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Original Contribution

The Controlled Direct Effect of Early-Life Socioeconomic Position on Periodontitis in a Birth Cohort

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This study used data from the 1982 Pelotas Birth Cohort Study, Brazil, to estimate the controlled direct effect of early-life socioeconomic position (SEP) on periodontitis at age 31 years, controlling for adulthood income and education, smoking, and dental hygiene. Sex was included as a covariate. Early-life SEP was measured at participant birth based on income, health services payment mode, maternal education, height, and skin color (lower versus middle/higher SEP). Periodontitis was assessed through clinical examination at age 31 years (healthy, mild periodontitis, or moderate-to-severe disease). Adulthood behaviors (smoking, dental hygiene) were the mediators, and adulthood SEP (education and income) represented the exposure-induced mediator-outcome confounders. A regression-based approach was used to assess the controlled direct effect of early-life SEP on periodontitis. Multinomial regression models were used to estimate risk ratios and their 95% confidence intervals. The prevalences of mild and moderate-to-severe periodontitis were 23.0% and 14.3%, respectively ($n = 539$). Individuals from the lowest early-life SEP had a higher risk of moderate-to-severe periodontitis controlled for mediators and exposure-induced mediator-outcome confounders: risk ratio = 1.85 (95% confidence interval: 1.06, 3.24), E value 3.1. We found that early-life SEP was associated with the development of periodontitis in adulthood that was not mediated by adulthood SEP and behaviors.

cohort study; longitudinal study; oral health; periodontitis; socioeconomic position

Abbreviations: CAL, clinical attachment loss; CDE, controlled direct effect; OHS, Oral Health Study; SEP, socioeconomic position.

Half of the world's population suffers from oral diseases (1). Periodontitis is an inflammatory disease affecting periodontal tissues and alveolar bone (2). Its severe form affects more than 750 million people, with a prevalence of 10.5% for all ages combined. Some health-related behaviors are known risk factors for periodontitis, such as smoking and inadequate oral hygiene (3). The majority of known risk factors for periodontitis are influenced by social conditions (4); the "causes behind the causes" of health are known as social determinants of health (5).

The social determinants of health include (but are not restricted to) social and economic experiences such as income, education, employment, and working environment. Life-course epidemiology postulates that health conditions are influenced by dynamic changes of the circumstances in which people are born, grow, live, work, and age (6). Understanding those influences can shed light on the onset and progression of chronic health conditions in order to inform effective and timely interventions.

The critical period theory of the life-course epidemiology proposes that conditions in a specific development period in life, usually in early life, determine the occurrence of disease later on (6). This model has proven to be accurate for several chronic conditions (7). In oral health, there is evidence that relatively low socioeconomic position (SEP) at birth is associated with unsound teeth in young adulthood, regardless of family income in adolescence and young adulthood (8), and with tooth loss and need of prostheses at age 24 (9). Even though the critical period theory seems to explain the relationship between low SEP and oral health, it does not rule out the possibility that different

life-course theories act together. Low SEP at birth might favor the establishment of the disease, which progresses based on the influence of more proximal factors.

Socioeconomic conditions can have lifelong implications on periodontal health. A birth cohort study in Dunedin, New Zealand, identified an association between early-life SEP and periodontitis in adulthood (10). However, it is now known that there are more accurate analytical approaches to estimate such an association than the techniques applied by Poulton et al. (10). For example, their conclusions are drawn from regression models in which confounders and mediators were included indiscriminately. Advances in causal inference methods highlight important aspects that need to be taken into account when estimating causal associations, such as the role of each variable (e.g., confounders, mediators, effect modifiers) and potential interactions between them (11).

Despite increasing evidence of the association between SEP and periodontitis (12–15), there is scant information on the influence that the circumstances in which people are born and grow have on their periodontal health later in life based on longitudinal studies. Additionally, there is no evidence of this association in middle- and low-income countries. Therefore, the dynamics of early-life SEP's impact on adult oral health remains unclear. Accordingly, in this study, we aimed to estimate the effect of early-life SEP on periodontitis in adulthood that is not mediated by adulthood SEP (income and education) and behaviors.

