details and for description of measures. All sample sizes have been rounded to the nearest 10 as per our restricted data licensing protocols.
[a]Sample sizes and percentages are unweighted and prior to imputation.

2.3 | Statistical Analysis

Because our outcome measure of self-reported PD is dichotomous, we estimate a series of log-linear models to obtain risk ratios using the 'modified' Poisson approach (Talbot et al. 2023; Zou 2004). Wald confidence intervals were obtained using the large-sample Normal approximation for maximum likelihood estimates, based on the robust standard errors and the delta method.

Because of HS&B:80's complex sampling design, we weight all our analyses so that our estimates are generalizable to the population of surviving high school sophomores and seniors enrolled in U.S. high schools in 1980. To handle missing data, we multiply impute all variables using chained equations (Royston 2005; Royston and White 2011); following widely used guidance (Carpenter et al. 2023; White, Royston, and Wood 2011) and recognizing that the average proportion of missing data in our sample is about 0.07, we impute 10 datasets. Multiple imputation allows us to retain sample size and estimate unbiased parameters so long as values of missing items are missing at random, conditional on covariates in the imputation model. Standard errors for each imputed dataset were computed to account for clustering at the school level via the Huber–White sandwich estimator (Rogers 1994; Abadie et al. 2023; Huber 1967) and then combined using Rubin's rules for multiple imputation (Van Buuren 2018; Rubin 2004).

2.4 | Ethics

Data collection for the 2021 round of HS&B:80 was reviewed and approved by the Institution Review Boards of [The University of Minnesota and NORC at the University of Chicago]. HS&B:80 survey data are available via the U.S. Department of Education's restricted data access protocols. Note that all reported sample sizes are rounded to the nearest 10 as per the restricted use data protocols mandated by the U.S. Department of Education's Institute for Education Sciences (IES); IES has reviewed and approved this manuscript.

3 | Results

3.1 | Participant Characteristics

Table 1 reports descriptive statistics for each variable in our analysis separately for people diagnosed and not diagnosed with PD. About 15% of the HS&B:80 cohort reported that they had been diagnosed with PD by 2021. This self-reported rate may be lower than other published prevalence rates because the entire cohort completed at least 10th grade and because the sample excludes (by design) people who immigrated to the United States after 1980.

3.2 | Multivariable Analysis

Table 2 reports the results of a series of four log-linear models. All coefficients are expressed as risk ratios. Model 1 controls for the series of demographic, family socioeconomic and spatial measures described above and in Table 1. Key findings from Model 1 are that (conditional on these other attributes) students from rural areas are less likely to report periodontal disease at midlife, while disabled students are more likely to do so.

Model 2 then adjusts for the set of school context measures described above. This model allows us to describe associations between school contexts and the risk of midlife PD conditional on demographic, family socioeconomic and spatial factors. Of note, students who attended private (as opposed to public or Catholic) high schools are substantially less likely to report periodontal disease at midlife (net of observed demographic, family socioeconomic and spatial factors). In Model 2, the coefficient for rural residence remains nearly unchanged; rural students are at about 25% (95% CI: 7%–38%) lower risk of midlife PD as compared to urban students.

Model 3 then adds measures of students' (non-degree attainment) educational outcomes. Two findings are notable. First, students with higher senior year grades are—holding all else constant—at a lower risk of PD; each 1 point increase in grade point average is

TABLE 2 | Log-linear models of periodontal disease status and demographic, educational and spatial factors.

	Model 1		Model 2		Model 3		Model 4	
	RR	**[95% CI]**	**RR**	**[95% CI]**	**RR**	**[95% CI]**	**RR**	**[95% CI]**
Gender [vs. male]								
Female	1.03	[0.90–1.19]	1.04	[0.90–1.19]	1.07	[0.92–1.25]	1.08	[0.93–1.26]
Race/ethnicity [vs. non-Hispanic White]								
Non-Hispanic Black	0.99	[0.79–1.25]	1.02	[0.79–1.31]	1.06	[0.82–1.38]	1.06	[0.82–1.38]
Hispanic	0.95	[0.77–1.17]	0.96	[0.76–1.21]	0.98	[0.78–1.24]	0.98	[0.78–1.24]
Other race/ethnicity	1.11	[0.71–1.73]	1.10	[0.71–1.72]	1.14	[0.73–1.77]	1.15	[0.73–1.79]
Region of residence in adolescence [vs. northeast]								
South	0.99	[0.80–1.21]	0.99	[0.80–1.22]	0.98	[0.79–1.22]	1.00	[0.81–1.25]
Midwest	0.88	[0.73–1.07]	0.87	[0.72–1.07]	0.86	[0.70–1.04]	0.87	[0.71–1.06]
West	1.04	[0.85–1.28]	1.07	[0.86–1.32]	1.04	[0.84–1.30]	1.04	[0.84–1.30]
Urbanicity of residence in adolescence [vs. urban]								
Suburban	0.96	[0.81 to 1.14]	0.94	[0.78–1.13]	0.96	[0.79–1.15]	0.96	[0.80–1.15]
Rural	0.78	**[0.64–0.95]**	0.76	**[0.62–0.93]**	0.78	**[0.63–0.96]**	0.78	**[0.63–0.96]**
Parental education (highest of mother, father) [vs. some college]								
Less than high school	1.21	[0.87–1.68]	1.21	[0.87–1.68]	1.23	[0.88–1.71]	1.21	[0.87–1.68]
High school	1.13	[0.90–1.41]	1.13	[0.90–1.41]	1.13	[0.91–1.41]	1.12	[0.89–1.40]
Bachelor's degree	0.93	[0.69–1.26]	0.94	[0.69–1.27]	0.96	[0.71–1.31]	0.98	[0.72–1.34]
Graduate/professional	0.94	[0.71–1.25]	0.96	[0.71–1.28]	0.98	[0.73–1.31]	1.00	[0.74–1.35]
Childhood family income (ln)	0.91	[0.78–1.06]	0.92	[0.78–1.07]	0.92	[0.79–1.08]	0.92	[0.79–1.08]
Father's occupational prestige	1.01	**[1.00–1.02]**	1.01	**[1.00–1.02]**	1.01	**[1.00–1.02]**	1.01	**[1.00–1.02]**
Number of siblings	0.92	[0.85–1.00]	0.92	[0.85–1.01]	0.92	[0.84–1.02]	0.92	[0.84–1.01]
Family-owned or rented home in 1980 [vs. rented]								
Owned	0.94	[0.76–1.18]	0.94	[0.76–1.18]	0.95	[0.76–1.18]	0.95	[0.77–1.19]
High school class in 1980 [vs. sophomore]								
Senior	1.02	[0.88–1.18]	1.02	[0.88–1.18]	1.02	[0.88–1.19]	1.03	[0.89–1.19]
Disability status in 12th grade [vs. not disabled]								
Disabled	1.25	**[1.00–1.57]**	1.25	[0.99–1.56]	1.26	**[1.00–1.58]**	1.26	**[1.00–1.59]**
School type [vs. public]								
Catholic			0.87	[0.59–1.29]	0.92	[0.62–1.35]	0.92	[0.62–1.37]
Private			0.66	**[0.44–0.99]**	0.67	[0.44–1.02]	0.68	[0.45–1.04]
School social context								
% of grads going to college			1.00	**[1.00–1.01]**	1.00	**[1.00–1.01]**	1.00	**[1.00–1.01]**
Math value added			0.92	[0.82–1.04]	0.92	[0.82–1.04]	0.92	[0.82–1.04]
% of students who are white			1.00	**[1.00–1.01]**	1.00	**[1.00–1.00]**	1.00	**[1.00–1.00]**

