Association of rotating night shift work with tooth loss and severe periodontitis among regular employees in Japan: a cross-sectional study (#93343)

First submission

Guidance from your Editor

Please submit by **6 Jan 2024** for the benefit of the authors (and your token reward) .

Structure and Criteria
Please read the 'Structure and Criteria' page for general guidance.

Custom checks
Make sure you include the custom checks shown below, in your review.

Raw data check
Review the raw data.

Image check
Check that figures and images have not been inappropriately manipulated.

If this article is published your review will be made public. You can choose whether to sign your review. If uploading a PDF please remove any identifiable information (if you want to remain anonymous).

Files

Download and review all files from the materials page.

2 Table file(s)
1 Raw data file(s)
2 Other file(s)

Custom checks

Human participant/human tissue checks

- Have you checked the authors ethical approval statement?
- Does the study meet our article requirements?
- Has identifiable info been removed from all files?
- Were the experiments necessary and ethical?

Structure and Criteria

Structure your review

The review form is divided into 5 sections. Please consider these when composing your review:

1. **BASIC REPORTING**
2. **EXPERIMENTAL DESIGN**
3. **VALIDITY OF THE FINDINGS**
4. General comments
5. Confidential notes to the editor

You can also annotate this PDF and upload it as part of your review

When ready submit online.

Editorial Criteria

Use these criteria points to structure your review. The full detailed editorial criteria is on your guidance page.

BASIC REPORTING

- Clear, unambiguous, professional English language used throughout.
- Intro & background to show context. Literature well referenced & relevant.
- Structure conforms to PeerJ standards, discipline norm, or improved for clarity.
- Figures are relevant, high quality, well labelled & described.
- Raw data supplied (see PeerJ policy).

EXPERIMENTAL DESIGN

- Original primary research within Scope of the journal.
- Research question well defined, relevant & meaningful. It is stated how the research fills an identified knowledge gap.
- Rigorous investigation performed to a high technical & ethical standard.
- Methods described with sufficient detail & information to replicate.

VALIDITY OF THE FINDINGS

- Impact and novelty not assessed. *Meaningful* replication encouraged where rationale & benefit to literature is clearly stated.
- All underlying data have been provided; they are robust, statistically sound, & controlled.
- Conclusions are well stated, linked to original research question & limited to supporting results.

Standout reviewing tips

The best reviewers use these techniques

Tip	*Example*
Support criticisms with evidence from the text or from other sources	*Smith et al (J of Methodology, 2005, V3, pp 123) have shown that the analysis you use in Lines 241-250 is not the most appropriate for this situation. Please explain why you used this method.*
Give specific suggestions on how to improve the manuscript	*Your introduction needs more detail. I suggest that you improve the description at lines 57- 86 to provide more justification for your study (specifically, you should expand upon the knowledge gap being filled).*
Comment on language and grammar issues	*The English language should be improved to ensure that an international audience can clearly understand your text. Some examples where the language could be improved include lines 23, 77, 121, 128 – the current phrasing makes comprehension difficult. I suggest you have a colleague who is proficient in English and familiar with the subject matter review your manuscript, or contact a professional editing service.*
Organize by importance of the issues, and number your points	*1. Your most important issue* *2. The next most important item* *3. …* *4. The least important points*
Please provide constructive criticism, and avoid personal opinions	*I thank you for providing the raw data, however your supplemental files need more descriptive metadata identifiers to be useful to future readers. Although your results are compelling, the data analysis should be improved in the following ways: AA, BB, CC*
Comment on strengths (as well as weaknesses) of the manuscript	*I commend the authors for their extensive data set, compiled over many years of detailed fieldwork. In addition, the manuscript is clearly written in professional, unambiguous language. If there is a weakness, it is in the statistical analysis (as I have noted above) which should be improved upon before Acceptance.*

Association of rotating night shift work with tooth loss and severe periodontitis among regular employees in Japan: a cross-sectional study

Yukihiro Sato [Corresp., 1], **Eiji Yoshioka** [1], **Yasuaki Saijo** [1]

[1] Division of Public Health and Epidemiology, Department of Social Medicine, Asahikawa Medical University, Asahikawa, Hokkaido, Japan

Corresponding Author: Yukihiro Sato
Email address: ys@epid.work

Background. The modern 24/7 society demands night shift work, which is a possible risk factor for chronic diseases. This study aimed to examine the associations of rotating night shift work duration with tooth loss and severe periodontitis **Methods.** This cross-sectional study used data from a self-administered questionnaire survey conducted among 3,044 regular employees through a Japanese web research company in 2023. We employed linear regression models for tooth loss and Poisson regression models for severe periodontitis, adjusting for demographic, health-related, and work-related variables and socioeconomic status. **Results.** Among participants included, 10.9% worked in rotating night shifts for 1–5 years, while 11.0% worked in such shifts for ≥6 years. In fully adjusted models, rotating night shift work duration of 1–5 years was associated with tooth loss (beta -0.74, 95% confidence interval [CI] -1.55, 0.08) and severe periodontitis (prevalence ratio 1.80, 95%CI 1.33, 2.43); however, the association with tooth loss was not statistically significant. **Discussion.** There was no statistically significant association of rotating night shift work duration of ≥6 years with tooth loss and severe periodontitis. This study suggests potential associations of rotating night shift work duration with tooth loss and severe periodontitis.

