Association of Childhood Socioeconomic Status with Edentulism Among Chinese Middle-aged Adults

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Abstract

Objectives

The purpose of this study was to examine the association between childhood socioeconomic status (SES) and edentulism using directed acyclic graphs (DAGs) for the selection of confounders, and after adjusting for childhood health, adult SES, adult health-related behaviors and father’s health-related behaviors.

Methods

Chinese respondents in a Health and Retirement Longitudinal Study (CHARLS) were assessed at age 45 and 59 years. Childhood SES was determined using the father’s education, parents’ occupation, father’s working status, family’s financial situation, self-perceived childhood health, relationship with the father, mother’s effort to care for her child, mother’s love and affection, parents quarrel and fight, residential community safety, primary residence, neighbors’ help, neighborhood relation, enough food availability and access to medical care and convenience. Father’s health-related behaviors were established by taking into account smoking and drinking habits. Childhood health was determined by considering childhood hospitalization and self-perceived childhood health status. Adult SES was established based on adulthood educational achievements. Adult health-related behaviors were determined by taking into account smoking and drinking habits, as well as physical activities and sleep time. Edentulism was determined using self-reported lost all of teeth. The mediators were selected using DAGs, cross-tabulation and binary logistic regression models based on DAGs. Model assessment of the regression equation was evaluated by Hosmer-Lemeshow goodness-of-fit test.

Results

Data from a total of 7,459 respondents were available, 140 of whom were edentulous (1.9%). The prevalence of edentulism at ages 45 and 59 years was substantially higher among those with low childhood SES. In all adjusted models based on DAGs, edentulism was negatively associated with father’s occupation as farmer (OR = 5.7, 95% CI = 1.3–25.0) and neighbor’s unwillingness to help (OR = 4.9, 95% CI = 1.6–15.4).

Conclusion
Childhood SES was associated with the prevalence of edentulism among middle-aged Chinese adults, whereas the father’s occupation, and neighbor’s help were negatively associated with edentulism. The experiences in early life associated with low SES contributes to poor dental health. Therefore, more attention needs to be paid to childhood SES in order to determine optimal recommendations and develop more effective intervention strategies.

Background
Edentulism or toothlessness, the state of having lost all natural teeth, is a worldwide public health issue, especially in low- and middle-income countries (LMICs), due to its high prevalence and associated disability. Monitoring edentulism is a determining factor in the assessment of the performance of the dental health care system and adequacy of population health surveillance. Edentulism is an irreversible condition and, as the final marker of dental disease burden, dental consequences include impaired masticatory function, unhealthy diet, and poor dental health quality of life. Edentulism has been associated with coronary heart disease, stroke, and all-cause mortality, as well as with a negative impact on life quality, due to pain, infection, speech difficulties and decreased self-esteem. A recent study investigated the potentially deleterious physical and social effects of edentulism in younger ages, and found that living with edentulism was associated with depression in younger individuals.

Socioeconomic status (SES) is a major determinant of dental health and prevention of oral diseases, and is a high priority for prevention efforts. Multiple studies indicate that dental health is associated with socioeconomic factors, such as education, economic status, social class, income and residence. Edentulism is closely associated with SES and is more prevalent in poor populations. Mediators of the effect of SES on dental health include material deprivation, physical, psychosocial and behavioral factors, as well as access to health care services. Economic difficulty, one of the most important determinants of tooth loss among elders, is associated with increased
psychological distress, which influences immune function, thereby raising the risk of periodontal disease. Low SES affects health care access, and lack of access to dental care may contribute to tooth loss, thus the prevalence of severe tooth loss remains high among adults from low childhood SES groups. According to the World Health Organization (WHO) Study on global AGEing and adult health (SAGE) (2007-2010), the prevalence rate of edentulism in China was between 8.0-9.0%. A comprehensive literature review reported the theory of the life course epidemiology, which proposes that physical and social exposures during a specific developmental period in life (e.g., gestation, childhood, adolescence, and young adulthood), have potent and long-term effects on health outcomes or disease risk later in life. Several theories have been developed to explain how childhood exposures affect adult health and disease development. Research has demonstrated a direct connection between childhood SES and adult health, regardless of whether a child manifests health consequences during childhood or changes SES from childhood to adulthood. Children with low SES experience greater health problems in childhood, and aspects of their SES are biologically incorporated through both critical developmental periods and cumulative effects, which ultimately lead to poor adult health outcomes. A dose response effect has been observed between a lower SES and adverse health outcomes across different developmental stages of life. Further studies have indicated that childhood SES exposures are effective predictors of adult health outcomes. They propose that changes of organ systems or physiologic processes that happen during critical periods are irreversible, emphasizing the that physical and social environments experiences have cumulative effects on health later in life. Dental health disparities in childhood is a useful example for understanding the life course.

Studies to date have not focused on childhood SES and later edentulism. In fact, few studies based on birth cohort analysis have been published, one study reported that changes in socioeconomic advantage or disadvantage were associated with dental caries and tooth loss in adulthood. The findings from the Survey of Health, Ageing and Retirement in Europe highlighted
the long-lasting relation between childhood living conditions and oral health. Another study based on the Costa Rican Longevity and Healthy Aging Study 1945-1955 Retirement Cohort, found that socioeconomic conditions in early life had long-term consequences on severe tooth loss. The New Zealand cohort study found a threefold increase in adult periodontal disease and caries in low versus high childhood SES groups. A Korean study determined that father’s education level was associated with the edentulous status of elders.

