The use of interdental cleaning devices and periodontal disease contingent on the number of remaining teeth in Korean adults

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This study aimed to investigate the effect of interdental brushes and dental floss on the prevention of periodontitis in participants with ≥ 20 or < 20 remaining teeth by using the Korea National Health and Nutrition Examination Survey 2016–2018. Data from 11,614 participants were analysed using multivariate logistic regression after adjusting for sociodemographic factors (age and sex), socioeconomic factors (level of education and individual income), oral health-related variables (daily toothbrushing), and systemic health-related variables (smoking, diabetes, and obesity). The adjusted odds ratio (AOR) showed statistically significant results for both floss (AOR, 1.41; 95% confidence interval (CI) 1.22–1.64) and interdental brushes (AOR, 1.16; 95% CI 1.01–1.34). However, no significant difference was found in the subjects with fewer than 20 teeth. The subgroup analysis showed that interdental brushes had a significant preventive effect on women who had more than 20 teeth. Among participants with fewer than 20 teeth, interdental brush users had more periodontitis in men. Regarding those with more than 20 teeth, health inequality was alleviated when floss and interdental brushes were used. The bottom line is that the effect of preventing periodontitis in interdental brushes and dental floss was more evident in participants with ≥ 20 remaining teeth rather than in participants with < 20 remaining teeth.

Bacterial plaque in the form of biofilms that remain primarily in the interdental area even after tooth brushing can cause periodontal tissue inflammation. To prevent this condition, different cleaning methods, such as dental flossing and interdental brushing, are applied to effectively remove plaques. The American Dental Association recommends self-cleaning of the interdental area to control periodontal disease, a problem common in the population. Numerous studies on interdental cleaning have shown that dental floss, interdental brushes, and water flossers can effectively remove plaque that remains between teeth.

However, data about the effects of dental flossing and interdental brushing on oral health and periodontal disease prevention are insufficient. Based on a recent large-scale longitudinal study, interdental cleaning could alleviate self-reported gingivitis. However, its effectiveness in preventing advanced periodontitis has not been confirmed. According to the study of Kim and Han, dental floss, but not interdental brushes, could prevent periodontal disease. Thus, a stronger and more reliable approach is needed, as the efficacy of these interdental hygiene tools in the overall population is not clearly elucidated.

The prevalence of severe periodontitis among elderly individuals can be masked by a high frequency of edentulism and a large number of missing teeth. In fact, several studies have assessed the importance of more than 20 teeth when used as an explanatory or outcome variable. Based on the Korea National Health and Nutrition Examination Survey (KNHANES), there was a significant difference in the prevalence of periodontitis according to the presence of more than 20 teeth among floss and interdental brush users (Supplementary Fig. S1).

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Therefore, it is necessary to examine the prevention effect of periodontitis in interdental cleaners by dividing them into subjects with 20 or more teeth and subjects with less than 20 teeth. However, most studies assessed the efficacy of interdental cleaners in the overall population without considering the number of remaining teeth. Hence, this study aimed to investigate the effect of interdental brushes and dental floss on periodontitis prevention among healthy adults with 20 or more remaining teeth or 19 or fewer remaining teeth using KNHANES.

### Results

In total, 11,614 adults aged 19 years or older were eligible for this study. All variables had a number of different missing values, so the total number by each variable is different. Table 1 shows their characteristics. In the group with 20 or more teeth, 83.4% and 85.6% of participants with periodontitis did not use dental floss and an interdental toothbrush, respectively. In the group with fewer than 20 teeth, 93.4% and 87.6% of participants did not use dental floss and an interdental toothbrush, respectively.