Association of rotating night shift work with tooth loss and severe periodontitis among regular employees in Japan: a cross-sectional study

Yukihiro Sato[1], Eiji Yoshioka[1], Yasuaki Saijo[1]

[1] Division of Public Health and Epidemiology, Department of Social Medicine, Asahikawa Medical University, Asahikawa, Hokkaido, Japan

Corresponding Author:
Yukihiro Sato[1]
1-1-1, Midorigaoka higashi2-jo, Asahikawa, Hokkaido, 078-8510, Japan
Email address: ys@epid.work

13 **Abstract**

14 **Background.**

15 The modern 24/7 society demands night shift work, which is a possible risk factor for chronic
16 diseases. This study aimed to examine the associations of rotating night shift work duration with
17 tooth loss and severe periodontitis

18 **Methods.**

19 This cross-sectional study used data from a self-administered questionnaire survey conducted
20 among 3,044 regular employees through a Japanese web research company in 2023. We
21 employed linear regression models for tooth loss and Poisson regression models for severe
22 periodontitis, adjusting for demographic, health-related, and work-related variables and
23 socioeconomic status.

24 **Results.**

25 Among participants included, 10.9% worked in rotating night shifts for 1–5 years, while 11.0%
26 worked in such shifts for ≥6 years. In fully adjusted models, rotating night shift work duration of
27 1–5 years was associated with tooth loss (beta -0.74, 95% confidence interval [CI] -1.55, 0.08)
28 and severe periodontitis (prevalence ratio 1.80, 95%CI 1.33, 2.43); however, the association with
29 tooth loss was not statistically significant.

30 **Discussion.**

31 There was no statistically significant association of rotating night shift work duration of ≥6 years
32 with tooth loss and severe periodontitis. This study suggests potential associations of rotating
33 night shift work duration with tooth loss and severe periodontitis.

INTRODUCTION

Oral diseases, such as dental caries, periodontal diseases, and tooth loss, can lead to a decline in work productivity. Dental caries destroy dental hard tissues in the crowns and roots of teeth, causing acute pain (Selwitz, Ismail & Pitts, 2007; Pitts et al., 2017). Periodontal diseases are chronic inflammatory conditions, which cause pain and discomfort (Pihlstrom, Michalowicz & Johnson, 2005; Kinane, Stathopoulou & Papapanou, 2017). Tooth loss is a complex consequence mainly caused by dental caries and periodontal diseases, which hinder the ability to sleep and communicate (Sato et al., 2016; Haworth et al., 2018; Koyama et al., 2018). Treatment of oral diseases often requires extended clinic visits. Consequently, oral diseases can result in considerable hours lost from work (Kelekar & Naavaal, 2018). Moreover, poor periodontal status has been reported to be associated with a potential decline in work performance (Zaitsu et al., 2020; Sato et al., 2023). Thus, it is crucial to focus on preventing oral diseases among working adults.

The modern 24/7 society demands a diversity of flexible work-hour patterns, and working in night shifts is a common in industrialised nations (IARC, 2020). In 2012, 21.8% of the employed population of Japan worked in the night shift, and this proportion could to continue to increase (Kubo, 2014). The proportion of workers engaged in night shift work was 13.3% in the European Union in 2018 (IARC, 2020) and 27% in the United States in 2015(IARC, 2020). Night shift work disrupts circadian rhythms, increasing the risk of chronic diseases like diabetes and cardiovascular disease (Strohmaier et al., 2018). The possible mechanisms are the induction of oxidative stress, immunosuppression, and chronic inflammation (Strohmaier et al., 2018; IARC, 2020). Therefore, night shift work can also lead to oral diseases through these mechanisms. In addition, three other potential pathways related to oral diseases are conceivable.

The first is the frequency of tooth brushing, which is a fundamental preventive behaviour for dental caries and periodontal diseases. An earlier study indicated that night shift office workers in Japan reported less frequent tooth brushing compared to daytime workers (Ishizuka et al., 2016). Therefore, tooth brushing habits can be a key contributing factor. The second potential pathway is infrequent visits to dental clinics for prevention. Suzuki et al. reported that night work was associated with a disruption in regular dental check-ups (Suzuki et al., 2017). The frequency of visits to dental clinics for prevention might be a factor linking night shift work and poor oral conditions. The third potential pathway is loneliness. Loneliness is a potential risk factor for poor oral health status (Hajek, Kretzler & König, 2022). Previous studies have suggested that night shift workers can experience social isolation, which could be a mediator connecting night shift work and chronic diseases through lifestyle and psychosocial factors (Vetter et al., 2016; Cheng & Drake, 2018). Therefore, loneliness might mediate the association between night shift work and oral diseases.

Our literature search revealed studies related to night shift work and oral diseases. Dong-Hun et al. reported associations between shift work and periodontitis among 4,597 Korean full-time employees (Han et al., 2013). Shift work, including evening, night, rotating, and irregular schedule work, was associated with periodontitis, with an odds ratio of 1.22. Night workers also had an increased odds ratio of periodontitis, although not statistically significant. An inflammatory marker partially explained the associations between shift work and periodontitis. Two studies reported by Ishizuka et al. revealed associations between night shift work and the presence of at least one decayed tooth among 376 male workers and 142 male sales workers (Ishizuka et al., 2016, 2019). However, Ghasemi et al. indicated null associations of night shift work with decay, missing, filled teeth and >4mm of periodontal pocket among 180

male workers of a factory (Ghasemi et al., 2022). However, these studies had several limitations. First, three of the four studies only focused on male workers and the sample size was relatively small. Second, loneliness was not considered a potential mediator in all the studies. Third, all four studies assessed night shift work status using the current work schedule. Dong-Hun et al. pointed out the need to consider the impact of accumulated circadian disruption (Han et al., 2013). Therefore, this study aimed to examine cross-sectional associations of rotating night shift work duration with tooth loss and severe periodontitis among 3,044 regular employees in Japan. In addition, we investigated whether tooth brushing habits, preventive dental visits, and loneliness mediate the associations.