Directed acyclic graphs (DAGs) are nonparametric graphical tools to represent causal relationships among variables underlying the exposures and outcomes, considering potential confounders and mediators, which have been advocated for dental research, but which have yet to be widely adopted. DAGs can be used to identify potential confounders, mediators and colliders, as they specify the relationships among other variables that influence the exposures or outcomes. DAGs can also incorporate mediator variables as a consequence of the exposure and a cause of the outcome, as well as inform the data analysis strategy based on the relations among variables. DAGs were constructed to guide the selection of the variables to be adjusted for statistical analysis to obtain unbiased estimates.

No birth cohort study has been conducted with Chinese population health data, and there is lack of evidence regarding the association between childhood SES and edentulism in China. To the best of our knowledge, this is the first study to examine the association between childhood SES and edentulism in China, especially using DAGs to estimate the effect of childhood SES on edentulism. 

Methods

2.1 The sample

The study used the China Health and Retirement Longitudinal Study (CHARLS) from a nationally representative dataset was collected, using a steady-state design, from 450 villages or communities in 150 counties or districts of 28 provinces. The baseline survey was conducted in 2011, through a
four-stage, stratified, cluster probability sampling design. The surveys in 2014 and 2015 contained assessments of social, economic and health status, and recruited additional individuals who just became 45 years old. Further details are provided elsewhere, we pooled data from the baseline survey and new respondents in the rounds 2 and 3 surveys. For the analyses in this study, we combined the 2011–2015 data, the exclusion criteria were as follows: (i) those aged 60 years; (ii) those who did not report an edentulous status; and (iii) those with values missing from the questionnaires. A total of 8,641 respondents were included in the initial data, edentulous status was measured for 7,938 respondents, and 479 were excluded. Ultimately, 7,459 respondents (3,308 males and 4,151 females) were selected for the fully-adjusted model analysis.

2.2 Measure

Edentulism was assessed based on the response question: “Have you lost all of your teeth?”, the variable had two options (yes or no).

2.2.1 Childhood SES and father’s health-related behaviors

Parental SES levels were used as childhood SES, and were derived from CHARLS. Father’s education consisted of four responses (illiterate, elementary school, middle school, and high school or above). The occupation of the parents were dichotomized in two groups (farmer and non-agricultural). The father’s working status was divided into “all of childhood” and “part of childhood”. Family’s financial situation and self-perceived childhood health were classified as four groups (very good, good, fair, poor, or very poor). Relationship with father was classified as four groups (excellent, very good, good, or poor). Mother’s effort to care for her child was classified into four groups (a lot, some, a little, or none at all). Mother’s expression of love and affection were classified as four groups (often, sometimes, rarely, or never). Parents quarrel and fight were classified as four groups (often, sometimes, not very often, or never). Residential community security was divided into three groups
(very safe, somewhat safe, or not safe). Primary residence was divided into two groups (rural or urban), neighbors’ help included three groups (willing to, somewhat willing to, or unwilling to). Neighborhood relation included three groups (very close-knit, somewhat close-knit, or not close-knit). Enough food, medical convenience, and father’ smoking and drinking habits had two options (yes and no).

2.2.2 Childhood health
Childhood hospitalization (≥1 month) had two options (yes and no). Self-perceived childhood health status was classified as five groups (very good, good, fair, poor, or very poor).

2.2.3 Adult SES
Adult SES was assessed by adult educational achievements, divided into four groups (illiterate, elementary school, middle school, or high school and above).

2.2.4 Health-related behaviors
Health-related behaviors included smoking (yes and no) and drinking (1 time/month, ≤1 times/month, and not drinking). Physical activities every week had two options (yes and no). Sleep time was divided into four groups (≤4 h/day, 4-6 h/day, 6-8 h/day and 8 h/day).

2.3 Directed acyclic graphs (DAGs)
We used DAGs to analyze mediators of the association between the main exposure and the outcome, DAGs are considered as sets of arrows between exposures and outcomes and specify the relationships among mediators of exposures and outcomes. In this study DAGs were prepared based on theory, literature review and empirical evidence, as shown in Figure 1. This conceptual model identifies the minimally sufficient set of mediators and makes explicit assumptions to account for mediators of the relationship of childhood SES and edentulism. In the CHARLS dataset, there were
four set of mediators: (1) father’s health-related behaviors; (2) childhood health; (3) adulthood SES; (4) adulthood health-related behaviors. We identified 16 variables of childhood SES, 2 variables of both father’s health-related behaviors and child health, 4 variables of adult health-related behaviors, and only one variable of adult SES. We used DAGitty v2.3 \(^49\) to assess the postulated DAGs.