METHODS

1982 Pelotas Birth Cohort Study

In 1982, the 3 maternity hospitals in the city of Pelotas, in southern Brazil, were visited daily, and all 5,914 children born in that year were invited to be part of a prospective population-based birth cohort study. This population has been followed up several times. Nested oral health studies (OHSs) were conducted in 1997 (OHS-97), 2006 (OHS-06), and 2013 (OHS-13). For the present study, we used information about the cohort gathered in 1982 (birth), 2004–2005 (age 23 years), 2006 (age 24 years), 2012 (age 30 years) and 2013 (age 31 years). All follow-up assessments were approved by the Ethics Committee of the Federal University of Pelotas, and a signed consent form was collected either from the parents of participating children or the adult participants. Detailed methodological information can be accessed elsewhere (16, 17).

Oral Health Study 2013

The first OHS was carried out in 1997, when participants were 15 years old. At that time, a random sample of 900 individuals was invited to take part in OHS-97. A total of 888 individuals completed OHS-97. In 2013, the researchers intended to follow up the participants of OHS-97.

Six examiners and 6 interviewers conducted OHS-13. The examiners were dentists with experience in epidemiologic studies. Interviews and clinical oral examinations were conducted through home visits. Prior to the data collection, examiners were trained, and 30 volunteers were clinically examined. The lowest intraclass correlation coefficient for clinical attachment loss (CAL) was 0.85. The questionnaire included sociodemographic and behavioral information. The clinical oral examination followed the biosafety procedures recommended by the World Health Organization for epidemiologic surveys, and headlights, dental mirrors, and PCP2 periodontal probes (Hu-Friedy Manufacturing Co., LLC, Chicago, Illinois) were used. Gingival recession and periodontal pocket depth were examined in 6 sites (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual and distolingual) per tooth of all teeth, excluding third molars. Teeth that could not be assessed due to physical barriers, such as a large amount of calculus and/or an orthodontic band, were excluded from the oral examination. CAL was estimated as a sum in millimeters of gingival recession and pocket depth at each site.

Exposure

Early-life SEP was the exposure. We categorized SEP into tertiles and then dichotomized it into relatively poorer (first tertile) versus middle and relatively richer groups (second and third tertiles). There is evidence that middle- and upper-income groups in Brazil are comparable, while the poor income group lags well behind (18).

Family income at birth was collected in 5 prespecified categories. In order to obtain 3 SEP categories with a comparable number of individuals, a principal components analysis was conducted with 4 variables: health services payment mode (out of pocket, public free, or private health insurance), maternal education, height, and skin color. These characteristics were selected previously by the 1982 Pelotas Birth Cohort because they were the closest information relating to SEP indicators collected at birth (19). Affordability of services and education are directly related to SEP, and height and skin color have long association with SEP. A score was derived from the first component, and that was used to rank individuals within family SEP groups. After that, cutpoints within each category were identified in order to form 3 groups with approximately the same number of individuals.

Outcome

The outcome was periodontitis, assessed through clinical examination at age 31 years. In the present study, periodontitis was defined based on the case definitions proposed by the Centers for Disease Control and Prevention and the American Academy of Periodontology (20). Accordingly, mild periodontal disease was defined as ≥2 interproximal sites with CAL ≥3 mm, and ≥2 interproximal sites with probing depth ≥4 mm (not on the same tooth) or 1 site with probing depth ≥5 mm. Moderate periodontal disease was defined as ≥2 interproximal sites with CAL ≥4 mm (not on the same tooth), or ≥2 interproximal sites with probing depth ≥5 mm (not on the same tooth). Severe periodontal disease was identified in individuals with ≥2 interproximal sites with CAL ≥6 mm (not on the same tooth) and ≥1 interproximal site with probing depth ≥5 mm. For the present study, an ordinal variable was created: 1) healthy/no periodontitis, 2) mild periodontitis, and 3) moderate-to-severe periodontitis.