MATERIALS & METHODS

Ethical approval

This study was approved by the Asahikawa Medical University Research Ethics Committee (No. 22081) in 4 October 2022. The study adhered to the tenets of the Declaration of Helsinki (1983). All participants voluntarily responded to the survey anonymously and provided web-based informed consent before answering the online questionnaire. Participants responded to the questionnaire if they agreed to provide informed consent. Participants had the option to terminate or exit the survey at any time without providing a reason, and not completing the questionnaire was considered non-consent. Participants were incentivised with a credit point that could be used for online shopping and cash conversion.

Data sources and participants

This cross-sectional study used data from a self-administered questionnaire survey through a Japanese web research company (ASMARQ). The survey took place from 19 to 25 January and

from 28 February to 7 March 2023. The inclusion criteria were regular employees aged 20–64 years. We recruited participants using convenience sampling, and the recruitment continued until we reached 3,000 individuals. Finally, 3,132 participants who met the inclusion criteria completed the questionnaire survey.

The following question was included to identify invalid responses: 'Did you answer the previous questions accurately?' Respondents could choose between 'yes, I answered them accurately' and 'no'. Those who selected 'no' were excluded. Of the 3,132 responses, 88 invalid responses were excluded. Thus, the final analysis included 3,044 regular employees aged 20–64 years.

Independent variable: Rotating night shift work duration

To gather data on rotating night shift work duration, we used a question from the Nurses' Health Studies (Vetter et al., 2016) as follows: 'What is the total number of years during which you worked rotating night shifts (at least 3 nights/month in addition to days or evenings in that month)?' The available response options were 'Never', '1–2 years', '3–5 years', '6–9 years', '10–14 years', '15–19 years', '20–29 years', and '30 years or more'. Subsequently, we categorised them into three levels: 'None', '1–5 years', and '≥6 years or more'.

Dependent variable: Self-reported tooth loss and severe periodontitis

Tooth loss was assessed using self-reported number of teeth. Following prior research (Ueno et al., 2010, 2018; Matsui et al., 2016), we employed the following question: 'How many natural teeth do you currently have? (excluding wisdom teeth, there are 28 teeth. Including wisdom teeth, there are 32 teeth. Please do not include dental implants, dentures, and dental bridges in your count.)'. Respondents could choose from a range of 0 to 32 teeth.

Severe periodontitis was defined using a validated self-reported questionnaire (Iwasaki

126 et al., 2021). This screening questionnaire comprises four oral health questions related to gum
127 disease, loose tooth, lost bone, and bleeding gums. Considering the low prevalence of severe
128 periodontitis (6.2% in a previous study) (Iwasaki et al., 2021), we defined a score of ≥3 as
129 indicative of severe periodontitis.

130 **Potential mediator variables: Toothbrushing habits, preventive dental visits, and loneliness**

131 We considered three potential pathways: tooth brushing habits, preventive dental visits, and
132 loneliness. Toothbrushing habits were evaluated using a question from the Survey of Dental
133 Diseases (Ministry of Health, Labour and Welfare, 2016). We created four categories: 'three
134 times or more a day', 'twice a day', 'once a day', and 'every few days or less'.

135 The frequency of preventive dental visits was assessed through the following question:
136 'How often do you receive preventive regular check-ups at a dental clinic? (Please do not include
137 visits for treatment)'. Response options were 'none', 'once every six months', 'once a year',
138 'once every two or three years'.

139 Loneliness was measured using the validated Japanese version of the 3-item UCLA
140 loneliness scale Version 3 (Russell, 1996; Arimoto & Tadaka, 2019). Scores on this scale range
141 from 3 (indicating the lowest level of loneliness) to 12 (indicating the highest level).

142 **Covariates**

143 Based on previous studies (Han et al., 2013; Ishizuka et al., 2016, 2019; Ghasemi et al., 2022),
144 we selected the variables below as covariates. Demographic variables were included: age and
145 gender. Work-related variables included the following: occupational category, working hours in
146 the past 7 days, and job title. Occupational categories were determined using the Japan Standard
147 Occupational Classification. Because some job categories were small, they were classified as
148 'others'. Health-related variables included paper cigarette smoking status, electronic cigarette

149 smoking status, alcohol consumption status, psychological distress according to the Kessler
150 Psychological Distress Scale (K6) (Ishizuka et al., 2016; Vetter et al., 2016; Matsui et al., 2016),
151 medical history of diabetes, and medical history of cardiovascular disease (CVD). In light of
152 socioeconomic status, the following variables were included: marital status, number of persons
153 living together, annual household income, and education level.

154 **Statistical analysis**

155 Linear regression analysis with a robust error variance was employed to estimate the beta for the
156 number of teeth. This method can provide valid estimations even when the dependent variables
157 are skewed (Schmidt & Finan, 2018). The beta can be interpreted as the expected differences in
158 the number of teeth. Poisson regression analysis with a robust error variance was employed to
159 estimate prevalence ratios (PRs) for severe periodontitis (Zou, 2004). The fully adjusted model
160 included age, gender, occupational category, working hours in the past 7 days, job title, paper
161 cigarette smoking status, electronic cigarette smoking status, alcohol consumption status,
162 psychological distress, medical history of diabetes, medical history of CVD, marital status,
163 number of persons living together, annual household income, and education level. We
164 independently added each potential mediator variable to the fully adjusted model to assess the
165 potential pathway using the difference method (Judd & Kenny, 1981). We calculated the
166 percentage change contributed by each potential mediator variable. Statistical significance was
167 set at two-sided $p<0.05$ at 95% confidence intervals (CIs). All analyses were performed using the
168 R (ver. 4.3.0; R Foundation for Statistical Computing) for macOS.