### 2.4 Statistical analysis

The differences in edentulism by sex, childhood SES, father’s health-related behaviors, childhood health, adult SES, and health-related behaviors were analyzed using the Pearson’s Chi-Square tests or Fisher’s Exact tests. To account multicollinearity problems among childhood SES, confounding factors and edentulism variable, we applied a multicollinearity test. The variance inflation factor (VIF) and tolerance (TOL) were analyzed for detecting multicollinearity problems \(^50,51\) (VIF\(<5.0\) or TOL\(>0.2\)) \(^52\).

To adjust for potential confounders, three stepwise binary logistic regression models were run to examine the association between childhood SES and edentulism. Sex, childhood SES and father’s health-related behaviors childhood health were adjusted in model 1; adult SES was subsequently adjusted in model 2; finally, health-related behaviors were adjusted in model 3. The odds ratio (OR) and the 95% confidence interval (CI) were used to compare the effects on the independent variables. We checked the presence of interaction effects between independent variables, performed overall model evaluation and goodness-of-fit statistics of the model. The statistical significance was considered as two-sided \(P\)-value < 0.05. All analyses were conducted using the Stata 14 software (Stata Corp. LLC, College Station, Texas, USA).

### Results

#### 3.1 Adjustment sets and regression analysis

The descriptive statistics and univariate analysis are presented in Table 1 and 2. A total of 140 respondents were edentulous (1.9%). Individuals whose father’s occupation was farmer were more likely to be edentulous than those whose father’s occupation was non-agricultural (1.9% vs 0.9%, \(p = 0.027\)). Individuals whose mother’s occupation was farmer were more likely to be edentulous than
those whose mother’s occupation was non-agricultural (1.9% vs 0.6%, \( p = 0.028 \)). Individuals whose parents often quarrel were more likely to be edentulous than those whose parents quarrel less often (2.5% in often quarrel vs 1.6% in sometimes, 1.4% in not very often, 0.7% in never; \( p = 0.005 \)). Individuals whose neighbor were unwilling to help were more likely to be edentulous than those whose neighbors were more willing to help (3.6% in unwilling vs 1.6% in somewhat willing, 1.9% in very willing; \( p = 0.009 \)). Individuals whose adult education achievement was illiterate were more likely to be edentulous than those with other education levels (3.8% in illiterate vs 2.1% in elementary school, 1.8% in middle school, 0.9% in high school or above; \( p = 0.001 \)).

The results of the multicollinearity test, presented in Table 3, reveal that there was no multicollinearity problem with these variables, and all the VIF values were ≤ 3.0 and TOL values were ≥ 0.2. The binary logistic regression analyses based on DAGs are presented in Table 4. As shown in model 1, sex, when father’s health-related behaviors and childhood health were adjusted, father’s occupation as farmer (OR = 5.6, 95% CI = 1.3–24.4), neighbor’s unwillingness to help (OR = 5.3, 95% CI = 1.8–15.8), and neighbor’s somewhat willing to help (OR = 4.4, 95% CI = 1.6–12.2) were negatively associated with edentulism, and adequate calibration was assessed by the Hosmer-Lemeshow test (\( c^2 = 60.9, p = 0.023 \)), goodness-of-fit test (Hosmer-Lemeshow: \( c^2 = 9.2, p = 0.328 \)). As shown in model 2, adult when SES was adjusted, father’s occupation as farmer (OR = 5.4, 95% CI = 1.2–23.8), 15.2) and neighbor’s somewhat willing to help (OR=3.8, 95% CI=1.3–10.8) were negatively associated with edentulism, and adequate calibration was assessed by the Hosmer-Lemeshow test (\( c^2 = 4.2, p = 0.834 \)). As shown in model 3, when health-related behaviors were adjusted, father’s occupation as farmer (OR = 6.0, 95% CI = 1.3–27.0), neighbor’s unwillingness to help (OR = 4.9, 95% CI = 1.6-15.4) and neighbor’s somewhat willing to help (OR = 3.7, 95% CI = 1.3-11.1) remained negatively associated with edentulism, and adequate calibration was assessed by the likelihood ratio test (\( c^2 = 69.6, p = 0.042 \)).

Discussion
To the best of our knowledge, this is the first study to examine the association between childhood SES
and edentulism across the life course of middle-aged Chinese adults. We used DAGs to analyze mediators variables adjusted in the statistical models. Childhood SES was found to be strongly associated with edentulism. After controlling for sex, father’s health-related behaviors, childhood health, adult SES and health-related behaviors, the father’s occupation as farmer, and neighbor’s unwillingness to help in the final model remained negatively associated with edentulism. In this study, the regression models based on DAGs suggested the effects of childhood SES on edentulism in middle-aged adults. These results support the research hypothesis that low childhood SES is negatively associated with edentulism across the life course.

Due to the omission of key variables and inclusion of non-existing causal paths, the logistic regression may result in an inappropriate analytical model. To assess the analysis validity, in this study, DAGs were used to illustrate the assumption of the association of childhood SES and edentulism, the mediators of adult SES, childhood health, health-related behaviors and father’s health-related behaviors, thereby providing a clearer picture of the relationships between exposures and outcomes. In this study, the statistical models based on DAGs showed the negative effect of low childhood SES on edentulism. Due to the existence of multivariable and complicated factors of edentulism, compared with the different adjusted variables, the mediators of the association of childhood SES and edentulism were preliminarily determined using DAGs. For the path from childhood SES to edentulism, DAGs showed a typical situation in LMICs, where adult SES, childhood health, health-related behaviors and father’s health-related behaviors may be mediators of the effects of childhood SES and edentulism.