(Continues)

TABLE 2 | (Continued)

	Model 1		Model 2		Model 3		Model 4	
	RR	**[95% CI]**	**RR**	**[95% CI]**	**RR**	**[95% CI]**	**RR**	**[95% CI]**
School average soc. status			0.97	[0.73–1.31]	0.95	[0.70–1.28]	0.96	[0.71–1.30]
% in academic track, grade 10			1.00	**[1.00–1.01]**	1.00	**[1.00–1.01]**	1.00	**[1.00–1.01]**
Highest mathematics course [vs. less than algebra I]								
Algebra I or geometry					1.00	[0.79–1.26]	1.01	[0.80–1.27]
Algebra II					0.93	[0.70–1.25]	0.94	[0.70–1.27]
Trigonometry or calculus					0.79	[0.57–1.10]	0.83	[0.59–1.16]
Grades in senior year					0.85	**[0.75–0.97]**	0.88	[0.77–1.00]
Curricular track [vs. college preparatory]								
Vocational					1.16	[0.90–1.50]	1.11	[0.85–1.43]
General					1.01	[0.80–1.28]	0.97	[0.76–1.23]
Cognitive skills								
Reading achievement					1.04	[0.90–1.20]	1.05	[0.90–1.21]
Vocabulary achievement					1.12	[0.97–1.31]	1.13	[0.97–1.32]
Math achievement					1.04	[0.89–1.22]	1.06	[0.91–1.23]
Educational attainment [vs. some college]								
High school or less							1.00	[0.83–1.21]
Bachelor's degree							0.76	**[0.62–0.93]**
Graduate/professional							0.73	**[0.57–0.94]**

Note: Sample restricted to the 13,080 'High School and Beyond' sample members who participated in the 2021–2022 round of data collection. See text for more details and for description of measures. Analyses employ longitudinal sampling weights, account for the clustered sampling design, and impute missing values. All sample sizes have been rounded to the nearest 10 as per our restricted data licensing protocols. Bolded confidence intervals do not contain zero within them.

associated with a 15% (95% CI: 3%–25%) lower risk. Second, after adjusting for these (non-attainment) educational outcomes, the conditional associations between rural residence, private school attendance and PD risk are largely unchanged.

Model 4 begins with Model 3 but adds educational degree attainment. As anticipated, students with higher educational credentials are at a lower risk of self-reported PD at midlife. Net of other attributes in the model, for example, bachelor's degree recipients are at a 27% (95% CI: 6%–43%) lower risk of PD at age ~60. Of note, however, is that in this model the conditional associations between rural residence, private school attendance, course grades and PD risk are largely unchanged as compared to Model 3. Where students live, what kind of school they attended, the grades they earned in those schools and the degrees they ultimately attained are all independently associated with midlife PD risk.

In Table 3 we re-estimate Model 4—the model with the full set of predictors—in such a way as to consider heterogeneity in all these conditional associations by gender (on the left side of Table 3) and by race/ethnicity (the right side of Table 3). For each model, we report relative risks as they pertain to the reference category (women in one case, non-Hispanic Whites in the other). Coefficient estimates for women and for non-Hispanic Whites largely mirror those in Model 4 of Table 2—except that the confidence intervals are somewhat larger due to reduced sample sizes.

However, in only a few instances do we find evidence of gender or racial/ethnic heterogeneity in these conditional associations. That is, we find little evidence that demographic, socioeconomic, spatial or educational predictors of midlife PD risk vary appreciably by gender or race/ethnicity.

3.3 | Supplemental Analyses: Tobacco Use, Diabetes, Body Mass and Occupation

Given our data and research design, we are not able to make strong causal claims about the effects of early life factors on PD risk; thus, we are also not able to make firm conclusions about factors that mediate effects of those early life variables. Nonetheless, we offer Table 4 as exploratory evidence.

Tobacco use (Apatzidou 2022; Beklen, Sali, and Yavuz 2022; Silva 2021; Zhang et al. 2021), diabetes (Graves, Ding, and Yang 2020; Llambés, Arias-Herrera, and Caffesse 2015; Mealey and Oates 2006; Polak et al. 2020), body mass (Arboleda et al. 2019; Iwashita et al. 2021; Khan et al. 2020) and occupation type (Irie

TABLE 3 | Log-linear models of periodontal disease status, and demographic, educational and spatial factors, comparisons across gender and race/ethnicity groups.