Mediators

Smoking status and dental hygiene at age 24 years were the mediators. Smoking status was dichotomized as current or former

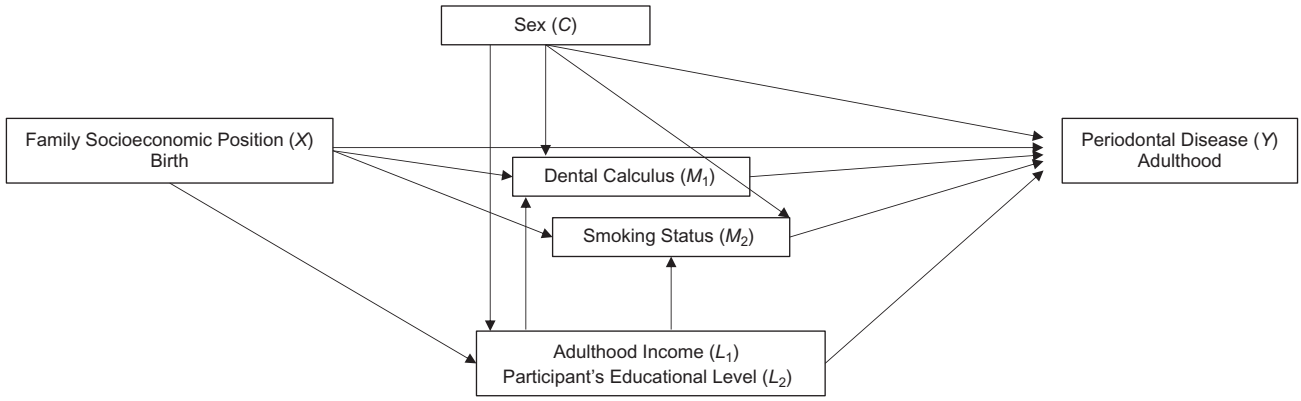

Figure 1. Directed acyclic graph showing causal pathways between early life socioeconomic position and periodontitis in adulthood, 1982 Pelotas Birth Cohort Study, Brazil, 1982–2013.

smoker versus nonsmoker. Dental calculus was used as a proxy of dental hygiene. It was collected in 6 sites for all teeth and coded as present/absent per tooth. All present teeth were then summed, and dental calculus was categorized in 0 or 1 tooth versus ≥2 teeth with calculus.

Exposure-induced mediator-outcome confounders

Adulthood income and education were included as exposure-induced mediator-outcome confounders. Income data were collected at age 23 years as a continuous variable referring to the sum of all household earnings in the previous month and, for analytical purposes, categorized into tertiles and then dichotomized (first versus second and third tertiles). Education was collected as completed years of study at age 30 years, and it was categorized in years as 0–8 (corresponding to primary school in Brazil), 9–11 (high school), and ≥12 years of study.

Covariate

Sex was considered as a covariate because there is evidence that there are sex differences in periodontitis experience, with men having a higher prevalence of disease. Ideally, the analysis would have been stratified by sex, but this approach was restricted by sample size. Therefore, the most appropriate way to acknowledge the potential influence that sex might have on the association between SEP and periodontitis was to control for this variable.

Statistical analysis

Figure 1 presents our directed acyclic graph. The pathway of interest in this study was the direct path from early-life SEP to periodontitis in adulthood. We estimated the controlled direct effect (CDE) of SEP at birth on periodontitis at age 31 years, not mediated by adulthood smoking, oral hygiene, income, and education. Let X, the SEP, denote the exposure for an individual; let Y, periodontitis, denote the outcome; let M denote the value of a single mediator (e.g., smoking) on the X-Y pathway; let L denote exposure-induced mediator confounders (adulthood income and education); and let C denote confounding factors. The controlled direct effect (CDE(m)) is expressed as the average change in the potential outcome if the mediator is uniformly set to a level ($M = m$) in the population where the treatment is changed from level ($X = x$) to ($X = x^*$) (11). In other words, CDE considers what the effect of the exposure would be if we were to intervene on the mediator across the population.

The 2 most important assumptions to estimating CDE are: 1) the association between the exposure X and the outcome Y is unconfounded conditional on C; and 2) the association between the mediator M and the outcome Y is unconfounded conditional on C, L, and X (21, 22).