The results of this study are consistent with those in previous life-course epidemiological studies on other adult diseases, and also support the hypothesis that low childhood SES is negatively associated with edentulism in middle-aged adults. After controlling for sex, father’s health-related behaviors, childhood health, adult SES and health-related behaviors, the effects of the father’s
occupation, neighbor’s help and edentulism were attenuated, but still statistically significant. Our findings are consistent with those of previous studies which indicated that children whose parents were farmers were more likely to present edentulism in adulthood\textsuperscript{30,56}. Another study showed that social support was a positive factor for dental health-related quality of life\textsuperscript{22}, which is consistent with the results of this study, indicating that children who lived in an environment where neighbors were unwilling to help, were more likely to be edentulous in adulthood. In this study, the respondents were 45-59 years old, born between 1955 and 1970 and the survey was conducted from 2011 to 2015. Additionally, the respondents spent their childhood and early adulthood before 1988 year, when China was mainly an agricultural society with undeveloped industrialization, men played the main role in society, the role of the male occupation in the family was more emphasized than that female. Therefore, the father’s occupation as an effective indicator of childhood SES, had a stronger association with edentulism than that of the mother.

This study has a number of limitations. For example, some mediating variables in adulthood were not considered, this study could consider associated factors that were available in CHARLS. Therefore, the results were explained based on the limited variables, and it was acknowledged that the effects of childhood SES on edentulism may not be determined by variables that could not be adjusted. For instance, CHARLS did not include any data on childhood dental health information, dental preventive or nutritional information in childhood, which are important associated factors. Another limitation was that CHARLS contained limited information on the SES of the respondents between childhood and aged 45+, and SES from childhood into adulthood may have independent impacts on edentulism. In addition, we assessed childhood SES using retrospective data, and analyzed parents’ SES as proxy variables, although these variables were proved to be well validated. Moreover, the data of childhood SES relied on some self-reported variables, which could potentially introduce reporting bias, although other studies have suggested that the self-reported dental health variables were valid and reflected dental status\textsuperscript{57,58}. Retrospective reporting of Childhood SES might be subject to differential recall
bias. To date, the assessment of dental health in CHARLS has not been systematically validated, such as the survival bias. The results indicated that the prevalence of edentulism (1.9%) was lower than the global incidence (4.1%) \(^{59}\). These could potentially result in the underestimation of the effects of childhood SES on edentulism. Notwithstanding these limitations, CHARLS is a unique resource for studying childhood SES in relation to adult dental health in China.

Despite these limitations, this study has many strengths. For example, we used a unique and representative population of middle-aged Chinese adults, and analyzed numerous childhood SES variables. To the best of our knowledge, this study is the first using a large sample to analyze the association between childhood SES and edentulism in middle-aged adults in a LMICs country. Another major strength of this study is the assessment of the associations of exposure and outcome using DAGs in the statistical analyses. To confirm the potential association between childhood SES and edentulism, we adjusted sex, father’s health-related behaviors, childhood health, adult SES and health-related behaviors in the final logistic regression model. Regardless of the childhood SES, the study of adult dental health may have overestimated the effects of other variables, such as adulthood SES. Childhood SES has been suggested as an important risk factor for dental health \(^2\), and inequality with respect to awareness, attitudes, philosophies of dental health as well as access to dental health care \(^7\). Irrespective of individual factors, edentulism is also significantly associated with the lack of, or limited access to, dental care and higher SES inequalities, which happened often in health care resource-limited settings. In some LMICs, tooth extraction, which cause edentulism, is the only treatment available for dental problems. Children who lived mainly with low SES were more likely to have access to inadequate health care services, which had difficulty to meet their basic dental health demands \(^60\). Family’s SES positively correlated with high quality and affordability of dental health services \(^45\), poor childhood SES could limit the capacity to afford dental health services and thus those children were restricted in access to dental health services. Low childhood SES may be a restrain on the family living status, which may cause direct risk factors, and medical convenience was
the embodiment of the accessibility to dental health services, which further affected childhood diet quality, dental health and health-related behaviors. Inequitable distribution of dental health services may explain the association between childhood SES and edentulism, and medical inconvenience in childhood may place individuals at higher risk of edentulism. Children who did not receive adequate and advanced dental health services, but received less preventive dental health information may become vulnerable to dental diseases, which could be avoided. Studies have shown that health-related behaviors, such as smoking and alcohol consumption contribute to lower the SES in cardiovascular disease (CVD) mortality. Low childhood SES may be a higher risk factor in adulthood. Behavioral and psychosocial factors may have an influence on childhood and adulthood health. Also, since hygiene behaviors and dietary patterns are developed in childhood, childhood SES influences nutritional and immune development and may change the susceptibility to infectious dental diseases in adulthood.