169

170 **RESULTS**

171 Table 1 presents the basic characteristics, potential mediator variables, night shift work duration,

and oral health status of the participants. The mean age was 44.9 years (standard deviation = 10.8). The study population comprised 71.2% men, 28.6% women, and 0.2% others. Among the participants, 10.9% and 11.0% had worked in the night shift for 1–5 years and ≥6 years, respectively. The mean number of teeth was 26.2 (standard deviation = 6.5), and the prevalence of severe periodontitis was 8.4%. The most common occupational category was clerical workers (25.6%), followed by professional workers (22.0%), and administrative and managerial workers (19.3%). Workers with a history of rotating night shift work reported less frequent tooth brushing. There was ≤5% difference in the proportion of individuals not going for preventive dental visits based on rotating night shift work duration. The UCLA loneliness scale showed a similar mean. Workers who had not experienced rotating night shift work had an average of 26.4 teeth. Workers who worked in night shifts for 1–5 years and ≥6 years had averages of 25.2 and 26.0 teeth, respectively. Workers with experience of rotating night shift work for 1–5 years had the highest prevalence of severe periodontitis (none = 7.5%; 1–5 years = 14.4%; ≥6 years = 8.9%).

Table 2 shows cross-sectional associations of rotating night shift work duration with tooth loss and severe periodontitis. Age and gender-adjusted models showed a statistically significant association between rotating night shift work duration of 1–5 years and tooth loss (beta -1.32, 95%CI -2.18, -0.46). There was no statistically significant association between rotating night shift work duration of ≥6 years and tooth loss (beta -0.52, 95%CI -1.31, 0.27). In fully adjusted models, rotating night shift work duration of 1–5 years was associated with tooth loss, but this was not statistically significant (beta -0.79, 95%CI -1.61, 0.03). Rotating night shift work duration of ≥6 years was not associated with tooth loss (beta -0.02, 95%CI -0.84, 0.81).

In age and gender-adjusted models, compared to workers who had not experienced night

shift work, those with rotating night shift work duration of 1–5 years had a statistically significantly increased risk of having severe periodontitis (PR 2.12, 95%CI 1.58, 2.84), but not those with rotating night shift work duration of ≥6 years (PR 1.22, 95%CI 0.84, 1.77). Fully adjusted models indicated only a statistically significant association between rotating night shift work duration of 1–5 years and severe periodontitis (1–5 years: PR 1.80, 95%CI 1.33, 2.43; ≥6 years: PR 1.22, 95%CI 0.83, 1.78). The mediation analyses using the difference method present that the three potential mediator variables did not attenuate the significant association between rotating night shift work duration of 1–5 years and severe periodontitis (toothbrushing habits: -0.6%; preventive dental visits: -4.2%; loneliness: 0.7%).

DISCUSSION

In this study, we analysed cross-sectional data collected from 3,044 regular employees in Japan. Our findings indicated that rotating night shift work duration of 1–5 years was cross-sectionally associated with an increased risk of tooth loss and severe periodontitis; however, the association with tooth loss was not statistically significant. Rotating night shift work duration of ≥6 years was not statistically significantly associated with tooth loss and severe periodontitis. The three proposed potential pathways did not attenuate the significant association between rotating night shift work duration of 1–5 years and severe periodontitis.

This study had some limitations. Firstly, the current results were obtained from a cross-sectional survey; thus, the temporal relationship of variables was not established, and there is a possibility of reverse causation. Since all the previous studies were cross-sectional (Han et al., 2013; Ishizuka et al., 2016, 2019; Ghasemi et al., 2022), a cohort study is needed to confirm the validity of the results. Secondly, it is important to note that participants in our study had a higher

socioeconomic status. For example, 18.2% of the participants reported an annual household income of 12 million Yen or more, although the average income reported in a national survey was 6.4 million Yen for worker households in 2022 (Ministry of Internal Affairs and Communications, 2022). This could potentially lead to an underestimation of the impact on individuals with lower socioeconomic status. Thirdly, the healthy worker effect may have influenced our results (Li & Sung, 1999). Unhealthy individuals could have been unable to work due to health conditions and thus excluded from our study. Therefore, the impact of night shift work may be underestimated. Our findings indicated that rotating night shift work duration of ≥6 years was not associated with a risk of severe periodontitis, in contrast to rotating night shift work duration of 1–5 years. This result might indicate the presence of the healthy worker effect. Finally, participants with night shift work may have provided overly negative responses to questions on tooth loss and periodontitis. Information bias might affect the current results.

The duration of night shift work is a more suitable indicator than the current night shift work status because oral diseases are chronic conditions. Night shift work duration considers accumulated circadian disruption. Our results provide new insights into the associations between night shift work and oral diseases. However, in this study, a dose-response relationship was not observed. Earlier studies have explored the existence of a dose-response relationship between night shift work duration and health outcomes (Wang et al., 2013; Torquati et al., 2018; Cheng et al., 2019; Li et al., 2019). To examine a dose-response relationship, further investigations should consider the current night shift work status and the duration.

We found an association between night shift work and periodontitis, similar to that of a previous study in Korea (Han et al., 2013). Night shift work was associated with an increased risk of tooth loss, but this was not statistically significant. This could be because tooth loss is a

multifaceted outcome. In Japan, tooth extraction is mainly attributed to dental caries and periodontal diseases; however, orthodontics and impacted teeth also play a role in tooth loss (Suzuki et al., 2022). To gain a more precise understanding of this association in a further studies, it is more appropriate to measure the incidence of tooth loss specifically due to dental caries and periodontitis.

Similar to a previous study (Han et al., 2013), our study found no significant role of oral health-related behaviours in linking rotating night shift work duration with oral diseases. In addition, we found that loneliness also did not mediate the association. A study in Korean emphasised the importance of inflammatory markers in connecting night shift work to periodontitis (Han et al., 2013). Hence, the previous study (Han et al., 2013) and our findings suggest the possibility of a direct pathway as the primary explanation. However, due to the cross-sectional study design, the temporal relationship is not guaranteed. Future cohort studies are needed to further investigate this matter.