	Model 4 from Table 2, differences by gender				Model 4 from Table 2, differences by race/ethnicity					
	Women		RR_{Men}/RR_{Women}		NH Whites		RR_{Black}/RR_{White}		RR_{Latinx}/RR_{White}	
	RR	[95% CI]	Ratio	[95% CI]	RR	[95% CI]	RR	[95% CI]	RR	[95% CI]
Gender [vs. male]										
Female		—		—	0.18	**[−0.00–0.36]**	0.65	**[0.46–0.94]**	0.76	[0.53–1.10]
Race/ethnicity [vs. non-Hispanic White]										
Non-Hispanic Black	0.93	[0.66–1.31]	0.78	[0.48–1.27]		—		—		—
Hispanic	0.87	[0.65–1.17]	0.79	[0.51–1.23]		—		—		—
Other race/ethnicity	0.89	[0.44–1.78]	0.59	[0.25–1.39]		—		—		—
Region of residence in adolescence [vs. northeast]										
South	1.07	[0.80–1.44]	1.12	[0.74–1.71]	1.02	[0.79–1.34]	0.82	[0.49–1.37]	0.77	[0.44–1.33]
Midwest	0.96	[0.73–1.24]	1.18	[0.80–1.74]	0.91	[0.73–1.14]	0.77	[0.45–1.34]	0.86	[0.48–1.53]
West	1.38	**[1.04–1.82]**	1.84	**[1.17–2.89]**	1.12	[0.86–1.45]	1.12	[0.61–2.05]	0.61	[0.34–1.08]
Urbanicity of residence in adolescence [vs. urban]										
Suburban	1.01	[0.79–1.29]	1.12	[0.75–1.69]	1.05	[0.84–1.30]	1.25	[0.81–1.94]	0.78	[0.47–1.30]
Rural	0.81	[0.62–1.07]	1.10	[0.71–1.71]	0.86	[0.68–1.10]	1.01	[0.54–1.88]	0.78	[0.45–1.34]
Less than high school	0.99	[0.67–1.47]	0.68	[0.38–1.21]	1.32	[0.88–1.98]	0.70	[0.36–1.39]	0.80	[0.44–1.47]
High school	1.17	[0.90–1.52]	1.13	[0.76–1.68]	1.17	[0.91–1.49]	0.91	[0.49–1.68]	0.76	[0.47–1.24]
Bachelor's degree	1.08	[0.71–1.64]	1.25	[0.70–2.23]	1.01	[0.74–1.37]	1.21	[0.61–2.41]	0.69	[0.32–1.47]
Graduate/professional	1.10	[0.76–1.59]	1.23	[0.68–2.24]	1.01	[0.74–1.38]	1.05	[0.47–2.37]	1.06	[0.44–2.53]
Childhood family income (ln)	0.85	[0.68–1.06]	0.83	[0.59–1.16]	0.88	[0.70–1.10]	1.33	[0.96–1.84]	0.99	[0.68–1.43]
Father's occupational prestige	1.00	**[1.00–1.01]**	1.00	[0.98–1.01]	1.01	**[1.00 to 1.02]**	1.00	[0.98–1.02]	1.01	[0.99–1.03]
Number of siblings	0.93	[0.83–1.03]	1.01	[0.91–1.11]	0.93	[0.85–1.03]	0.98	[0.87–1.11]	0.98	[0.85–1.13]
Family-owned or rented home in 1980 [vs. rented]										
Owned	0.92	[0.69–1.22]	0.93	[0.61–1.40]	0.96	[0.72–1.26]	0.91	[0.57–1.45]	1.22	[0.78–1.90]
High school class in 1980 [vs. sophomore]										
Senior	1.09	[0.90–1.31]	1.14	[0.86–1.51]	1.01	[0.85–1.20]	0.88	[0.64–1.21]	1.44	**[1.02–2.05]**
Disability status in 12th grade [vs. not disabled]										
Disabled	1.14	[0.83–1.57]	0.82	[0.54–1.25]	1.33	**[1.03–1.72]**	0.63	[0.37–1.09]	0.97	[0.58–1.61]
School type [vs. public]										
Catholic	1.02	[0.60–1.71]	1.30	[0.64–2.62]	0.85	[0.51–1.41]	1.50	[0.69–3.27]	1.59	[0.73–3.45]

(Continues)

TABLE 3 | (Continued)