Conclusions
In conclusion, this study contributes to the literature on the life course pathways from childhood SES to edentulism. The findings of this study suggested that low childhood SES was negatively associated with edentulism. Additionally, the results of this study supported the evidence of the association between childhood SES and dental health in a representative sample of Chinese adults. We also identified the risk factors of low childhood SES, which can help policy makers and researchers to understand the importance of childhood SES, and should not be neglected by public health especially in LMICs. This study can generate optimal recommendations and intervention strategies to meet the needs of dental health in childhood in LMICs.

Abbreviations
SES: childhood socioeconomic status; DAGs: directed acyclic graphs; CHARLS: Chinese respondents in a Health and Retirement Longitudinal Study; LMICs: Low- and middle-income countries; WHO: World Health Organization; SAGE: Study on global AGEing and adult health; VIF: Variance inflation factor; TOL: Tolerance; OR: Odds ratio; CI: Confidence interval; CVD: cardiovascular disease.

Declarations
**Ethics approval and consent to participate**

This study used secondary data from CHARLS. The agency responsible for the survey is Peking University.

**Consent for publication**

Not applicable.

**Availability of data and material**

Please contact CHARLS (China Health and Retirement Longitudinal Study) for data requests.

http://charls.pku.edu.cn/zh-CN

**Competing interests**

The authors declare no conflict of interest.

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**Authors’ contributions**

XNZ contributed to the conception and design of the study, data analysis, interpretation of the results, and drafted and critically reviewed the manuscript; SC contributed to data analysis. All authors gave final approval and agree to be accountable for all aspects of this work.

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Tables

Table 1. Univariate analysis of gender and childhood SES of Chinese adult’s edentulism

| Variables                  | Edentulism | N (%) | P-value |
|----------------------------|------------|-------|---------|
|                            | Yes (%)    | No (%)|         |
| **Gender**                 |            |       |         |
| Male                       | 61 (1.8)   | 3247 (98.2) | 3308 (44.4) | 0.852 |
| Female                     | 79 (1.9)   | 4072 (98.1) | 4151 (55.7) |       |
| **Childhood SES**          |            |       |         |
| Father's education         |            |       |         |
| Illiterate                 | 75 (2.4)   | 3037 (97.6) | 3112 (44.9) | 0.019 |
| Elementary school          | 41 (1.5)   | 2773 (98.5) | 2814 (40.6) |       |
| Middle school              | 6 (1.0)    | 583 (99.0)  | 589 (8.5)   |       |
| High school or above       | 7 (1.7)    | 403 (98.3)  | 410 (5.9)   |       |
| Father's occupation        |            |       |         |
| Farming                    | 92 (1.9)   | 4717 (98.2) | 4806 (81.8) | 0.027 |
| Non-agricultural           | 10 (0.9)   | 1060 (99.1) | 1070 (18.2) |       |
| Mother's occupation        |            |       |         |
| Farming                    | 123 (1.9)  | 6220 (98.1) | 6343 (92.5) | 0.028 |
| Non-agricultural           | 3 (0.6)    | 510 (99.4)  | 513 (7.5)   |       |
| Father's work status       |            |       |         |
Table 2. Univariate analysis of childhood health, adult SES and health related behaviors of Chinese adult's edentulism