A series of studies on night shift work and oral diseases highlights the importance of oral disease prevention among night shift workers. Even though Japan has a universal health coverage system covering dentistry (Zaitsu, Saito & Kawaguchi, 2018), previous studies (Ishizuka et al., 2016, 2019) and our study reported the association between night shift work and oral diseases. Therefore, in countries without dental coverage in their healthcare insurance, this association can be more pronounced. Oral diseases can lead to reduced work productivity (Zaitsu et al., 2020; Sato et al., 2023) and result in economic burdens (Righolt et al., 2018). Night shift work might contribute to producing economic burdens through the development of oral diseases. Employers and managers should recognise night shift work as a potential risk factor for chronic diseases like diabetes, cardiovascular diseases, and oral diseases.

CONCLUSIONS

This study, involving 3,044 regular employees in Japan, reported cross-sectional associations of rotating night shift work duration of 1–5 years with tooth loss and severe periodontitis. However, night shift work duration was not statistically significantly associated with tooth loss. Rotating night shift work duration of ≥6 years was not significantly associated with tooth loss and severe periodontitis. Three proposed pathways (tooth brushing habits, preventive dental visits, and loneliness) did not explain the significant association. Dental diseases in the workforce can lead to reduced working hours (Kelekar & Naavaal, 2018) and place economic burdens on society (Righolt et al., 2018). In particular, poor periodontal health can bring about decreased work productivity (Zaitsu et al., 2020; Sato et al., 2023). It is essential to maintain the oral health of daytime and night shift workers.

AUTHOR CONTRIBUTIONS

Yukihiro Sato: conceived, designed, and carried out the experiments, analysed the data, drafted the article, approved the final draft, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Eiji Yoshioka: interpreted data, reviewed the drafted article, approved the final draft, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Yasuaki Saijo: interpreted data, reviewed the drafted article, approved the final draft, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

The authors declare no competing interests.

DATA AVAILABILITY

The raw data is available in the Supplementary File.

GRANT DISCLOSURES

This study was supported by a Grant-in-Aid for Early-Career Scientists from the Japan Society for the Promotion of Science KAKENHI (grant number 22K17264). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

299 **REFERENCES**

300 Arimoto A, Tadaka E. 2019. Reliability and validity of Japanese versions of the UCLA loneliness
301 scale version 3 for use among mothers with infants and toddlers: a cross-sectional study.
302 *BMC Women's Health* 19:105. DOI: 10.1186/s12905-019-0792-4.

303 Cheng P, Drake CL. 2018. Psychological Impact of Shift Work. *Current Sleep Medicine Reports*
304 4:104–109. DOI: 10.1007/s40675-018-0114-7.

305 Cheng M, He H, Wang D, Xu L, Wang B, Ho KM, Chen W. 2019. Shift work and ischaemic heart
306 disease: meta-analysis and dose–response relationship. *Occupational Medicine* 69:182–
307 188. DOI: 10.1093/occmed/kqz020.

308 Ghasemi H, Darmohammadi R, Namdari M, Ghorbani Z. 2022. Oral health outcomes and shift
309 working among male workers: A cross-sectional survey. *PLOS ONE* 17:e0275924. DOI:

10.1371/journal.pone.0275924.

Hajek A, Kretzler B, König H-H. 2022. Oral Health, Loneliness and Social Isolation. A Systematic Review and Meta-Analysis. *The journal of nutrition, health & aging* 26:675–680. DOI: 10.1007/s12603-022-1806-8.

Han D-H, Khang Y-H, Jung-Choi K, Lim S. 2013. Association between shift work and periodontal health in a representative sample of an Asian population. *Scandinavian Journal of Work, Environment & Health*:559–567. DOI: 10.5271/sjweh.3370.

Haworth S, Shungin D, Kwak SY, Kim H-Y, West NX, Thomas SJ, Franks PW, Timpson NJ, Shin M-J, Johansson I. 2018. Tooth loss is a complex measure of oral disease: Determinants and methodological considerations. *Community Dentistry and Oral Epidemiology* 46:555–562. DOI: 10.1111/cdoe.12391.

321 IARC. 2020. *Night Shift Work*. Lyon (FR): International Agency for Research on Cancer.

322 Ishizuka Y, Yoshino K, Suzuki S, Sato R, Onose Y, Eguchi T, Takayanagi A, Kamijo H, Sugihara

323 N. 2019. Factors Associated with Untreated Decayed Teeth in Male Sales Workers: An

324 Internet Survey. *The Bulletin of Tokyo Dental College* 60:153–161. DOI:

325 10.2209/tdcpublication.2018-0053.

326 Ishizuka Y, Yoshino K, Takayanagi A, Sugihara N, Maki Y, Kamijyo H. 2016. Comparison of the

327 oral health problems and behavior of male daytime-only and night-shift office workers: An

328 Internet survey. *Journal of Occupational Health* 58:155–162. DOI: 10.1539/joh.15-0146-

329 OA.

330 Iwasaki M, Usui M, Ariyoshi W, Nakashima K, Nagai-Yoshioka Y, Inoue M, Kobayashi K,

331 Borgnakke WS, Taylor GW, Nishihara T. 2021. Validation of a self-report questionnaire

for periodontitis in a Japanese population. *Scientific Reports* 11:15078. DOI: 10.1038/s41598-021-93965-4.

Judd CM, Kenny DA. 1981. Process Analysis: Estimating Mediation in Treatment Evaluations. *Evaluation Review* 5:602–619. DOI: 10.1177/0193841X8100500502.

Kelekar U, Naavaal S. 2018. Hours Lost to Planned and Unplanned Dental Visits Among US Adults. *Preventing chronic disease* 15:E04. DOI: 10.5888/pcd15.170225.

Kinane DF, Stathopoulou PG, Papapanou PN. 2017. Periodontal diseases. *Nature Reviews Disease Primers* 3:17038. DOI: 10.1038/nrdp.2017.38.

