Exploring Potential Pathways Between Parity and Tooth Loss Among American Women

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"Jedes kind kostet die mutter einen zahn," an old German saying that literally means "every child costs the mother one tooth," embodies a pervasive belief in many cultures, including that of the United States, that tooth loss is a natural consequence of pregnancy.[1,2] This belief stems, in part, from the popular view that pregnancy weakens teeth as a result of calcium depletion; such a notion, although wholly unsupported,[3–5] is given credibility by findings indicating that pregnancy actually does have an adverse impact on oral tissues.[6–13]

Despite this widespread conviction, few investigations have explored the association between parity (i.e., the number of live-born children a woman has delivered) and tooth loss. Whereas some have found no association between parity and tooth loss,[14–16] others have found that increased parity is related to increased levels of edentulism and fewer teeth.[17–19] To our knowledge, however, no studies have examined the mechanisms by which parity may affect tooth loss. Accordingly, our primary goal was to identify mediators of the relationship between parity and tooth loss in a large sample of White and Black American women.

THEORETICAL MODEL

Our theoretical model of the parity–tooth loss relationship (Figure 1) was based on that of Adler et al.,[20] who suggested that one's socioeconomic position may affect one's general health via 3 distinct pathways: (1) health care, (2) psychosocial factors, and (3) health behaviors. In our theoretical model, we hypothesized that parity (which has been shown to be closely related to socioeconomic position) would affect tooth loss both directly (i.e., physiologically), via hormonal changes that accompany pregnancy, and indirectly, via 3 pathways similar to those of Adler's model: dental health care, psychosocial factors (specifically marital status, social support, and financial

stress), and dental health–damaging behaviors (specifically smoking and a cariogenic diet).

It is likely that all of these potential mediating variables are affected by parity and, in some cases, by one another. For example, psychosocial factors may influence tooth loss either directly, through their effects on inflammatory periodontal disease levels, or indirectly, through dental care or health-damaging behaviors. Likewise, behaviors that damage dental health may influence tooth loss directly (through physiological changes associated with pregnancy) or indirectly (through dental care).

Pregnancy affects a woman's hormonal exposure throughout her lifetime, and hormonal exposure is related to periodontal health[21,22] and tooth loss.[23,24] There are several examples of evidence supporting indirect relationships through the 3 groups of potential mediators included in our theoretical model. First, dental care utilization has been shown to be low among pregnant women,[25,26] even though they are often eligible for higher levels of dental insurance coverage.[27] Second, increased parity may be related to decreased dental insurance coverage.[28]
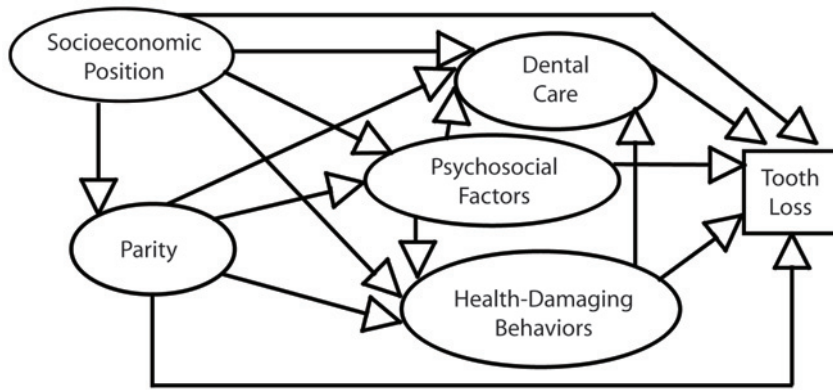
Third, psychosocial status is related to both pregnancy[29] and parity,[28,30] as well as to dental health (via dental care).[31,32] Finally, although smoking typically declines during pregnancy, increased parity is related to relapses in smoking after delivery,[33] and smoking is directly related to psychological stress.[34] Indeed, smokers are less likely to visit the dentist than nonsmokers despite requiring more regular dental care (because of smoking-related dental disease).[35–37]

Path analyses of our proposed theoretical model, which included these dental care, psychosocial, and behavioral variables, allowed us to explore the complex relationships between and among variables. We hypothesized that increased parity would be associated with increased tooth loss and that the relationship would be mediated in part by dental care, psychosocial, and behavioral factors.