| SES, socioeconomic status.               | Yes | No      | Yes | No | Yes | No |
|------------------------------------------|-----|---------|-----|----|-----|----|
| All of childhood                         | 129 (1.8) | 6948 (98.2) | 7077 (97.1) | 0.567 |
| Part of childhood                        | 5 (2.4) | 207 (97.6) | 212 (2.9) |    |
| Family’s financial situation            |     |         |     |    |     |    |
|   Very good                              | 2 (2.1) | 93 (97.9) | 95 (1.3) | 0.564 |
|   Good                                   | 11 (1.6) | 682 (98.4) | 693 (9.3) |    |
|   Fair                                   | 73 (1.9) | 3796 (98.1) | 3869 (52.1) |    |
|   Poor                                   | 18 (1.5) | 1199 (98.5) | 1217 (16.4) |    |
|   Very poor                              | 36 (2.3) | 1523 (97.7) | 1559 (21.0) |    |
| Relationship with father                 |     |         |     |    |     |    |
|   Excellent                              | 41 (1.8) | 2185 (98.2) | 2226 (30.9) | 0.811 |
|   Very good                              | 45 (1.9) | 2394 (98.2) | 2439 (33.8) |    |
|   Good                                   | 25 (2.1) | 1176 (97.9) | 1201 (16.7) |    |
|   Poor                                   | 21 (1.6) | 1322 (98.4) | 1343 (18.6) |    |
| Mother’s effort to watch over            |     |         |     |    |     |    |
|   A lot                                  | 79 (2.0) | 3977 (98.1) | 4056 (56.0) | 0.283 |
|   Some                                   | 36 (2.2) | 1576 (97.8) | 1612 (22.2) |    |
|   A little                               | 16 (1.4) | 1173 (98.7) | 1189 (16.4) |    |
|   Not at all                             | 5 (1.3) | 386 (98.7) | 391 (5.4) |    |
| Mother’s love and affection              |     |         |     |    |     |    |
|   Often                                  | 76 (1.8) | 4223 (98.2) | 4299 (59.4) | 0.216 |
|   Sometimes                              | 33 (2.3) | 1423 (97.7) | 1456 (20.1) |    |
|   Rarely                                 | 21 (2.3) | 889 (97.7) | 910 (12.6) |    |
|   Never                                  | 6 (1.1) | 562 (98.9) | 568 (7.9) |    |
| Parents quarrel                          |     |         |     |    |     |    |
|   Often                                  | 3 (2.5) | 402 (99.3) | 405 (5.4) | 0.005 |
|   Sometimes                              | 23 (1.6) | 1448 (98.4) | 1471 (19.7) |    |
|   Not very often                         | 36 (1.4) | 2491 (98.6) | 2527 (33.9) |    |
|   Never                                  | 67 (0.7) | 2572 (97.5) | 2639 (35.4) |    |
| Parents fight                            |     |         |     |    |     |    |
|   Often                                  | 3 (2.5) | 118 (97.5) | 121 (1.7) | 0.366 |
|   Sometimes                              | 6 (1.3) | 458 (98.7) | 464 (6.6) |    |
|   Not very often                         | 12 (1.2) | 968 (98.8) | 980 (13.9) |    |
|   Never                                  | 104 (1.9) | 5362 (98.1) | 5466 (77.7) |    |
| No enough food                           |     |         |     |    |     |    |
|   Yes                                    | 80 (2.0) | 3845 (98.0) | 3925 (53.1) | 0.286 |
|   No                                     | 59 (1.7) | 3410 (98.3) | 3469 (46.9) |    |
| Residential community security           |     |         |     |    |     |    |
|   Very safe                              | 60 (1.8) | 3322 (98.2) | 3382 (46.4) | 0.288 |
|   Somewhat safe                          | 56 (1.7) | 3198 (98.3) | 3254 (44.7) |    |
|   Not safe                               | 17 (2.6) | 634 (97.4) | 651 (8.9) |    |
| Primary residence                        |     |         |     |    |     |    |
|   Rural                                  | 102 (2.0) | 4568 (97.8) | 4670 (91.3) | 0.591 |
|   Urban                                  | 8 (1.8) | 437 (98.2) | 445 (8.7) |    |
| Neighbor’s help                          |     |         |     |    |     |    |
|   Very willing to                        | 70 (1.9) | 3697 (98.1) | 3767 (51.3) | 0.009 |
|   Somewhat willing to                    | 48 (1.6) | 3022 (98.4) | 3070 (41.8) |    |
|   Not willing to                         | 18 (3.6) | 488 (96.4) | 506 (6.9) |    |
| Neighborhood relation                    |     |         |     |    |     |    |
|   Very close-knit                        | 64 (1.8) | 3452 (98.2) | 3516 (47.6) | 0.903 |
|   Somewhat close-knit                    | 69 (1.9) | 3571 (98.1) | 3640 (49.3) |    |
|   Not close-knit                         | 5 (2.2) | 221 (97.8) | 226 (3.1) |    |
| Medical convenience                      |     |         |     |    |     |    |
|   Yes                                    | 92 (1.6) | 5521 (98.4) | 5613 (94.9) | 0.688 |
|   No                                     | 4 (1.3) | 295 (98.7) | 299 (5.1) |    |
|   Very poor                              | 8 (2.2) | 349 (97.7) | 357 (4.8) |    |
| Variables                               | Edentulism | N (%)     | P-value |
|-----------------------------------------|------------|-----------|---------|
|                                         | Yes (%)    | No (%)    |         |
| **Father's health-related behaviors**   |            |           |         |
| Smoking                                 |            |           |         |
| Yes                                     | 78 (1.9)   | 3942 (98.1) | 4020 (53.9) | 0.663 |
| No                                      | 62 (1.8)   | 3377 (98.2) | 3439 (46.1) |     |
| Drinking                                |            |           |         |
| Yes                                     | 13 (2.2)   | 571 (97.8)  | 584 (7.8)  | 0.517 |
| No                                      | 127 (1.9)  | 6748 (98.0) | 6875 (92.2) |     |
| **Childhood health**                    |            |           |         |
| Childhood hospitalization≥1month        |            |           |         |
| Yes                                     | 2 (1.3)    | 158 (98.8)  | 160 (2.7)  | 0.703 |
| No                                      | 94 (1.6)   | 5651 (98.4) | 5745 (97.3) |     |
| **Self-perceived childhood health**     |            |           |         |
| Very good                               | 25 (1.9)   | 1299 (98.1) | 1324 (17.8) | 0.870 |
| Good                                    | 27 (2.1)   | 1288 (98.0) | 1315 (17.7) |     |
| Fair                                    | 67 (1.7)   | 3786 (98.3) | 3853 (51.8) |     |
| Poor                                    | 13 (2.2)   | 572 (97.8)  | 585 (7.8)  |     |
| Very poor                               | 8 (2.2)    | 349 (97.7)  | 357 (4.8)  |     |
| **Adult SES**                           |            |           |         |
| Education attainments                   |            |           |         |
| Illiterate                              | 27 (3.8)   | 678 (96.2)  | 705 (13.1) | 0.001 |
| elementary school                       | 44 (2.1)   | 2047 (97.9) | 2091 (38.8) |     |
| middle school                           | 31 (1.8)   | 1697 (98.2) | 1728 (32.1) |     |
| High school or above                    | 8 (0.9)    | 860 (99.1)  | 868 (16.1) |     |
| Smoker                                  |            |           |         |
| Yes                                     | 53 (2.0)   | 2652 (98.0) | 2705 (36.3) | 0.703 |
| No                                      | 87 (1.8)   | 4655 (98.2) | 4742 (63.7) |     |
| Drinking                                |            |           |         |
| 1 times / month                         | 35 (1.7)   | 2062 (98.3) | 2097 (28.1) | 0.099 |
| ≤1times / month                         | 8 (1.1)    | 751 (99.0)  | 759 (10.2)  |     |
| Not drinking                            | 97 (2.1)   | 4501 (97.9) | 4598 (61.7) |     |
| Sleep time                              |            |           |         |
| ≤4h/day                                 | 31 (2.1)   | 1417 (97.9) | 1448 (19.4) | 0.867 |
| 4-6h/day                                | 42 (1.8)   | 2286 (98.2) | 2328 (31.2) |     |
| 6-8h/day                                | 55 (1.8)   | 2930 (98.2) | 2985 (40.0) |     |
| 8h/day                                  | 12 (1.7)   | 686 (98.3)  | 698 (9.4)  |     |
| Physical activities in every week       |            |           |         |
| Yes                                     | 81 (2.2)   | 3681 (97.9) | 3762 (50.5) | 0.703 |
| No                                      | 59 (1.6)   | 3633 (98.4) | 3692 (49.5) |     |