	Model 4 from Table 2, differences by gender				Model 4 from Table 2, differences by race/ethnicity					
	Women		RR_{Men}/RR_{Women}		NH Whites		RR_{Black}/RR_{White}		RR_{Latinx}/RR_{White}	
	RR	[95% CI]	Ratio	[95% CI]	RR	[95% CI]	RR	[95% CI]	RR	[95% CI]
Private	0.73	[0.40–1.33]	1.18	[0.44–3.14]	0.72	[0.46–1.14]	1.37	[0.33–5.69]	1.23	[0.41–3.69]
School social context										
% of grads going to college	1.00	[0.99–1.01]	1.00	[0.99–1.01]	1.00	[0.99–1.01]	1.00	[0.99–1.02]	0.99	[0.98–1.01]
Math value added	0.94	[0.81–1.09]	1.02	[0.81–1.29]	0.98	[0.85–1.13]	0.80	[0.60–1.05]	0.94	[0.71–1.26]
% of students who are White	1.00	**[1.00–1.01]**	1.01	**[1.00–1.01]**	1.00	[0.99–1.00]	1.00	[0.99–1.01]	1.01	**[1.00–1.02]**
School average soc. status	0.84	[0.58–1.22]	0.76	[0.42–1.37]	0.87	[0.60–1.26]	1.22	[0.56–2.70]	1.30	[0.66–2.58]
% in academic track, grade 10	1.00	**[1.00–1.01]**	1.01	**[1.00–1.01]**	1.00	**[1.00–1.01]**	0.99	[0.99–1.00]	1.00	[0.99–1.01]
Highest mathematics course [vs. less than algebra I]										
Algebra I or geometry	0.96	[0.71–1.30]	0.90	[0.58–1.39]	0.91	[0.69–1.20]	1.22	[0.73–2.04]	1.14	[0.67–1.94]
Algebra II	0.97	[0.67–1.42]	1.06	[0.62–1.82]	0.90	[0.64–1.26]	0.95	[0.51–1.79]	0.94	[0.50–1.74]
Trigonometry or calculus	0.84	[0.53–1.34]	1.00	[0.48–2.10]	0.74	[0.48–1.15]	1.42	[0.63–3.22]	0.97	[0.39–2.42]
Grades in senior year	0.83	**[0.71–0.97]**	0.90	[0.71–1.12]	0.85	**[0.72–0.99]**	1.11	[0.81–1.52]	1.18	[0.81–1.72]
Curricular track [vs. college preparatory]										
Vocational	1.16	[0.81–1.67]	1.09	[0.65–1.84]	1.03	[0.73–1.45]	1.43	[0.86–2.37]	1.10	[0.59–2.03]
General	0.88	[0.63–1.23]	0.83	[0.50–1.37]	0.92	[0.68–1.26]	0.95	[0.56–1.62]	1.54	[0.92–2.57]
Cognitive skills										
Reading achievement	0.96	[0.80–1.15]	0.84	[0.65–1.08]	1.04	[0.87–1.24]	1.22	[0.88–1.68]	1.09	[0.78–1.51]
Vocabulary achievement	1.06	[0.88–1.28]	0.87	[0.66–1.15]	1.17	[0.99–1.38]	0.79	[0.57–1.08]	1.04	[0.74–1.46]
Math achievement	1.13	[0.92–1.38]	1.13	[0.85–1.51]	1.10	[0.93–1.31]	0.90	[0.63–1.28]	0.83	[0.58–1.19]
Educational attainment [vs. some college]										
High school or less	1.00	[0.78–1.29]	1.04	[0.73–1.48]	1.02	[0.81–1.29]	0.94	[0.58–1.53]	0.88	[0.54–1.42]
Bachelor's degree	0.87	[0.67–1.13]	1.35	[0.92–1.98]	0.75	**[0.59–0.95]**	1.11	[0.70–1.75]	1.02	[0.64–1.64]
Graduate/ professional	0.88	[0.63–1.21]	1.51	[0.94–2.43]	0.70	**[0.53–0.91]**	1.14	[0.66–1.99]	0.85	[0.47–1.51]

Note: Sample restricted to the 13,080 'High School and Beyond' sample members who participated in the 2021–2022 round of data collection. See text for more details and for description of measures. Analyses employ longitudinal sampling weights, account for the clustered sampling design and impute missing values. All sample sizes have been rounded to the nearest 10 as per our restricted data licensing protocols. Bolded confidence intervals do not contain zero within them.

TABLE 4 | Exploratory analysis of the roles of smoking, diabetes, body mass and occupation.

	Model 4 (from Table 2)		Model 5		Change in RR (Model 4–Model 5)
	RR	[95% CI]	RR	(95% CI)	
Gender [vs. male]					
Female	1.08	[0.93–1.26]	1.08	[0.92–1.25]	0.004
Race/ethnicity [vs. non-Hispanic White]					
Non-Hispanic Black	1.06	[0.82–1.38]	1.07	[0.83–1.38]	−0.002
Hispanic	0.98	[0.78–1.24]	1.01	[0.81–1.27]	−0.029
Other race/ethnicity	1.15	[0.73–1.79]	1.16	[0.73–1.86]	−0.018
Region of residence in adolescence [vs. northeast]					
South	1.00	[0.81–1.25]	1.02	[0.82–1.26]	−0.012
Midwest	0.87	[0.71–1.06]	0.87	[0.71–1.06]	−0.001
West	1.04	[0.84– 1.30]	1.10	[0.88–1.36]	−0.053
Urbanicity of residence in adolescence [vs. urban]					
Suburban	0.96	[0.80–1.15]	0.95	[0.79–1.15]	0.004
Rural	0.78	**[0.63–0.96]**	0.78	**[0.63–0.96]**	0.004
Parental education (highest of mother, father) [vs. some college]					
Less than high school	1.21	[0.87–1.68]	1.18	[0.86–1.62]	0.026
High school	1.12	[0.89–1.40]	1.13	[0.90–1.40]	−0.006
Bachelor's degree	0.98	[0.72–1.34]	1.00	[0.74–1.36]	−0.019
Graduate/professional	1.00	[0.74–1.35]	1.00	[0.74–1.36]	−0.001
Childhood family income (ln)	0.92	[0.79–1.08]	0.93	[0.80–1.09]	−0.013
Father's occupational prestige	1.01	**[1.00–1.02]**	1.01	**[1.00–1.02]**	0.001
Number of siblings	0.92	[0.84–1.01]	0.93	[0.85–1.01]	−0.004
Family-owned or rented home in 1980 [vs. rented]					
Owned	0.95	[0.77–1.19]	0.95	[0.76–1.19]	0.002
High school class in 1980 [vs. sophomore]					
Senior	1.03	[0.89–1.19]	1.06	[0.92–1.23]	−0.036
Disability status in 12th grade [vs. not disabled]					
Disabled	1.26	**[1.00–1.59]**	1.19	[0.94–1.51]	0.069
School type [vs. public]					
Catholic	0.92	[0.62–1.37]	0.89	[0.61–1.29]	0.034
Private	0.68	[0.45–1.04]	0.67	[0.43–1.02]	0.017
School social context					
% of grads going to college	1.00	**[1.00–1.01]**	1.00	**[1.00–1.01]**	−0.001
Math value added	0.92	[0.82–1.04]	0.92	[0.82–1.04]	0.003

(Continues)

TABLE 4 | (Continued)