METHODS

Study Population

We used data from the Third National Health and Nutrition Examination Survey

Objectives. We assessed the impact of parity on tooth loss among American women and examined mediators of this relationship.

Methods. The study sample comprised 2635 White and Black non-Hispanic women who had taken part in the third National Health and Nutrition Examination Survey. We examined the relationship between parity and tooth loss, by age and by socioeconomic position, and tested a theoretical model focusing on direct and indirect influences of parity on dental disease. Robust regression techniques were used to generate path coefficients.

Results. Although parity was associated with tooth loss, the relationship was not moderated through dental care, psychosocial factors, or dental health–damaging behaviors.

Conclusions. Parity is related to tooth loss among American women, but the mechanisms of the association remain undefined. Further investigation is warranted to determine whether disparities in dental health among women who have been pregnant are caused by differences in parity or to physiological and societal changes (e.g., factors related to pregnant women's access to care) paralleling reproductive choices. (*Am J Public Health.* 2008;98:1263–1270. doi: 10.2105/AJPH.2007.124735)

FIGURE 1—Theoretical model of relationships between parity and tooth loss.

(NHANES III), a nationally representative study of the civilian, noninstitutionalized US population conducted from 1988 to 1994. Dental health data from NHANES III have been used extensively.[38–40] White and Black non-Hispanic women between the ages of 18 and 64 years who reported at least 1 pregnancy, had undergone a dental examination, and had retained at least 1 natural tooth were eligible for inclusion. As a result, the sample included nulliparous women who reported a history of pregnancy but had not delivered a live-born infant (e.g., whose pregnancy had ended in miscarriage, abortion, or stillbirth).

Women who were missing data on socioeconomic position measures (education, income, and occupation) and on parity were excluded. Completely edentulous women were not included because of the likelihood that they were different from other women in ways not assessed in our analysis; for example, they may have had a genetic predisposition to medical conditions with a profound effect on dentition (e.g., severe periodontitis), which in turn may have necessitated extraction of all teeth (and these conditions may have been related to parity as well).

Measures

Our outcome variable was tooth loss, measured as the sum of all permanent teeth (excluding third molars) identified as "missing" or "missing and replaced" because of disease. Explanatory variables included measures of socioeconomic position, parity, dental care,

psychosocial factors, and health-damaging behaviors.

Socioeconomic measures included family income (calculated as the poverty–income ratio [PIR]), education (number of years of school completed), and occupation (calculated using the Duncan socioeconomic index [SEI]).[41] (The PIR is the ratio of the midpoint of a family's income category to the inflation-adjusted poverty threshold; a ratio below 1 indicates that the family is below the poverty threshold. The SEI, an occupational prestige measure used by the US Census Bureau, is a mixture of occupational prestige scores and census occupation scores.) Parity was based on self-reported information.

Dental care measures included dental insurance coverage and frequency of dental care visits. In NHANES III, participants were asked whether they were covered by any health insurance that paid for any dental care. As a measure of frequency of dental visits, participants were asked "How often do you go to the dentist or dental hygienist?"

Three measures were used to assess psychosocial status: financial stress, marital status, and social support. Women who reported that they had no food or no money for food on 1 or more days during the previous month were considered to be under financial stress. Marital status was dichotomized as married (including women who were married but were not living with their husband, and living together with someone as married) versus unmarried. Six questions exploring frequency of

social contact, church or meeting attendance, and club or group membership were used to assess social support.

The dental health–damaging behaviors examined were smoking and consumption of a cariogenic diet. Smoking measures—self-reported smoking, number of cigarettes smoked per day, and serum cotinine concentration—captured both active and passive smoking. Women were categorized as current smokers (those who reported having smoked at least 100 cigarettes in their lifetime and were currently smoking), ex-smokers (those who reported having smoked 100 cigarettes in their lifetime but were not currently smoking), or nonsmokers (those who had not smoked 100 cigarettes in their lifetime).

As part of a food frequency questionnaire, participants were asked about their monthly consumption of 4 groups of cariogenic foods (those high in refined carbohydrates): cakes, cookies, and brownies; chocolate candy and fudge; artificially flavored beverages and fruit drinks; and nondiet sodas. These items were combined as a single measure of number of servings of cariogenic foods consumed per month.