SES, socioeconomic status.

Table 3. Multicollinearity test for Chinese adult’s edentulism
| Variables                                      | VIF  | TOL  |
|-----------------------------------------------|------|------|
| Gender                                        | 2.58 | 0.387|
| Childhood SES                                 |      |      |
| Father’s education                            | 1.10 | 0.907|
| Father’s occupation                           | 1.02 | 0.984|
| Mother’s occupation                           | 1.80 | 0.556|
| Father’s work status                          | 1.01 | 0.987|
| Family’s financial situation                  | 1.20 | 0.835|
| Relationship with father                      | 1.20 | 0.836|
| Mother’s effort to watch over                 | 1.24 | 0.807|
| Mother’s love and affection                   | 1.29 | 0.775|
| Parents quarrel                               | 1.39 | 0.720|
| Parents fight                                 | 1.40 | 0.716|
| No enough food                                | 1.16 | 0.866|
| Residential community security                | 1.13 | 0.885|
| Primary residence                             | 1.78 | 0.563|
| Neighbor’s help                               | 1.42 | 0.705|
| Neighborhood relation                         | 1.50 | 0.668|
| Medical convenience                           | 1.02 | 0.985|
| Father’s health-related behaviors             |      |      |
| Smoking                                       | 1.05 | 0.957|
| Drinking                                      | 1.05 | 0.953|
| Childhood health                              |      |      |
| Childhood hospitalization≥1month              | 1.03 | 0.974|
| Self-perceived childhood health               | 1.06 | 0.942|
| Adult SES                                     |      |      |
| Education attainments                         | 1.27 | 0.787|
| Adult health-related behaviors                |      |      |
| Smoking                                       | 2.13 | 0.471|
| Drinking                                      | 1.37 | 0.729|
| Sleep time                                    | 1.01 | 0.987|
| Physical activities in every week             | 1.01 | 0.992|
| Mean VIF                                      |      | 1.31 |

Table 4. Odds ratios (95% CI) of childhood SES, father’s health related behaviors, childhood health, SES health and related behaviors for edentulism