For the single-mediator scenario, under the regression-based approach the model allowing for exposure-mediator ($X \times M$) interaction can be written as

$$E[Y|x, m, c] = \theta_0 + \theta_1 x + \theta_2 m + \theta_3 xm + \theta'_4 c.$$

The CDE from the above model, in the risk difference scale, can then be estimated as: $CDE(m) = \theta_1(x - x^*) + \theta_3(x - x^*)m$. In the risk ratio scale, the estimation of the CDE in the presence of 1 mediator and with $X \times M$ interaction is given by RR $(\mathrm{CDE}(m)) = \frac{P(Y_{xm} = 1, c)}{P(Y_{x^*m} = 1, c)}$. For the case in which there is no interaction, $\theta_3 = 0$, the CDE is reduced to simply the coefficient of $(x - x^*)$, θ_1.

In a situation in which there are multiple mediators of interest, such as in this study, some adjustments must be made (21). This is because of the presence of exposure-induced mediator-outcome confounders. Similar to the single-mediator scenario, estimation of CDE in the presence of multiple mediators can be carried out using either a regression-based approach or weighting (21, 23). However, when there is an exposure-induced mediator-outcome confounder, using weighting can destabilize the estimates (11, 24). Additionally, as in our case, with 2 mediators and 2 exposure-induced mediator-outcome confounders that occur dynamically and influence the subsequent variables, deriving weights can be quite challenging for the nesting structure below:

$$L_1(x)$$

$$L_2(L_1(x), x)$$

$$M_1(x, L_1(x), L_2(L_1(x), x))$$

$$M_2(x,L_1(x),\ (L_2(x,L_1(x)),\ M_1(x,L_1(x),\ L_2(x,L_1(x))))).$$

Hence, following VanderWeele (11, pp 114–118), we took the regression-based approach to estimate CDE for the multiple-mediators scenario. In the absence of $X \times M$ interaction, the CDE, as in the single-mediation case, reduces to $\theta_1(x - x^*)$ in the risk difference scale and to $\exp(\theta_1(x - x^*))$ in the risk ratio scale. That was our chosen approach.

Sensitivity analysis

Misclassification and unmeasured confounding could overestimate the association between SEP and periodontitis. Therefore, we conducted 2 sensitivity analyses: one for unmeasured confounding and another for measurement bias. For unmeasured confounding, the E value was used. It was proposed by VanderWeele and Ding (25) and estimates how strong the association of the confounder factor with both exposure and outcome, conditional on the measured covariates, would need to be in order to change or eliminate the observed effect of the exposure on outcome.

For the misclassification sensitivity analysis, we repeated the analysis using 4 different case definitions to check the consistency of the findings. We used 3 case definitions from the Dunedin study (10) and the "sensitive" case definition proposed by the 5th European Workshop in Periodontology (26).

Multiple imputation by chained equations was performed to deal with missing data (27). Results from the imputed sample are reported below, and results for the complete-case sample are presented as Web Tables 1–6.

RESULTS

From $n = 888$ in OHS-97, a total of 539 (61.0%) individuals participated in OHS-13. Socioeconomic and demographic indicators of those participants evaluated in OHS-13 were comparable to those of the original cohort study (Table 1).

Table 2 displays a cross-tabulation of covariates and the 2 levels of the outcome (periodontitis), as well as crude estimates from multinomial regression analyses of covariates and periodontitis. Individuals from low SEP at birth had a prevalence of mild periodontitis of 25.8%, while it was 21.8% among those in higher SEP categories. The lower-SEP group were more likely to present with moderate-to-severe periodontitis (risk ratio = 1.7). Higher risk of both levels of periodontitis in the crude analysis were observed among men, while those in the worst tertile of dental calculus presented an increased level of mild periodontitis. An association was also observed between the more severe level of disease and being a smoker at age 24, as well as having undertaken less than 12 years of study.

Adjusted estimates are presented in Table 3. The CDE of family SEP at birth on periodontitis case definitions from the Centers for Disease Control and Prevention and the American Academy of Periodontology showed that individuals from the lowest SEP tertile had a higher risk of mild (risk ratio = 1.29 (95% confidence interval: 0.79, 2.11)) and moderate-to-severe (risk ratio = 1.85 (95% confidence interval: 1.06, 3.24)) periodontitis. The E values for these estimates were 1.9 (mild periodontitis) and 3.1 (moderate-to-severe periodontitis). The E value of 3.1 suggests that an unmeasured confounding would have to increase the likelihood of low SEP at birth and decrease the likelihood of moderate-to-severe periodontitis by 3.1-fold each if SEP were to have no causal effect.