Age at most recent live birth and time elapsed since most recent live birth were based on self-reported data. Women were considered to have diabetes if they reported a history of nonpregnancy-related diabetes.

Statistical Analyses

We first conducted univariate and bivariate analyses, by socioeconomic tertile, focusing on parity, tooth loss, and other variables of interest that would later be used in the modeling procedures. For the most part, we used repeated measures analysis of variance (ANOVA) to examine between-group differences in numbers of missing teeth by age and socioeconomic status; when ANOVA assumptions (e.g., homoskedasticity) were violated, we used the Kruskall–Wallis test. We used the Pearson χ^2 test to examine differences between categorical variables.

To maximize use of the available data and avoid collinearity problems in our modeling procedures, we created summed standardized scales for socioeconomic position, smoking, age at most recent live birth, and length of time since most recent live birth. In doing so, we

initially assessed correlations between items, then standardized the items, and finally examined Cronbach α reliabilities. When α reliabilities were 0.60 or more, we created scales by summing the standardized items. Because we chose a model-based approach over a sampling-based approach,[42] we did not compute population estimates. Monte Carlo simulation was used to impute missing values for variables other than socioeconomic position, parity, and tooth loss in PRELIS[43]; Stata[44] was used in all other analyses. We used Dunn–Sidak corrections to adjust for multiple comparisons.

The scale for socioeconomic position included years of education, PIR score, and SEI score; these variables were positively and significantly correlated at levels of 0.42 (education and PIR score), 0.36 (PIR score and SEI score), and 0.49 (education and SEI score). Smoking included self-reported smoking, number of cigarettes smoked per day, and serum cotinine concentrations; these variables were significantly correlated at levels of 0.67 (self-reported smoking and number of cigarettes smoked per day), 0.70 (numbers of cigarettes smoked per day and serum cotinine concentration), and 0.64 (self-reported smoking and serum cotinine concentration). The correlation between age at most recent live birth and time since most recent live birth was 0.84. Cronbach α reliabilities for the socioeconomic position, smoking, and age–time summary variables were 0.69, 0.87, and 0.89, respectively.

Preliminary analyses demonstrated nonnormal and extremely skewed distributions for several variables, especially tooth loss, and postestimation analyses revealed notable heteroskedasticity and influential outliers in the data. Thus, we used 2 algorithms in our robust path analysis, one that reduced the effects of influential outliers[45] and one that asymptotically attenuated heteroskedasticity with a White sandwich variance estimator.[46]

In the path analysis for each robust regression algorithm, we conducted specific-to-general hierarchical regressions[47] for those variables that loaded significantly on the outcome variable to create the initial part of the full model. Then we used a stepwise backward elimination approach to trim the robust regression models of nonsignificant paths and created a path diagram based on this final model. We

assessed zero-order relationships between the independent variables that loaded on each endogenous variable and performed intermediate regressions for each of the endogenous variables. All indirect paths were identified, and the sums of each of these indirect effects were calculated as the products of direct paths.

Next, we computed the spurious (unexplained) effects of each independent variable as the difference between zero-order effects and overall effects (direct effects added to the sum of indirect effects),[48] and we calculated an error term for each endogenous variable (square root of $1 - R^2$). Finally, we used ANOVA procedures to examine the interaction between parity and socioeconomic position.

RESULTS

Sample Characteristics

Of the 7078 White and Black non-Hispanic women aged 18 to 64 years examined in the NHANES III mobile examination center, 91.8% completed all or part of the dental examination, and of these women 95.2% had at least 1 tooth. Approximately 19% of the women reported no pregnancies, and 9.6% were missing data on socioeconomic position or parity. Of the remaining sample members, 40.4% were missing data on multiple variables; because our primary aim was to identify pathways through which parity affects tooth loss, we excluded these women. Our analysis included 60% of initially eligible women (n=2635).

Descriptive Analyses

Characteristics of the study participants by socioeconomic position tertile are presented in Table 1. Socioeconomic position was inversely related to parity and tooth loss. Women in the lowest socioeconomic tertile were far more likely than women in the middle and high tertiles to have borne more children; they also had more missing teeth. Figure 2 illustrates mean numbers of missing teeth according to parity level, stratified by age group and socioeconomic tertile. Within each age group and each socioeconomic tertile, women who reported more births had more missing teeth than did women who reported fewer births.