| Variables                                      | Model 1 (gender + childhood SES+ father’s health related behaviors + childhood health) | Model 2 (m) |
|-----------------------------------------------|--------------------------------------------------------------------------------------|-------------|
| Gender (vs Female) Male                       | 0.7 (0.38-1.42)                                                                     | 0.363       |
| Childhood SES                                 |                                                                                      |             |
| Father’s education (vs High school and above) |                                                                                      |             |
| Illiterate                                    | 1.5 (0.22-10.27)                                                                    | 0.825       |
| Elementary school                             | 1.5 (0.31-7.68)                                                                     | 0.599       |
| Middle school                                 | 1.2 (0.24-5.94)                                                                     | 0.682       |
| Father’s occupation (vs Non-agricultural)     |                                                                                      |             |
| Farming                                       | 5.6 (1.30-24.39)                                                                    | 0.021       |
| Mother’s occupation (vs Farming)              |                                                                                      |             |
| Non-agricultural                              | 0.7 (0.12-4.62)                                                                     | 0.753       |
| Father’s work status (vs All of childhood)    |                                                                                      |             |
| Part of childhood                             | 4.4 (0.95-20.48)                                                                    | 0.059       |
| Family’s financial situation (vs Very poor)   |                                                                                      |             |
| Very good                                     | 0.2 (0.02-2.49)                                                                     | 0.231       |
| Good                                          | 1.4 (0.28-7.54)                                                                     | 0.665       |
|                                | OR       | 95% CI     | p    |
|--------------------------------|----------|------------|------|
|                                 |          |            |      |
| Fair                            | 0.7      | (0.28-1.73)| 0.433|
| Poor                            | 0.8      | (0.26-2.27)| 0.628|
| **Relationship with father (vs Excellent)** |          |            |      |
| Poor                            | 0.9      | (0.33-2.73)| 0.913|
| Good                            | 1.0      | (0.39-2.70)| 0.964|
| Very good                       | 0.6      | (0.21-1.56)| 0.272|
| **Mother's effort to watch over (vs A lot)** |          |            |      |
| Some                            | 1.0      | (0.24-4.15)| 0.986|
| A little                        | 0.6      | (0.15-2.72)| 0.552|
| Not at all                      | 2.5      | (0.49-12.75)| 0.273|
| **Mother's love and affection (vs Never)** |          |            |      |
| Often                           | 1.7      | (0.43-6.57)| 0.462|
| Sometimes                       | 1.0      | (0.24-4.21)| 0.984|
| Rarely                          | 0.5      | (0.12-2.07)| 0.342|
| **Parents quarrel (vs Not often)** |          |            |      |
| Often                           | 2.4      | (0.27-20.50)| 0.438|
| Sometimes                       | 0.8      | (0.35-1.75)| 0.555|
| **Parents fight (vs Never)**    |          |            |      |
| Sometimes                       | 0.2      | (0.03-2.38)| 0.227|
| Not very often                  | 3.9      | (0.49-31.69)| 0.198|
| Often                           | 1.3      | (0.46-3.45)| 0.652|
| **No enough food (vs No) Yes**  |          |            |      |
| Somewhat safe                   | 1.1      | (0.29-4.06)| 0.913|
| Not safe                        | 0.6      | (0.17-2.21)| 0.448|
| **Primary residence (vs Rural) Urban** |          |            |      |
| Somewhat close-knit             | 0.7      | (0.11-4.05)| 0.657|
| Not close-knit                  | 1.3      | (0.29-5.41)| 0.766|
| **Neighbor's help (vs Very willing to)** |          |            |      |
| unwilling to                    | 5.3      | (1.75-15.82)| 0.003|
| Somewhat willing to             | 4.4      | (1.57-12.18)| 0.005|
| **Neighborhood relation (vs Very close-knit)** |          |            |      |
| Somewhat close-knit             | 0.6      | (0.12-2.68)| 0.480|
| Not close-knit                  | 1.3      | (0.29-5.41)| 0.766|
| **Medical convenience (vs No) Yes** |          |            |      |
| Smoking (vs Yes) Non            | 0.9      | (0.46-1.77)| 0.766|
| Drinking (vs Yes) No            | 0.5      | (0.19-1.36)| 0.178|
| **Childhood health**            |          |            |      |
| Childhood hospitalization≥1month (vs No) Yes | 1.3  | (0.14-11.71)| 0.824|
| **Self-perceived childhood health (vs Very good)** |          |            |      |
| Good                            | 1.4      | (0.28-6.58)| 0.709|
| Fair                            | 2.2      | (0.47-10.41)| 0.318|
| Poor                            | 2.1      | (0.54-8.37)| 0.285|
| Very poor                       | 1.4      | (0.33-6.19)| 0.642|
| **Adult SES**                   |          |            |      |
| Education attainments (vs Illiterate) |          |            |      |
| elementary school               |          |            |      |
| middle school                   |          |            |      |
| High school and above           |          |            |      |
| **Health-related behaviors**    |          |            |      |
| Smoking (vs Yes) No             |          |            |      |
| Drinking (vs Not drinking)      |          |            |      |
| 1 times / month                |          |            |      |
| ≤1 times / month               |          |            |      |
| Sleep time (vs 8h/day)          |          |            |      |
| ≤4h/day                        |          |            |      |
| 4-6h/day                       |          |            |      |
| 6-8h/day                       |          |            |      |
| **Physical activities in every week (vs No) Yes** |          |            |      |

Model 1: adjusted for gender, father’s health-related behaviors (father smoking and drinking) and childhood health (childhood hospitalization≥1month and self-perceived childhood health). Model 2: adjusted for variables in model 2 plus and adult SES. Model 3: adjusted for all variables in model 2 plus adult health-related behaviors (smoking, drinking, sleep time and physical activities in every week). OR, odds ratio; CI, confidence interval; SES, socioeconomic status.
Directed acyclic graph (DAG) includes the following variables: Childhood socioeconomic status (SES), Childhood health, Adulthood SES, Adulthood health related behaviors, Father’s health related behaviors and Edentulism at age 45-59. DAG representing the relationships among the exposures (childhood SES; represented by the green oval with the triangle), outcome (edentulism at age 45-59; represented by the blue oval with the line), and mediators. Variables represented as pink ovals (father’s health related behaviors) are ancestors of exposure and outcome while variables represented as blue ovals (childhood health, adulthood SES, and adulthood health related behaviors) are ancestors only of the outcome. Between the exposure and outcome, pink arrows are biasing paths and the green arrows are causal paths.