Koyama S, Aida J, Cable N, Tsuboya T, Matsuyama Y, Sato Y, Yamamoto T, Kondo K, Osaka K. 2018. Sleep duration and remaining teeth among older people. *Sleep Medicine* 52:18–22. DOI: 10.1016/j.sleep.2018.07.020.

343 Kubo T. 2014. Estimate of the number of night shift workers in Japan (In Japanese). *Journal of*
344 *UOEH* 36:273–276. DOI: 10.7888/juoeh.36.273.
345 Li W, Chen Z, Ruan W, Yi G, Wang D, Lu Z. 2019. A meta-analysis of cohort studies including
346 dose-response relationship between shift work and the risk of diabetes mellitus. *European*
347 *Journal of Epidemiology* 34:1013–1024. DOI: 10.1007/s10654-019-00561-y.
348 Li C-Y, Sung F-C. 1999. A review of the healthy worker effect in occupational epidemiology.
349 *Occupational Medicine* 49:225–229. DOI: 10.1093/occmed/49.4.225.
350 Matsui D, Yamamoto T, Nishigaki M, Miyatani F, Watanabe I, Koyama T, Ozaki E, Kuriyama N,
351 Kanamura N, Watanabe Y. 2016. Validity of self-reported number of teeth and oral health
352 variables. *BMC Oral Health* 17:17. DOI: 10.1186/s12903-016-0248-2.
353 Ministry of Health, Labour and Welfare. 2016.The Survey of Dental Diseases. *Available at*

354 *https://www.mhlw.go.jp/toukei/list/62-17.html* (accessed September 4, 2023).

355 Ministry of Internal Affairs and Communications. 2022.Family income and expenditure survey.

356 *Available at https://www.stat.go.jp/data/kakei/index.html* (accessed September 5, 2023).

357 Pihlstrom BL, Michalowicz BS, Johnson NW. 2005. Periodontal diseases. *The Lancet* 366:1809–

358 1820. DOI: 10.1016/S0140-6736(05)67728-8.

359 Pitts NB, Zero DT, Marsh PD, Ekstrand K, Weintraub JA, Ramos-Gomez F, Tagami J, Twetman

360 S, Tsakos G, Ismail A. 2017. Dental caries. *Nature Reviews Disease Primers* 3:17030.

361 DOI: 10.1038/nrdp.2017.30.

362 Righolt AJ, Jevdjevic M, Marcenes W, Listl S. 2018. Global-, Regional-, and Country-Level

363 Economic Impacts of Dental Diseases in 2015. *Journal of Dental Research* 97:501–507.

364 DOI: 10.1177/0022034517750572.

365 Russell DW. 1996. UCLA Loneliness Scale (Version 3): Reliability, Validity, and Factor
366 Structure. *Journal of Personality Assessment* 66:20–40. DOI:
367 10.1207/s15327752jpa6601_2.

368 Sato Y, Aida J, Kondo K, Tsuboya T, Watt RG, Yamamoto T, Koyama S, Matsuyama Y, Osaka
369 K. 2016. Tooth Loss and Decline in Functional Capacity: A Prospective Cohort Study from
370 the Japan Gerontological Evaluation Study. *Journal of the American Geriatrics Society*
371 64:2336–2342. DOI: 10.1111/jgs.14324.

372 Sato Y, Yoshioka E, Takekawa M, Saijo Y. 2023. Cross-sectional associations between oral
373 diseases and work productivity loss among regular employees in Japan. *Industrial Health*
374 61:3–13. DOI: 10.2486/indhealth.2021-0274.

375 Schmidt AF, Finan C. 2018. Linear regression and the normality assumption. *Journal of Clinical*

376 *Epidemiology* 98:146–151. DOI: 10.1016/j.jclinepi.2017.12.006.

377 Selwitz RH, Ismail AI, Pitts NB. 2007. Dental caries. *The Lancet* 369:51–59. DOI:
378 10.1016/S0140-6736(07)60031-2.

379 Strohmaier S, Devore EE, Zhang Y, Schernhammer ES. 2018. A Review of Data of Findings on
380 Night Shift Work and the Development of DM and CVD Events: a Synthesis of the
381 Proposed Molecular Mechanisms. *Current Diabetes Reports* 18:132. DOI:
382 10.1007/s11892-018-1102-5.

383 Suzuki S, Sugihara N, Kamijo H, Morita M, Kawato T, Tsuneishi M, Kobayashi K, Hasuike Y,
384 Sato T. 2022. Reasons for Tooth Extractions in Japan: The Second Nationwide Survey.
385 *International Dental Journal* 72:366–372. DOI: 10.1016/j.identj.2021.05.008.

386 Suzuki S, Sugiyama S, Okamoto M, Tanaka M, Takayanagi A, Yoshino K, Ishizuka Y, Satou R,

387 Kamijo H, Sugihara N. 2017. Working Environment Factors Associated with Regular
388 Dental Attendance. *The Bulletin of Tokyo Dental College* 58:193–197. DOI:
389 10.2209/tdcpublication.2016-0030.

390 Torquati L, Mielke GI, Brown WJ, Kolbe-Alexander T. 2018. Shift work and the risk of
391 cardiovascular disease. A systematic review and meta-analysis including dose–response
392 relationship. *Scandinavian Journal of Work, Environment & Health*:229–238. DOI:
393 10.5271/sjweh.3700.

394 Ueno M, Shimazu T, Sawada N, Tsugane S, Kawaguchi Y. 2018. Validity of self-reported tooth
395 counts and masticatory status study of a Japanese adult population. *Journal of Oral*
396 *Rehabilitation* 45:393–398. DOI: 10.1111/joor.12615.