Robust Regression Models and Path Analyses

Socioeconomic position, race, parity, frequency of dental care visits, smoking, diabetes, age at most recent live birth, and length of time since most recent live birth were significant predictors of tooth loss in both of our robust regression algorithms (Table 2). The interaction between parity and socioeconomic position was not significant. The path model based on our final trimmed model is shown in Figure 3. Values along the paths are robust standardized regression coefficients; these coefficients represent the relative contributions of each term to the endogenous variable at the end of the arrow. Error terms for each variable (shown in gray) are standard errors. All relationships shown were statistically significant in both robust regression algorithms ($P \leq .001$). Although the path model controlled for age, length of time since most recent live birth, and diabetes, we did not include these variables in Figure 3 for the sake of clarity.

In general, higher variable scores indicated less favorable characteristics. The exceptions were socioeconomic position, social support, and dental care, which were reverse scored. We identified direct paths between socioeconomic position and tooth loss and between parity and tooth loss (robust standardized regression coefficients of −0.15 and 0.12, respectively; $P \leq .001$ for both), which indicated that women of lower socioeconomic position and women of higher parity were more likely to have increased levels of tooth loss. The direct relationship between frequency of dental care visits and tooth loss indicated that, paradoxically, women who received dental care more frequently had more missing teeth. Smoking was also directly related to tooth loss.

We identified several indirect paths: (1) from socioeconomic position to tooth loss through marital status and parity; (2) from socioeconomic position through parity alone; (3) from socioeconomic position to tooth loss through dental insurance coverage and frequency of dental care visits; (4) from socioeconomic position through frequency of dental care visits alone; (5) from socioeconomic position to tooth loss through smoking and frequency of dental care visits; and (6) from socioeconomic

TABLE 1—Demographic Characteristics of Women Aged 18 to 64 Years, by Socioeconomic Position (SEP): Third National Health and Nutrition Examination Survey, 1988–1994

	Low SEP	Middle SEP	High SEP
Total, no.	878	878	879
Black, %	61.3	38.8	26.5
Age, y, mean (SD)	36.8 (13.0)	38.7 (12.7)	41.2 (11.3)
Education, y, %			
≤11	36.3	6.5	0.9
12	53.8	51.0	19.1
≥13	9.9	42.4	80.0
PIR score,[a] mean (SD)	1.5 (0.8)	3.0 (1.0)	4.6 (1.8)
SEI score,[b] mean (SD)	23.6 (6.4)	31.4 (9.1)	58.0 (21.1)
Parity, no., %			
0	14.7	24.6	27.9
1	17.1	19.3	18.8
2	27.1	27.9	30.8
3	19.8	15.8	12.5
4–6	18.5	11.3	9.7
≥7	2.9	0.9	0.3
Parity, mean (SD)	2.4 (1.9)	1.8 (1.6)	1.6 (1.4)
No. of years since most recent birth, mean (SD)	11.7 (10.6)	13.6 (10.9)	14.1 (10.3)
Dental insurance coverage, %	53.4	67.2	68.5
One or more dental visits per year, %	37.6	60.8	77.6
Married, %	49.1	61.9	73.6
Median no. of contacts per week	50.7	52.0	46.3
1 or more days with no food/money for food in previous month, %	7.3	1.8	0.5
Current smoking, %	33.5	24.8	16.3
Median serum cotinine level, µg/mL	1.1	0.4	0.2
No. of servings of cariogenic foods per month, mean (SD)	64.4 (55.7)	50.1 (46.8)	41.8 (33.3)
Diabetes (self-reported), %	6.5	2.3	3.2
No. of missing teeth,[c] mean (SD)	5.2 (6.37)	3.8 (5.50)	2.3 (4.27)

Note. PIR = poverty–income ratio; SEI = Duncan socioeconomic index. With the exception of social support (P = .60), all demographic factors differed significantly between the 3 socioeconomic tertiles ($P \leq .001$).
[a]PIR is the ratio of the midpoint of a family's income category to the inflation-adjusted poverty threshold; a ratio below 1 indicates that the family is below the poverty threshold.
[b]The SEI is an occupational prestige measure used by the US Census Bureau, which is a mixture of occupational prestige scores and census occupation scores.
[c]Median numbers of missing teeth were 3, 1, and 0 in the low, middle, and high tertiles, respectively.

position through smoking alone. The intermediate variables in these paths can be viewed as mediators of the relationship between socioeconomic position and dental disease. Socioeconomic position was related to parity and marital status, and marital status was related to parity: women at higher socioeconomic levels were more likely to be married and to have a low number of children than women at lower socioeconomic levels, and married women had more children than did unmarried women.