Table 1. Comparison of Demographic and Socioeconomic Characteristics at Birth Between the Original Sample and Those in the Oral Health Study 2013, 1982 Pelotas Birth Cohort Study, Brazil, 1982–2013

Variable	Pelotas Birth Cohort			Baseline, Nested Oral Health Study (Age 15 Years)			2013 Follow-up (Age 31 Years)		
	No.	%	95% CI	No.	%	95% CI	No.	%	95% CI
Sex									
Male	3,037	51.4	50.1, 52.6	480	54.1	50.8, 57.3	273	50.6	46.4, 54.9
Female	2,876	48.6	47.4, 49.9	408	45.9	42.7, 49.2	266	49.3	45.1, 53.6
Maternal skin color									
White	4,851	82.1	81.1, 83.0	743	83.8	81.2, 86.1	454	84.2	80.9, 87.1
Black	1,060	17.9	17.0, 18.9	144	16.2	13.9, 18.8	85	15.8	12.9, 19.1
Family SEP at birth, multiple of MW									
≤1.0	1,288	21.9	20.8, 23.0	161	18.2	15.8, 20.9	93	17.3	14.3, 20.7
1.1–3.0	2,789	47.4	46.1, 48.7	457	51.7	48.4, 55.0	282	52.4	48.2, 56.6
>3.0	1,808	30.7	29.6, 31.9	266	30.1	27.2, 33.2	163	30.3	26.5, 34.3
Maternal education at birth, years									
0–4	1,960	33.2	32.0, 34.4	285	32.2	29.2, 35.3	162	30.1	26.4, 34.1
5–8	2,454	41.5	40.3, 42.8	393	44.4	41.1, 47.7	254	47.2	43.0, 51.4
≥9	1,493	25.3	24.2, 26.4	208	23.5	20.8, 26.4	122	22.7	19.3, 26.4

Abbreviations: CI, confidence interval; MW, minimum wage; SEP, socioeconomic position.

Sensitivity analyses using different case definitions are also presented in Table 3. A clear association was not observed when the Dunedin case definitions were adopted. However, individuals from the lowest SEP at birth showed a higher risk of periodontitis (risk ratio = 1.36, 95% confidence interval: 1.08, 1.72) when the outcome was defined using the Tonetti and Claffey "sensitive" case definition. The E value associated with this estimate was 2.06.

DISCUSSION

In this study, early-life SEP had a direct effect on periodontitis in adulthood, controlled for well-known mediators, corroborating the critical-period life-course epidemiology theory. Although this theory has proven to be accurate for other chronic health conditions, to the best of our knowledge, there is only one study testing this theory on periodontitis using a prospective study design, and it was conducted in a high-income country and used occupation as the indicator of SEP (10). The statistical analysis reinforced our findings, which contributes a proof-of-principle of cause and effect between early-life SEP and periodontitis in adulthood.

The thoughtful statistical analysis and the study design are among the major strengths of the present study. The analysis was based on the most recent advances in causal inference methods, and sensitivity analyses were conducted to test for unmeasured confounding and measurement bias (11). Another point that deserves attention is the quality of the data. We used the largest and longest birth cohort study in middle- or low-income countries, and one of the only studies with oral health data clinically collected. For the present study, a comprehensive periodontal examination was performed, allowing the adoption of internationally recognized case definitions. Additionally, our study achieved a response rate considered high for a longitudinal study with such long follow-up. The cross-comparison of the follow-up sample and the original birth cohort demonstrated the representativeness of the follow-up sample and reinforced the internal consistency of our study, showing that the likelihood of selection bias was low.

The young age of the sample might have limited the statistical power of our analysis, because periodontitis has relatively low prevalence at this age. Additionally, diabetes, which would theoretically be a confounder in our analysis, could not be included due to the low prevalence. We also cannot rule out residual bias, mainly due to the limited information we had on smoking (even though the analyses were adjusted for it—our dichotomous variable might not have been enough). Nevertheless, a significant association between early-life SEP and periodontitis was observed. Another limitation is that SEP at birth was derived from several variables, including income data collected in prespecified categories, restricting its use.