	Model 4 (from Table 2)		Model 5		Change in RR (Model 4–Model 5)
	RR	[95% CI]	RR	(95% CI)	
% of students who are White	1.00	**[1.00–1.00]**	1.00	**[1.00–1.00]**	0.000
School average soc. status	0.96	[0.71–1.30]	0.97	[0.71–1.31]	−0.003
% in academic track, grade 10	1.00	**[1.00–1.01]**	1.00	**[1.00–1.01]**	0.000
Highest mathematics course [vs. less than algebra I]					
Algebra I or geometry	1.01	[0.80–1.27]	1.04	[0.83–1.31]	−0.036
Algebra II	0.94	[0.70–1.27]	0.98	[0.72–1.31]	−0.032
Trigonometry or calculus	0.83	[0.59–1.16]	0.87	[0.63–1.20]	−0.043
Grades in senior year	0.88	[0.77–1.00]	0.94	[0.83–1.07]	−0.064
Curricular track [vs. college preparatory]					
Vocational	1.11	[0.85–1.43]	1.08	[0.84–1.40]	0.024
General	0.97	[0.76–1.23]	0.95	[0.74–1.20]	0.022
Cognitive skills					
Reading achievement	1.05	[0.90–1.21]	1.03	[0.90–1.19]	0.011
Vocabulary achievement	1.13	[0.97–1.32]	1.13	[0.97–1.31]	0.009
Math achievement	1.06	[0.91–1.23]	1.08	[0.93–1.25]	−0.017
Educational attainment [vs. some college]					
High school or less	1.00	[0.83 to 1.21]	0.97	[0.80 to 1.18]	0.030
Bachelor's degree	0.76	**[0.62–0.93]**	0.82	[0.67–1.00]	−0.059
Graduate/professional	0.73	**[0.57–0.94]**	0.79	[0.60–1.03]	−0.054
Midlife occupational prestige		—	1.00	[0.99 to 1.01]	—
Smoking history at midlife [vs. never smoked]					
Past (not current) smoker		—	1.50	**[1.28–1.76]**	—
Current smoker		—	1.99	**[1.67–2.38]**	—
Body mass index at midlife [vs. normal weight]					
Underweight		—	0.99	[0.42–2.31]	—
Overweight		—	1.13	[0.94–1.36]	—
Obese I or II		—	1.22	**[1.02–1.47]**	—
Diabetes history at midlife [vs. no diabetes]					
History of diabetes		—	1.44	**[1.19–1.73]**	—

Note: Sample restricted to the 13,080 'High School and Beyond' sample members who participated in the 2021–2022 round of data collection. See text for more details, and for description of measures. Analyses emply longitudinal sampling weights, account for the clustered sampling design, and impute missing values. All sample sizes have been rounded to the nearest 10 as per our restricted data licensing protocols. Bolded confidence intervals do not contain zero within them.

et al. 2017; Thomson, Sheiham, and Spencer 2012) are all established correlates of PD risk, and each is associated with early life family SES, education, spatial location and demographic group membership. The 2021 HS&B:80 surveys gathered information about smoking histories, self-reported height and weight (from which we derive BMI), information about whether and when participants were diagnosed with diabetes and current or most recent occupation. The latter was coded to the standards of the 2010 Standard Occupational Classification and expressed in the metric of occupational prestige (Hout, Smith, and Marsden 2015).

In Table 4, the first column simply reproduces Model 4 from Table 2—the model that includes all measured covariates. Model 5 in Table 4 then adds measures of tobacco use, diabetes, body mass and occupation. The final column of Table 4 reports changes in the relative risks between Model 4 and 5. Two findings are notable. First, and as expected, tobacco use, diabetes and body mass are each associated with PD risk. Second, the addition of these established correlates of PD does little to change the degree to which education and rural residence are associated with PD risk.

4 | Discussion

Periodontal diseases are common, but compared to other chronic diseases, we know relatively little about the demographic and early life socioeconomic, spatial and educational factors that shape the risk of contracting them. PDs are preventable, treatable and closely linked to risk of several extra-oral chronic diseases—but because we know so little about the underlying drivers of disparities in their prevalence, we are limited in our ability to design and target effective prevention interventions. What we do know about disparities in PD risk generally comes from smaller unrepresentative samples; considers single sociodemographic, spatial or educational variables in isolation without full consideration for their interrelationships; focuses exclusively on educational attainment instead of on the full range of educational contexts, opportunities and outcomes that might shape risk; and does not consider childhood socioeconomic background or childhood spatial location in modelling adults' disease risk. Our goal was to overcome these limitations using new cohort data to better understand how early life factors shape adults' PD risk.

We find that adolescents' rural backgrounds and their education—not just their degree attainments, but also other dimensions of their achievements and of the schools they attended—are associated with their risk of self-reporting PD at midlife. All else equal, rural students are at 22% (95% CI: 4%–37%) lower risk than urban students, and bachelor's degree recipients are at a 27% (95% CI: 6%–43%) lower risk.

4.1 | Strengths and Limitations

Our analyses are innovative in several respects outlined above. However, our analyses are also limited in a few key respects.

First, PD is largely a function of the oral microbiome—such that in a perfect data world, we would study the composition of the microbiome itself (and not a clinical proxy for it). Unfortunately, genomic data from HS&B:80 will not be available for the next few years.

Second, we rely on sample members' own reports of their diagnoses of PD. A better option—although far more expensive and invasive—would be to perform clinical examinations of those sample members to assess the presence of oral diseases. For the foreseeable future, this is not possible within HS&B:80. Differential information bias is possible with self-report data and could have biased our measures of association. However, since individuals with fewer socioeconomic resources (and typically less education and more periodontitis) are more likely to underreport a history of periodontal disease, we believe this would have likely biased our results towards and underestimate of the true association (Wiernik et al. 2024).

Third, we are unable to distinguish between forms of PD such as periodontitis and gingivitis. This is an unavoidable limitation given the way that the key survey questions were asked in the 2021 HS&B:80 surveys.

Fourth, our analyses of gender and racial/ethnic heterogeneity in our results (in Table 3) may be underpowered. As such, our basic finding—that there appears to be little heterogeneity in findings across population subgroups—should be viewed as exploratory and preliminary.