DISCUSSION

As hypothesized, we found that increased parity was associated with tooth loss even after adjustment for relevant covariates (age, time since most recent birth, diabetes) and regardless of socioeconomic position. In fact, we found that parity's impact on tooth loss was stronger than the effects of either smoking or frequency of dental care visits, each of which is a well-established risk factor for tooth loss.[49–54]

To our knowledge, our results represent the first evidence in a large, heterogeneous sample of US women that parity is so profoundly related to tooth loss, and ours is the first study to attempt to identify possible reasons for this relationship. Although we are not the first to identify a positive relationship between parity and tooth loss,[17–19] researchers in previous large-scale investigations examining this connection have used data on elderly Scandinavian women. Thus, the results of these studies may not be generalizable to the racially and socioeconomically diverse US population.

Advantages of our investigation include the large, racially and socioeconomically diverse population included in the NHANES III database; the availability of detailed information on a large number of potential mediators and confounders; the high quality of the dental health data; and the use of a theoretical model examined via path analysis and robust regression techniques. We created our path coefficients through robust regression procedures that allowed us to minimize bias caused by outliers, and ensured that heteroskedasticity of model residuals did not compromise the results of the regression analyses. Because we confirmed the results of each robust regression with the robust algorithms, we are confident that these results are reliable.

Although parity is often defined as number of children born, it may also be viewed in a broader sense: as a composite construct that encompasses pregnancy, parity, and motherhood (raising children). These separate but interconnected facets of a woman's life may have profound biological, sociological, and behavioral effects. In particular, the pathological oral changes that occur as a result of the physiological alterations accompanying pregnancy are well documented.[3,6,7,11–13]

Studies have shown that gingivitis, inflammation of tooth-supporting soft tissues without accompanying breakdown of the alveolar bone, occurs in 30% to as many as 100% of pregnant women[12,13] and is associated with pathological changes in the oral microflora.[55,56] In general, such oral changes are considered transient, because in the vast majority of women, any gingivitis experienced during pregnancy subsides after childbirth. However, periodontal destruction (loss of
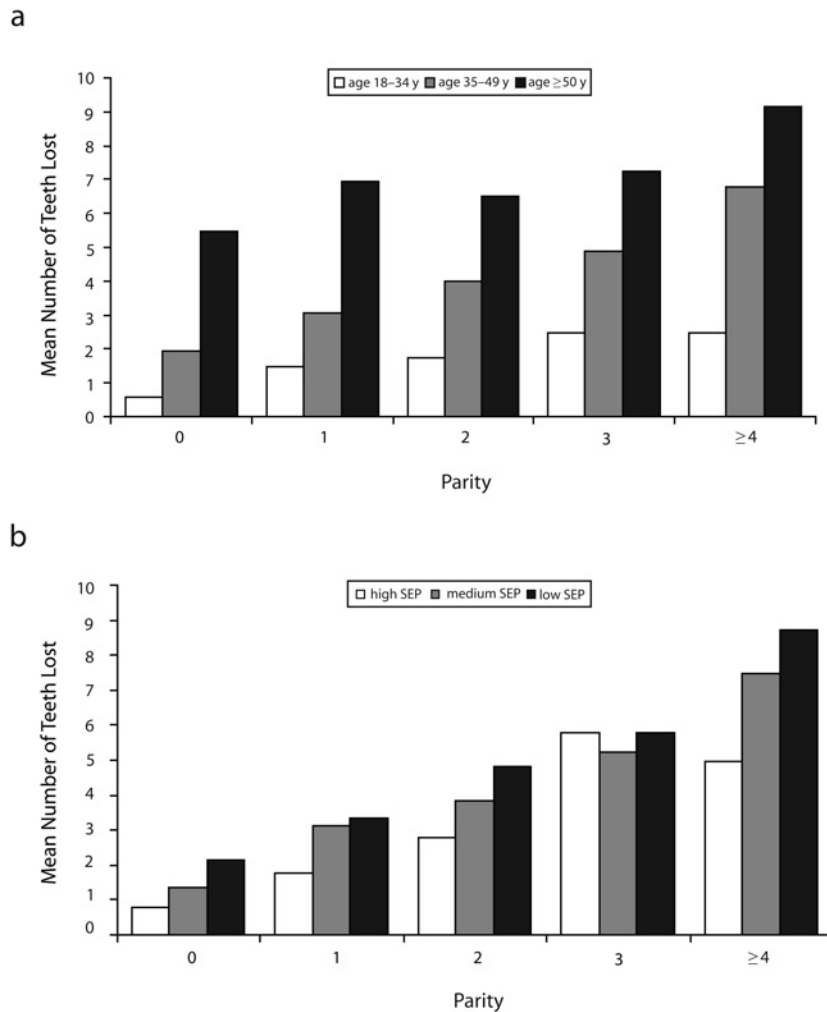
Note. SEP = socioeconomic position.