Table 2. Frequency (Row Percentages) of Periodontitis According to Covariates and Crude Estimates From Multinomial Logistic Regression Models, 1982 Pelotas Birth Cohort Study, Brazil, 1982–2013

Characteristic	Frequency						Crude Estimate			
	Mild Periodontitis			Moderate-to-Severe Periodontitis			Mild Periodontitis		Moderate-to-Severe Periodontitis	
	No.	Row %	95% CI	No.	Row %	95% CI	RR	95% CI	RR	95% CI
Sex										
Male	67	24.5	19.8, 30.0	50	18.3	14.1, 23.4	1.0	Referent	1.0	Referent
Female	57	21.4	16.9, 26.8	27	10.2	7.0, 14.4	0.7	0.5, 1.1	0.5	0.3, 0.8
Family SEP at birth										
High (middle and highest tertiles)	83	21.8	18.0, 26.3	48	12.6	19.5, 33.2	1.0	Referent	1.0	Referent
Low (lowest tertile)	41	25.8	9.6, 16.4	29	18.2	12.9, 25.1	1.4	0.9, 2.2	1.7	1.0, 2.9
Adulthood income at age 23 years										
High (middle and highest tertiles)	82	22.7	18.6, 27.3	52	14.4	11.1, 18.4	1.0	Referent	1.0	Referent
Low (lowest tertile)	35	23.5	17.3, 31.1	20	13.4	8.8, 20.0	1.0	0.7, 1.7	0.9	0.5, 1.7
Smoking status at age 24 years										
Nonsmoker	93	22.6	18.8, 26.9	54	13.1	10.2, 16.7	1.0	Referent	1.0	Referent
Smoker	24	24.2	16.7, 33.8	18	18.2	11.7, 27.2	1.2	0.7, 2.0	1.6	0.9, 2.8
Dental calculus at age 24 years										
Second and third tertiles	67	18.1	12.5, 25.5	22	15.9	10.7, 23.1	1.0	Referent	1.0	Referent
First tertile (worst)	45	24.7	20.7, 29.2	55	13.7	10.7, 17.5	1.5	0.9, 2.4	0.9	0.5, 1.6
Education at age 30 years, completed years of study										
≥12	51	22.8	17.7, 28.8	27	12.1	8.4, 17.1	1.0	Referent	1.0	Referent
0–11	61	22.8	18.1, 28.2	46	17.2	13.1, 22.2	1.1	0.7, 1.7	1.5	0.9, 2.6

Abbreviations: CI, confidence interval; RR, risk ratio; SEP, socioeconomic position.

Table 3. Controlled Direct Effect[a] of Family Socioeconomic Position at Participant's Birth on Periodontitis at Age 31 Years, Multinomial Logistic Regression in Multiply Imputed Sample, 1982 Pelotas Birth Cohort Study, Brazil, 1982–2013

Case Definition	Family SEP at Birth		E Value
	Lowest SEP[b]		
	RR	95% CI	
CDC/AAP case definition (20)			
Mild periodontitis	1.29	0.79, 2.11	1.9
Moderate-to-severe periodontitis	1.85	1.06, 3.24	3.1
Dunedin case definitions (10)			
≥1 sites with ≥4 mm CAL	1.07	0.85, 1.35	1.34
≥2 sites with ≥4 mm CAL	1.25	0.89, 1.68	1.81
≥1 sites with ≥5 mm CAL	1.24	0.90, 1.72	1.79
5th European Workshop (Tonetti and Claffey, "sensitive" case definition (26))[c]			
≥2 non-adjacent teeth with ≥3 mm of CAL	1.36	1.08, 1.72	2.06

Abbreviations: CAL, clinical attachment loss; CDC/AAP, Centers for Disease Control and Prevention/American Academy of Periodontology; CI, confidence interval; RR, risk ratio; SEP, socioeconomic position.

[a] Direct effect controlled for mediators and exposure-induced mediator-outcome confounders.

[b] Reference category: middle and highest SEP.