397 Ueno M, Zaitsu T, Shinada K, Ohara S, Kawaguchi Y. 2010. Validity of the self-reported number

398 of natural teeth in Japanese adults. *Journal of Investigative and Clinical Dentistry* 1:79–
399 84. DOI: 10.1111/j.2041-1626.2010.00016.x.

400 Vetter C, Devore EE, Wegrzyn LR, Massa J, Speizer FE, Kawachi I, Rosner B, Stampfer MJ,
401 Schernhammer ES. 2016. Association Between Rotating Night Shift Work and Risk of
402 Coronary Heart Disease Among Women. *JAMA* 315:1726–1734. DOI:
403 10.1001/jama.2016.4454.

404 Wang F, Yeung KL, Chan WC, Kwok CCH, Leung SL, Wu C, Chan EYY, Yu ITS, Yang XR,
405 Tse LA. 2013. A meta-analysis on dose–response relationship between night shift work
406 and the risk of breast cancer. *Annals of Oncology* 24:2724–2732. DOI:
407 10.1093/annonc/mdt283.

408 Zaitsu T, Saito T, Kawaguchi Y. 2018. The Oral Healthcare System in Japan. *Healthcare* 6. DOI:

10.3390/healthcare6030079.

Zaitsu T, Saito T, Oshiro A, Fujiwara T, Kawaguchi Y. 2020. The Impact of Oral Health on Work Performance of Japanese Workers. *Journal of Occupational and Environmental Medicine* 62.

Zou G. 2004. A Modified Poisson Regression Approach to Prospective Studies with Binary Data. *American Journal of Epidemiology* 159:702–706. DOI: 10.1093/aje/kwh090.

Table 1(on next page)

Table 1. Basic statistics of characteristics, potential mediator variables, night shift work duration, and oral health status of participants

Footnotes CVD, cardiovascular disease; SD, standard deviation. Psychological distress was assessed using the Kessler Psychological Distress Scale (K6).

1

		Total (n = 3,044)		Night shift work duration: None (n = 2,375, 78.0%)		1–5 years (n = 333, 10.9%)		≥6 years (n = 336, 11.0%)	
Dependent variables									
Number of teeth	(Mean, SD)	26.2	6.5	26.4	6.2	25.2	7.8	26.0	7.0
Severe periodontitis	(n, %)	256	8.4	178	7.5	48	14.4	30	8.9
Mediator variables									
Tooth brushing habits	(n, %)								
Three times or more a day		784	25.8	622	26.2	76	22.8	86	25.6
Twice a day		1,613	53.0	1,282	54.0	158	47.4	173	51.5
Once a day		592	19.4	434	18.3	86	25.8	72	21.4
Every few days or less		55	1.8	37	1.6	13	3.9	5	1.5
Preventive dental visits	(n, %)								
None		1,152	37.8	898	37.8	128	38.4	126	37.5
Once every six months		1,184	38.9	944	39.7	120	36.0	120	35.7
Once a year		424	13.9	315	13.3	56	16.8	53	15.8
Once every two or three years		284	9.3	218	9.2	29	8.7	37	11.0
UCLA loneliness scale	(Mean, SD)	6.4	2.4	6.3	2.4	6.8	2.3	6.5	2.5
Covariates									
Age	(n, %)								
21 to 24 years		63	2.1	48	2.0	15	4.5	0	0.0
25 to 29 years		252	8.3	181	7.6	48	14.4	23	6.8
30 to 34 years		329	10.8	254	10.7	39	11.7	36	10.7
35 to 39 years		335	11.0	248	10.4	47	14.1	40	11.9
40 to 44 years		381	12.5	285	12.0	38	11.4	58	17.3
45 to 49 years		495	16.3	395	16.6	41	12.3	59	17.6
50 to 54 years		504	16.6	392	16.5	51	15.3	61	18.2
55 to 59 years		439	14.4	368	15.5	32	9.6	39	11.6
60 to 64 years		246	8.1	204	8.6	22	6.6	20	6.0
Gender	(n, %)								
Men		2,166	71.2	1,638	69.0	255	76.6	273	81.3
Women		872	28.6	733	30.9	77	23.1	62	18.5
Others		6	0.2	4	0.2	1	0.3	1	0.3
Occupational category	(n, %)								
Administrative and managerial workers		588	19.3	489	20.6	49	14.7	50	14.9
Professional workers		670	22.0	508	21.4	83	24.9	79	23.5
Clerical workers		778	25.6	715	30.1	44	13.2	19	5.7
Sales workers		235	7.7	201	8.5	21	6.3	13	3.9
Service workers		246	8.1	155	6.5	46	13.8	45	13.4
Manufacturing process workers		126	4.1	74	3.1	15	4.5	37	11.0
Others		401	13.2	233	9.8	75	22.5	93	27.7
Working hours in the past 7 days	(n, %)								
0 to 39 h		315	10.3	233	9.8	41	12.3	41	12.2
40 to 44 h		888	29.2	736	31.0	74	22.2	78	23.2
44 to 49 h		476	15.	399	16.8	39	11.7	38	11.3