Fifth, our study shares all the common limitations of observational research. We may *think* in causal terms, perhaps hypothesizing that early life factors affect PD risk via causal pathways such as smoking, diabetes, BMI and occupation. But for now, we must settle for concluding that our findings are merely *consistent* with such a story.

5 | Conclusions

Adults' risk of PD is associated with where they grew up, what kinds of schools they attended, how they performed in those schools and the degrees they attained. These early life factors may impact known and more proximal determinants of midlife PD risk (such as smoking behaviours and diabetes). We agree that targeting those more proximate and well-studied determinants is important. However, we also believe that by providing evidence supporting (or refuting) the role of upstream social determinants of health—such as education, childhood socioeconomic origins and spatial location—as contributors to adult PD is important for informing future policies that can influence social determinants of health and reduce disparities.

Author Contributions

John Robert Warren: funding, collection of data, design and analyses, drafting, revision of manuscript. **Jessie Himmelstern:** analyses, revision of manuscript. **Chandra Muller:** funding, collecting data, editing manuscript. **Eric Grodsky:** funding, collecting data, editing manuscript. **Ryan Demmer:** interpretation of results, drafting, revising manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the National Center for Education Statistics. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from https://nces.ed.gov/pubsearch/licenses.asp with the permission of the National Center for Education Statistics.

References

Abadie, A., S. Athey, G. W. Imbens, and J. M. Wooldridge. 2023. "When Should You Adjust Standard Errors for Clustering?" *Quarterly Journal of Economics* 138: 1–35.

Apatzidou, D. A. 2022. "The Role of Cigarette Smoking in Periodontal Disease and Treatment Outcomes of Dental Implant Therapy." *Periodontology 2000* 90: 45–61.

Arboleda, S., M. Vargas, S. Losada, and A. Pinto. 2019. "Review of Obesity and Periodontitis: An Epidemiological View." *British Dental Journal* 227: 235–239.

Arora, N., P. N. Papapanou, M. Rosenbaum, D. R. Jacobs Jr., M. Desvarieux, and R. T. Demmer. 2014. "Periodontal Infection, Impaired Fasting Glucose and Impaired Glucose Tolerance: Results From the Continuous National Health and Nutrition Examination Survey 2009–2010." *Journal of Clinical Periodontology* 41: 643–652.

Beck, J. D., K. L. Moss, T. Morelli, and S. Offenbacher. 2018. "Periodontal Profile Class Is Associated With Prevalent Diabetes, Coronary Heart Disease, Stroke, and Systemic Markers of C-Reactive Protein and Interleukin-6." *Journal of Periodontology* 89: 157–165.

Behle, J. H., M. H. Sedaghatfar, R. T. Demmer, et al. 2009. "Heterogeneity of Systemic Inflammatory Responses to Periodontal Therapy." *Journal of Clinical Periodontology* 36: 287–294.

Beklen, A., N. Sali, and M. B. Yavuz. 2022. "The Impact of Smoking on Periodontal Status and Dental Caries." *Tobacco Induced Diseases* 20: 1–11.

Boillot, A., B. el Halabi, G. D. Batty, H. Rangé, S. Czernichow, and P. Bouchard. 2011. "Education as a Predictor of Chronic Periodontitis: A Systematic Review With Meta-Analysis Population-Based Studies." *PLoS One* 6: e21508.

Borrell, L. N., J. D. Beck, and G. Heiss. 2006. "Socioeconomic Disadvantage and Periodontal Disease: The Dental Atherosclerosis Risk in Communities Study." *American Journal of Public Health* 96: 332–339.

Borrell, L. N., B. A. Burt, H. W. Neighbors, and G. W. Taylor. 2008. "Social Factors and Periodontitis in an Older Population." *American Journal of Public Health* 98: S95–S101.

Carpenter, J. R., M. G. Kenward, J. W. Bartlett, T. P. Morris, M. Quartagno, and A. M. Wood. 2023. *Multiple Imputation and Its Application*. Hoboken, New Jersey: John Wiley & Sons.

Carroll, J. M., and C. Muller. 2018. "Curricular Differentiation and Its Impact on Different Status Groups Including Immigrants and Students With Disabilities." In *Handbook of the Sociology of Education in the 21st Century*, edited by B. Schneider, 251–273. Hoboken, New Jersey: Springer.

Chen, S.-H., J. F. Chen, Y. T. Hung, T. J. Hsu, C. C. Chiu, and S. J. Kuo. 2023. "Exploring the Relationship Between Periodontitis, Anti-Periodontitis Therapy, and Extra-Oral Cancer Risk: Findings From a Nationwide Population-Based Study." *Biomedicine* 11: 1949.

Choi, S., K. Kim, J. Chang, et al. 2019. "Association of Chronic Periodontitis on Alzheimer's Disease or Vascular Dementia." *Journal of the American Geriatrics Society* 67: 1234–1239.

Demmer, R. T., A. Breskin, M. Rosenbaum, et al. 2017. "The Subgingival Microbiome, Systemic Inflammation and Insulin Resistance: The Oral Infections, Glucose Intolerance and Insulin Resistance Study." *Journal of Clinical Periodontology* 44: 255–265.

Demmer, R. T., F. L. Norby, K. Lakshminarayan, et al. 2020. "Periodontal Disease and Incident Dementia: The Atherosclerosis Risk in Communities Study (ARIC)." *Neurology* 95: e1660–e1671.

Demmer, R. T., A. Squillaro, P. N. Papapanou, et al. 2012. "Periodontal Infection, Systemic Inflammation, and Insulin Resistance: Results From the Continuous National Health and Nutrition Examination Survey (NHANES) 1999–2004." *Diabetes Care* 35: 2235–2242.

Demmer, R. T., L. Trinquart, A. Zuk, et al. 2013. "The Influence of Anti-Infective Periodontal Treatment on C-Reactive Protein: A Systematic Review and Meta-Analysis of Randomized Controlled Trials." *PLoS One* 8: e77441.

Eke, P. I., W. S. Borgnakke, and R. J. Genco. 2020. "Recent Epidemiologic Trends in Periodontitis in the USA." *Periodontology 2000* 82: 257–267.