[c] Tonetti and Claffey "specific" case definition (presence of proximal attachment loss of ≥5 mm in at least 30% of all present teeth) was not evaluated as an outcome due to low prevalence (0.7%, 4 individuals).

Our findings are in line with previous studies showing that early-life socioeconomic circumstances are important determinants of health. Indeed, it has been discussed that time is significant for shaping the experience of SEP disadvantage on health (28). There are different hypotheses for such a lifelong impact on health outcomes, and the most frequently explored mechanisms are based on behavioral, psychosocial, and neomaterialist explanations (29–35).

The behavioral pathway involves socially patterned behaviors such as inadequate hygiene, infrequent use of oral health care, and smoking. The understanding of the impact of systemic risk factors shaped by SEP conditions on the onset, rate of progression, and severity of periodontitis has been increasing (29–32). It is argued that these behaviors are learned in early life, and that early-life SEP would influence and shape behaviors later on. These exposures could then increase the risk of periodontitis development and progression. From an understanding that poor oral hygiene can lead to periodontitis, we included a proxy for oral hygiene in our models. The most commonly used conditions are dental calculus, flossing, and brushing. Over half of the sample reported flossing at least once a day, and 95.6% reported brushing ≥2 times a day (data not shown). Because these variables are self-reported and might be subject to information bias, we used objectively measured dental calculus as a proxy of dental hygiene.

The psychosocial pathway identifies conditions such as social capital and stress as linking factors between socioeconomic disadvantage and poorer health. In fact, perceived social disadvantage and financial hardship could lead to increased stress levels. This impact on stress early in life, during sensitive periods of immune system maturation, could impair host immune responses and later change the inflammatory response (31). There are several studies showing that early-life SEP affects the immune response in adulthood (33). Considering the major role of the immune system in modulating periodontal destruction, it can be hypothesized that being exposed to lower SEP impairs the immune response of the individual, leading to a higher susceptibility to periodontitis.

The neomaterialist explanation lies in the idea that socioeconomic inequalities in health might be due to differential affordability of food, housing, hygiene products, and access to health care. This explanation also includes upstream determinants of health, from an understanding of the way that societies are organized and resources are invested in human, physical, health, and social structure and how this affects health (34). From the periodontitis perspective, societal characteristics such as income distribution, access to health services, and the quality of health services might influence the disease occurrence. Although the theories hypothesize how early-life SEP could affect periodontitis later through mediators, the CDE could be explained from a biological pathway through an inflammatory disease hypothesis. This hypothesis states that children from disadvantaged socioeconomic backgrounds, including inadequate housing, diet, and health care, are more susceptible to inflammatory diseases in adulthood. Because periodontitis is a low-grade local inflammation with a moderate systemic inflammatory response (35), it is hypothesized that the elevated inflammatory markers in blood can be related to an unbalanced inflammatory response, which might, in turn, make those individuals more susceptible to the occurrence of periodontitis.

Our study suggests that low early-life SEP increased the risk of moderate-to-severe periodontitis in adulthood, and this might challenge the assumption that adult oral health would be more influenced by immediate rather than past socioeconomic circumstances (36). Although there is evidence of the correlation between early-life and adulthood SEP, our analysis showed a direct effect

of early-life SEP on moderate-to-severe periodontitis, controlling for adulthood SEP and behaviors.

These findings do not rule out the potential impacts of proximal factors on the periodontitis pathogenesis. Considering the chronic, cumulative nature of periodontitis, the most likely life-course model to explain its occurrence is the accumulation-of-risk model, notwithstanding our findings that support the critical period. It is possible that the early-life SEP effect observed in our study could diminish in strength with further aging of the cohort, as more proximal influences come into play. That said, the life-course models are not mutually exclusive, and one can hypothesize pathways linking SEP to periodontitis based on each of the life-course theories (31). The aim of this study, however, was to test the critical period model.

The study findings support the hypothesis that early-life SEP has a direct effect on periodontitis in adulthood. Conducted within a well-designed longitudinal cohort, our study offers evidence toward a better understanding of the social determinants of periodontitis. Our findings corroborate previous evidence on life-course effects of social conditions on chronic diseases, indicating that reducing SEP inequalities in early life might have lifelong benefits.

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