50 to 54 h		427	6 14.0	320	13.5	54	16.2	53	15.8
55 to 59 h		248	8.1	203	8.5	22	6.6	23	6.8
60 to 64 h		267	8.8	205	8.6	33	9.9	29	8.6
65 to 97 h		423	13.9	279	11.7	70	21.0	74	22.0
Job title	(n, %)								
None		1,524	50.1	1,191	50.1	164	49.2	169	50.3
Titled		1,520	49.9	1,184	49.9	169	50.8	167	49.7
Paper cigarette smoking status	(n, %)								
Never smoked		1,412	46.4	1,163	49.0	120	36.0	129	38.4
Smoked at least once		279	9.2	195	8.2	49	14.7	35	10.4
Smoked habitually before		660	21.7	511	21.5	69	20.7	80	23.8
Smoking occasionally		70	2.3	44	1.9	14	4.2	12	3.6
Smoking almost every day		623	20.5	462	19.5	81	24.3	80	23.8
Electronic cigarette smoking status	(n, %)								
Never smoked		1,971	64.8	1,605	67.6	176	52.9	190	56.5
Smoked at least once		290	9.5	205	8.6	50	15.0	35	10.4
Smoked habitually before		207	6.8	151	6.4	30	9.0	26	7.7
Smoking occasionally		108	3.5	73	3.1	18	5.4	17	5.1
Smoking almost every day		468	15.4	341	14.4	59	17.7	68	20.2
Alcohol consumption status	(n, %)								
Every day		649	21.3	510	21.5	70	21.0	69	20.5
5 to 6 days a week		306	10.1	238	10.0	33	9.9	35	10.4
3 to 4 days a week		345	11.3	247	10.4	46	13.8	52	15.5
1 to 2 days a week		491	16.1	381	16.0	60	18.0	50	14.9
A few times a month		377	12.4	295	12.4	43	12.9	39	11.6
Almost never		545	17.9	440	18.5	50	15.0	55	16.4
Cannot drink		331	10.9	264	11.1	31	9.3	36	10.7
Psychological distress	(n, %)								
None		1,684	55.3	1,388	58.4	119	35.7	177	52.7
Moderate		1,013	33.3	746	31.4	155	46.5	112	33.3
Severe		347	11.4	241	10.1	59	17.7	47	14.0
Medical history of diabetes	(n, %)	121	4.0	90	3.8	15	4.5	16	4.8
Medical history of CVD	(n, %)	49	1.6	32	1.3	6	1.8	11	3.3
Marital status	(n, %)								
Married		2,022	66.4	1,579	66.5	203	61.0	240	71.4
Divorced		218	7.2	169	7.1	25	7.5	24	7.1
Single		781	25.7	613	25.8	100	30.0	68	20.2
Others		23	0.8	14	0.6	5	1.5	4	1.2
Number of persons living together	(n, %)								
0		624	20.5	484	20.4	83	24.9	57	17.0
1		725	23.8	584	24.6	63	18.9	78	23.2
2		751	24.7	591	24.9	93	27.9	67	19.9
3		651	21.4	505	21.3	60	18.0	86	25.6
≥4		293	9.6	211	8.9	34	10.2	48	14.3

Annual household income	(n, %)								
0 to 3.9 million yen		317	10.4	244	10.3	44	13.2	29	8.6
4 to 5.9 million yen		625	20.5	465	19.6	81	24.3	79	23.5
6 to 7.9 million yen		625	20.5	486	20.5	69	20.7	70	20.8
8 to 9.9 million yen		558	18.3	442	18.6	51	15.3	65	19.3
10 to 11.9 million yen		365	12.0	288	12.1	27	8.1	50	14.9
12 million yen or more		554	18.2	450	18.9	61	18.3	43	12.8
Education level	(n, %)								
High school or lower		509	16.7	349	14.7	65	19.5	95	28.3
Professional training college, junior college, and technical college		475	15.6	344	14.5	54	16.2	77	22.9
University		1,796	59.0	1,470	61.9	173	52.0	153	45.5
Master's or doctorate's degrees		264	8.7	212	8.9	41	12.3	11	3.3

2

Table 2(on next page)

Table 2. Cross-sectional associations of rotating night shift work duration with tooth loss and severe periodontitis (N = 3,044)

CI, confidence interval; PR, prevalence ratio. Fully adjusted model included age, gender, occupational category, working hours in the past 7 days, job title, paper cigarette smoking status, electronic cigarette smoking status, alcohol consumption status, psychological distress, medical history of diabetes, medical history of CVD, marital status, number of persons living together, annual household income, and education level.

1

		Night shift work duration			
	None	**1–5 years**		**≥6 years**	
Dependent variable: Number of teeth		**Beta**	**95% CI**	**Beta**	**95% CI**
Age and gender adjusted model	(Reference)	**-1.32**	**(-2.18, -0.46)**	-0.52	(-1.31, 0.27)
Fully adjusted model	(Reference)	-0.79	(-1.61, 0.03)	-0.02	(-0.84, 0.81)
Fully adjusted model + Toothbrushing habits	(Reference)	-0.74	(-1.55, 0.08)	-0.04	(-0.87, 0.78)
% of excess risk explained		(7.1%)		(-135.1%)	
Fully adjusted model + Preventive dental visits	(Reference)	-0.78	(-1.59, 0.03)	0.01	(-0.81, 0.83)
% of excess risk explained		(1.2%)		(161.3%)	
Fully adjusted model + UCLA loneliness scale	(Reference)	-0.80	(-1.62, 0.03)	-0.02	(-0.85, 0.80)
% of excess risk explained		(-0.2%)		(-19.7%)	
Dependent variable: Severe periodontitis		**PR**	**95% CI**	**PR**	**95% CI**
Age and gender adjusted model	(Reference)	**2.12**	**(1.58, 2.84)**	1.22	(0.84, 1.77)
Fully adjusted model	(Reference)	**1.80**	**(1.33, 2.43)**	1.22	(0.83, 1.78)
Fully adjusted model + Toothbrushing habits	(Reference)	**1.80**	**(1.33, 2.43)**	1.21	(0.83, 1.78)
% of excess risk explained		(-0.6%)		(2.5%)	
Fully adjusted model + Preventive dental visits	(Reference)	**1.83**	**(1.35, 2.48)**	1.23	(0.84, 1.80)
% of excess risk explained		(-4.2%)		(-5.5%)	
Fully adjusted model + UCLA loneliness scale	(Reference)	**1.79**	**(1.32, 2.42)**	1.21	(0.83, 1.78)
% of excess risk explained		(0.7%)		(0.9%)	

2