FIGURE 2—Tooth loss by parity level among 2635 women aged 18 to 64 years, stratified by age (a) and socioeconomic position (b): Third National Health and Nutrition Examination Survey, 1988–1994.

bony support of the teeth) has been shown to be common among pregnant women,[57–59] and investigators have found that periodontitis may worsen during pregnancy[60,61] or persist after parturition.[62] Gingivitis is a necessary prelude to irreversible periodontal breakdown,[63] and it has been postulated that repeated episodes of gingivitis during pregnancy, when combined with underlying periodontitis, could exacerbate the progression of existing periodontitis.[64]

Alternatively, empirical evidence demonstrates that pregnancy and parity have psychological sequelae, including anxiety and postpartum depression.[28–30] Because these psychological states have been shown to affect oral health by modulating behaviors (e.g., cigarette smoking[35,36] or compliance with recommended dental treatment[8,31,32,35,65]) or leading to direct alterations to the immune system,[66–68] repeated episodes of depression or psychological stress brought about by life changes such as pregnancy and parity can be hypothesized to ultimately have detrimental effects on oral health.

Because we did not find evidence of moderating effects of parity on dental disease outcomes via dental care, psychosocial factors, or health-damaging behaviors, our results could be viewed as supporting a biological association between parity and tooth loss. However, a perhaps more plausible reason that we did not find such evidence is that we were limited by the data gathered as part of NHANES III, in which the questions that explored key factors may not have captured the essence of these constructs. For example, regarding dental care, participants were asked "How often do you go to the dentist or dental hygienist?" and "Are you covered by any health insurance that paid for any dental care?" Although we assumed that frequency of dental care was positively correlated with regular preventive care, it is possible that, for some women, frequent dental care represented frequent emergency or palliative care.

In addition, in some states, the Medicaid program pays for dental care, and thus women of lower socioeconomic status may have reported having dental insurance coverage. Indeed, we found that 53% of women in the lowest socioeconomic tertile reported having dental insurance. Whereas a large proportion of these women probably had at least some of their dental care covered through Medicaid, it is likely that the majority of women in the highest socioeconomic tertile had private dental insurance. Medicaid reimbursement rates for dental care are generally low,[69] and preventive services are often not covered.

One would expect that effects of parity on frequency of dental care visits, financial stress, and social support in particular are strongest among women with young children living in the home. To increase the generalizability of our results, however, we included women up to the age of 64 years in our analyses. Post hoc bivariate correlation (Pearson r) tests of the effects of parity on tooth loss by age group indeed showed stronger correlations among women younger than 49 years (women 18–34 years, $r=0.23$, $P\leq.001$; women 35–49 years, $r=0.24$, $P\leq.001$) than among women 50 years or older ($r=0.19$; $P\leq.001$).