Eke, P. I., G. O. Thornton-Evans, L. Wei, W. S. Borgnakke, B. A. Dye, and R. J. Genco. 2018. "Periodontitis in US Adults: National Health and Nutrition Examination Survey 2009-2014." *Journal of the American Dental Association* 149: 576–588.

Flies, E. J., L. J. Clarke, B. W. Brook, and P. Jones. 2020. "Urbanisation Reduces the Abundance and Diversity of Airborne Microbes-But What Does That Mean for Our Health? A Systematic Review." *Science of the Total Environment* 738: 140337.

Genco, R. J., K. L. Falkner, S. Grossi, R. Dunford, and M. Trevisan. 2007. "Validity of Self-Reported Measures for Surveillance of Periodontal Disease in Two Western New York Population-Based Studies." *Journal of Periodontology* 78: 1439–1454.

Graves, D. T., Z. Ding, and Y. Yang. 2020. "The Impact of Diabetes on Periodontal Diseases." *Periodontology* 2000, no. 82: 214–224.

Grodsky, E., J. Manly, C. Muller, and J. R. Warren. 2022. "Cohort Profile: High School and Beyond." *International Journal of Epidemiology* 51: e276–e284.

Gundala, R., and V. K. Chava. 2010. "Effect of Lifestyle, Education and Socioeconomic Status on Periodontal Health." *Contemporary Clinical Dentistry* 1: 23.

Hout, M., T. W. Smith, and P. V. Marsden. 2015. "Prestige and Socioeconomic Scores for the 2010 Census Codes." Methodological Report MR124, Chicago, NORC. http://gss.norc.org/get-documentation/methodological-reports.

Huber, P. J. 1967. *The Behavior of Maximum Likelihood Estimates Under Nonstandard Conditions*. Vol. 1, 221–233. Berkeley, CA: University of California Press.

Irie, K., T. Yamazaki, S. Yoshii, H. Takeyama, and Y. Shimazaki. 2017. "Is There an Occupational Status Gradient in the Development of Periodontal Disease in Japanese Workers? A 5-Year Prospective Cohort Study." *Journal of Epidemiology* 27: 69–74.

Iwashita, M., M. Hayashi, Y. Nishimura, and A. Yamashita. 2021. "The Link Between Periodontal Inflammation and Obesity." *Current Oral Health Reports* 8: 76–83.

Kebschull, M., R. Demmer, and P. Papapanou. 2010. ""Gum Bug, Leave My Heart Alone!"—Epidemiologic and Mechanistic Evidence Linking Periodontal Infections and Atherosclerosis." *Journal of Dental Research* 89: 879–902.

Khan, M. S., M. Alasqah, L. M. Alammar, and Y. Alkhaibari. 2020. "Obesity and Periodontal Disease: A Review." *Journal of Family Medicine and Primary Care* 9: 2650–2653.

Lee, Y., H. Hu, L. Huang, P. Chou, and D. Chu. 2017a. "Periodontal Disease Associated With Higher Risk of Dementia: Population-Based Cohort Study in Taiwan." *Journal of the American Geriatrics Society* 65: 1975–1980.

Lee, Y., H. C. Lee, C. J. Hu, et al. 2017b. "Periodontitis as a Modifiable Risk Factor for Dementia: A Nationwide Population-Based Cohort Study." *Journal of the American Geriatrics Society* 65: 301–305.

Lertpimonchai, A., S. Tuntrakul, S. Rattanasiri, et al. 2023. "Validity of Simple Self-Reported Periodontal Status Questions." *International Dental Journal* 73: 121–127.

Llambés, F., S. Arias-Herrera, and R. Caffesse. 2015. "Relationship Between Diabetes and Periodontal Infection." *World Journal of Diabetes* 6: 927–935.

Lockhart, P. B., A. F. Bolger, P. N. Papapanou, et al. 2012. "Periodontal Disease and Atherosclerotic Vascular Disease: Does the Evidence Support an Independent Association? A Scientific Statement From the American Heart Association." *Circulation* 125: 2520–2544.

Mealey, B. L., and T. W. Oates. 2006. "Diabetes Mellitus and Periodontal Diseases." *Journal of Periodontology* 77: 1289–1303.

Müller, F. 2015. "Oral Hygiene Reduces the Mortality From Aspiration Pneumonia in Frail Elders." *Journal of Dental Research* 94: 14S–16S.

Naderi, S., and A. T. Merchant. 2020. "The Association Between Periodontitis and Cardiovascular Disease: An Update." *Current Atherosclerosis Reports* 22: 1–5.

Nguyen, V. B., T. T. Nguyen, N. C. N. Huynh, K. D. Nguyen, T. A. le, and H. T. Hoang. 2021. "Effects of Non-Surgical Periodontal Treatment in Rheumatoid Arthritis Patients: A Randomized Clinical Trial." *Dental and Medical Problems* 58: 97–105.

Niskanen, M. C., P. T. Mattila, A. O. Niinimaa, M. M. Vehkalahti, and M. L. E. Knuuttila. 2020. "Behavioural and Socioeconomic Factors Associated With the Simultaneous Occurrence of Periodontal Disease and Dental Caries." *Acta Odontologica Scandinavica* 78: 196–202.

Nwizu, N., J. Wactawski-Wende, and R. J. Genco. 2020. "Periodontal Disease and Cancer: Epidemiologic Studies and Possible Mechanisms." *Periodontology* 2000, no. 83: 213–233.

Orlandi, M., F. Graziani, and F. D'Aiuto. 2020. "Periodontal Therapy and Cardiovascular Risk." *Periodontology* 2000, no. 83: 107–124.

Polak, D., T. Sanui, F. Nishimura, and L. Shapira. 2020. "Diabetes as a Risk Factor for Periodontal Disease—Plausible Mechanisms." *Periodontology* 2000, no. 83: 46–58.

Renson, A., H. E. Jones, F. Beghini, et al. 2019. "Sociodemographic Variation in the Oral Microbiome." *Annals of Epidemiology* 35: 73–80.