Our finding that increased parity was associated with increased tooth loss may suggest that women of higher parity are more likely to have teeth extracted, whereas women of
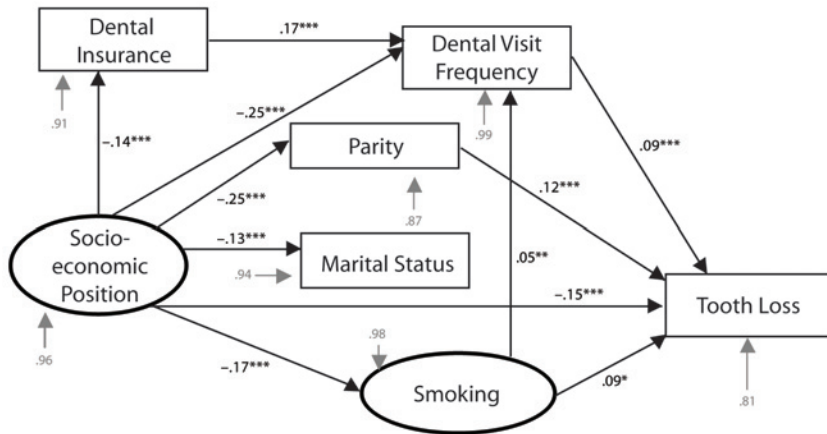
Note. The model controlled for race, age, length of time since most recent live birth, and diabetes status. Gray arrows denote standard errors. Black arrows indicate a significant relationship was found between the 2 variables. Values along the paths (black numbers) are standardized regression coefficients, which represent the relative contribution of each variable to the variable at the end of the arrow. Error terms for each endogenous variable are provided in grey typeface. **$P \le .01$; ***$P \le .001$.

FIGURE 3—Path diagram of socioeconomic position, parity, and tooth loss among 2635 women aged 18 to 64 years: Third National Health and Nutrition Examination Survey, 1988–1994.

TABLE 2—Results of Robust Regressions for Predictors of Tooth Loss Among Women Aged 18 to 64 Years: Third National Health and Nutrition Examination Survey, 1988–1994

	First Regression Algorithm,[a] Robust B (SE)	Second Regression Algorithm,[b] (95% CI)
Socioeconomic position	−0.15 (0.13)	−0.49 (−0.63, −0.36)
Race	0.17 (0.20)	1.41 (1.22, 1.61)
Parity	0.12 (0.07)	0.13 (0.07, 0.18)
Dental care frequency	0.09 (0.20)	0.37 (0.18, 0.57)
Smoking	0.09 (0.11)	0.25 (0.16, 0.35)
Age-time[c]	0.45 (0.12)	1.34 (1.23, 1.44)
Diabetes	0.05 (0.17)	0.32 (0.19, 0.47)

Note. See "Methods" section for descriptions of algorithms. With the exception of diabetes in the first algorithm ($P = .012$), all values were significant at $P \le .001$.
[a]$R^2 = 0.35$; $F_{7,2635} = 145.7$; $P \le .001$.
[b]$F_{8,2626} = 176.0$; $P \le .001$.
[c]Age at and length of time since most recent live birth.

lower parity are more likely to have teeth restored or treated. Indeed, it has been shown that both pregnancy and maternity alter patterns of dental treatment among women.[25,26,70] In the United States, in fact, it is generally recommended that pregnant women undergo dental care only during the second trimester,[71,72] and therefore dentists may be reluctant to offer women treatment either early or later in their pregnancy. Women seeking care during their first or third trimester may be offered alternative treatments, or treatment may be deferred.[70,72]

Dentists are also likely to alter treatment plans on the basis of a woman's ability to pay for a particular treatment, comply with scheduled appointments, and engage in adequate oral self-care to prevent disease progression; all of these factors are probably affected by pregnancy or motherhood. In addition, pregnant women may believe that they need to postpone dental therapy until

after they have given birth[73]; however, access to dental care among women with multiple children is likely to be restricted as a result of financial, time, or child-care constraints.[74,75]

Although recent studies have identified demographic, biological, and behavioral risk factors for dental disease,[9,37,49–52] social risk factors remain largely undefined and underexplored, despite the fact that (as is the case with systemic disease) disparities in dental disease are most likely caused by such factors.[77] The public health implications of identifying additional predictors of poor dental health are considerable. Women who have experienced changes in dental care, psychological status, or health behaviors because of pregnancy or motherhood are likely to represent a significant proportion of the US population, and interventions aimed at these women could have a positive impact on their dental health status.

Given the strong relationship between parity and tooth loss observed in this study, there is a clear need for future investigations designed to enhance understanding of the ways in which parity influences dental health. Treating depression and anxiety during and after pregnancy, improving pregnant women's access to and use of preventive dental care services, and enhancing family dental health programs could attenuate parity-related dental health disparities in the future. ■

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Human Participant Protection

This study was approved by the institutional review boards of New York University and Yale University.

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