Renvert, S., J. S. Berglund, G. R. Persson, and M. K. Söderlin. 2020. "The Association Between Rheumatoid Arthritis and Periodontal Disease in a Population-Based Cross-Sectional Case-Control Study." *BMC Rheumatology* 4: 1–8.

Rivas, A., G. Creazzo, and E. Vargas. 2023. "Periodontal Disease and Rheumatoid Arthritis: Exploring New Associations of Autoimmune Pathogenesis." *International Journal on Orl Health* 3: 1–9.

Rogers, W. 1994. "Regression Standard Errors in Clustered Samples." *Stata Technical Bulletin* 3: 19–23.

Royston, P. 2005. "Multiple Imputation of Missing Values: Update of Ice." *Stata Journal* 5: 527–536.

Royston, P., and I. R. White. 2011. "Multiple Imputation by Chained Equations (MICE): Implementation in Stata." *Journal of Statistical Software* 45: 1–20.

Rubin, D. B. 2004. *Multiple Imputation for Nonresponse in Surveys*. Vol. 81. Hoboken, New Jersey: John Wiley & Sons.

Sanz, M., A. Marco del Castillo, S. Jepsen, et al. 2020. "Periodontitis and Cardiovascular Diseases: Consensus Report." *Journal of Clinical Periodontology* 47: 268–288.

Sen, S., L. D. Giamberardino, K. Moss, et al. 2018. "Periodontal Disease, Regular Dental Care Use, and Incident Ischemic Stroke." *Stroke* 49: 355–362.

Silva, H. 2021. "Tobacco Use and Periodontal Disease—The Role of Microvascular Dysfunction." *Biology* 10: 441.

Sobocki, B. K., C. A. Basset, B. Bruhn-Olszewska, et al. 2022. "Molecular Mechanisms Leading From Periodontal Disease to Cancer." *International Journal of Molecular Sciences* 23: 970.

Stewart, R., U. Stenman, M. Hakeberg, C. Hägglin, D. Gustafson, and I. Skoog. 2015. "Associations Between Oral Health and Risk of Dementia in a 37-Year Follow-Up Study: The Prospective Population Study of Women in Gothenburg." *Journal of the American Geriatrics Society* 63: 100–105.

Sun, J., Y. Zheng, X. Bian, H. Ge, J. Wang, and Z. Zhang. 2021. "Non-Surgical Periodontal Treatment Improves Rheumatoid Arthritis Disease Activity: A Meta-Analysis." *Clinical Oral Investigations*, 1–11.

Tadakamadla, S. K., J. Tadakamadla, J. Kroon, R. Lalloo, and N. W. Johnson. 2020. "Effect of Family Characteristics on Periodontal Diseases in Children and Adolescents—A Systematic Review." *International Journal of Dental Hygiene* 18: 3–16.

Talbot, D., M. Mésidor, Y. Chiu, M. Simard, and C. Sirois. 2023. "An Alternative Perspective on the Robust Poisson Method for Estimating Risk or Prevalence Ratios." *Epidemiology* 34: 1–7.

Thomson, W. M., A. Sheiham, and A. J. Spencer. 2012. "Sociobehavioral Aspects of Periodontal Disease." *Periodontology 2000* 60: 54–63.

Van Buuren, S. 2018. *Flexible Imputation of Missing Data*. Boca Raton, Florida: CRC Press.

Verma, U. P., P. Singh, and A. K. Verma. 2023. "Correlation Between Chronic Periodontitis and Lung Cancer: A Systematic Review With Meta-Analysis." *Cureus* 15, no. 3: e36476. https://doi.org/10.7759/cureus.36476.

Watson, C. A., and S. Nilam. 2017. "Educational Level as a Social Determinant of Health and Its Relationship to Periodontal Disease as a Health Outcome." *Journal of Dental Science and Therapy* 1: 8–11.

White, I. R., P. Royston, and A. M. Wood. 2011. "Multiple Imputation Using Chained Equations: Issues and Guidance for Practice." *Statistics in Medicine* 30: 377–399.

Widyarman, A. S., C. F. Theodorea, N. S. Udawatte, et al. 2021. "Diversity of Oral Microbiome of Women From Urban and Rural Areas of Indonesia: A Pilot Study." *Frontiers in Oral Health* 2: 738306.

Wiernik, E., A. Renuy, S. Kab, et al. 2024. "Prevalence of Self-Reported Severe Periodontitis: Data From the Population-Based CONSTANCES Cohort." *Journal of Clinical Periodontology* 51: 884–894.

Winning, L., C. C. Patterson, C. E. Neville, F. Kee, and G. J. Linden. 2017. "Periodontitis and Incident Type 2 Diabetes: A Prospective Cohort Study." *Journal of Clinical Periodontology* 44: 266–274.

Yamamoto, T., K. Kondo, H. Hirai, M. Nakade, J. Aida, and Y. Hirata. 2012. "Association Between Self-Reported Dental Health Status and Onset of Dementia: A 4-Year Prospective Cohort Study of Older Japanese Adults From the Aichi Gerontological Evaluation Study (AGES) Project." *Psychosomatic Medicine* 74: 241–248.

Zardawi, F., S. Gul, A. Abdulkareem, A. Sha, and J. Yates. 2021. "Association Between Periodontal Disease and Atherosclerotic Cardiovascular Diseases: Revisited." *Frontiers in Cardiovascular Medicine* 7: 625579.

Zhang, J., J. Yu, J. Dou, P. Hu, and Q. Guo. 2021. "The Impact of Smoking on Subgingival Plaque and the Development of Periodontitis: A Literature Review." *Frontiers in Oral Health* 2: 751099.

Zhou, M., J. Dong, L. Zha, and Y. Liao. 2021. "Causal Association Between Periodontal Diseases and Cardiovascular Diseases." *Genes* 13: 13.

Zou, G. 2004. "A Modified Poisson Regression Approach to Prospective Studies With Binary Data." *American Journal of Epidemiology* 159: 702–706.