| Subjects with variable | 20 or more teeth | Less than 20 teeth |
|-----------------------|------------------|-------------------|
|                       | Normal          | Periodontitis*    | p value | Normal          | Periodontitis*    | p value |
|                       | n | Weighted% | n | Weighted% |       | n | Weighted% | n | Weighted% |
| Number of natural teeth | 7815 | 26.77 ± 0.03 | 1199 | 25.79 ± 0.05 | <0.001 | 893 | 11.49 ± 0.21 | 782 | 13.10 ± 0.21 | <0.001 |
| Age*                  | 7815 | 44.25 ± 0.28 | 1199 | 56.53 ± 0.33 | <0.001 | 893 | 69.54 ± 0.39 | 782 | 68.24 ± 0.46 | 0.017 |
| Sex                   |                |                   |       |                   |       |                |                   |       |
| Male                  | 3051 | 37.6 | 1710 | 51.6 | <0.001 | 366 | 39.9 | 418 | 54.1 | <0.001 |
| Female                | 4764 | 62.4 | 1489 | 48.4 |       | 527 | 60.1 | 364 | 45.9 |       |
| Income                |                |                   |       |                   |       |                |                   |       |
| Low                   | 2044 | 22.8 | 842 | 26.5 | <0.001 | 262 | 26.9 | 252 | 32.7 | 0.418 |
| Medium–low            | 2183 | 24.1 | 832 | 25.7 |       | 241 | 25.5 | 213 | 26.5 |       |
| Medium–high           | 2291 | 26.0 | 781 | 24.0 |       | 216 | 25.0 | 180 | 23.0 |       |
| High                  | 2366 | 27.1 | 742 | 23.7 |       | 175 | 20.5 | 135 | 17.8 |       |
| Education             |                |                   |       |                   |       |                |                   |       |
| ≤ Elementary school   | 1278 | 13.7 | 757 | 24.8 | <0.001 | 478 | 54.7 | 392 | 50.6 | 0.289 |
| Middle school         | 971 | 11.0 | 404 | 14.1 |       | 116 | 13.9 | 127 | 17.8 |       |
| High school           | 2723 | 32.8 | 999 | 32.5 |       | 172 | 22.1 | 135 | 21.2 |       |
| ≥ University or college | 3612 | 42.5 | 897 | 28.6 |       | 74 | 9.2 | 71 | 10.4 |       |
| Flossing*             |                |                   |       |                   |       |                |                   |       |
| No                    | 6330 | 71.1 | 2659 | 83.4 | <0.001 | 812 | 92.4 | 719 | 93.4 | 0.514 |
| Yes                   | 2512 | 28.9 | 521 | 16.6 |       | 67 | 7.6 | 48 | 6.6 |       |
| Interdental brushing* |                |                   |       |                   |       |                |                   |       |
| No                    | 6997 | 78.8 | 2695 | 85.6 | <0.001 | 785 | 89.2 | 671 | 87.6 | 0.431 |
| Yes                   | 1845 | 21.2 | 485 | 14.4 |       | 94 | 10.8 | 96 | 12.4 |       |
| Daily toothbrushing   |                |                   |       |                   |       |                |                   |       |
| Once or none          | 652 | 6.8 | 372 | 11.4 | <0.001 | 180 | 19.0 | 179 | 23.1 | 0.074 |
| Twice or more         | 8190 | 93.2 | 2808 | 88.6 |       | 698 | 81.0 | 587 | 76.9 |       |
| Smoking               |                |                   |       |                   |       |                |                   |       |
| Current               | 1187 | 13.3 | 789 | 23.8 | <0.001 | 116 | 13.8 | 180 | 23.9 | <0.001 |
| Past                  | 1412 | 15.9 | 777 | 24.0 |       | 222 | 23.2 | 211 | 27.2 |       |
| Never                 | 6245 | 70.9 | 1613 | 52.2 |       | 541 | 63.0 | 376 | 48.9 |       |
| Diabetes*             |                |                   |       |                   |       |                |                   |       |
| Normal                | 511 | 6.6 | 547 | 17.6 | <0.001 | 190 | 22.7 | 218 | 29.7 | 0.023 |
| Impaired fasting glucose | 1482 | 20.1 | 921 | 29.0 |       | 243 | 31.7 | 198 | 27.2 |       |
| Diabetes              | 5434 | 73.3 | 1559 | 53.4 |       | 359 | 45.5 | 300 | 43.1 |       |
| Body mass index*      |                |                   |       |                   |       |                |                   |       |
| Underweight           | 2607 | 28.9 | 1351 | 40.5 | <0.001 | 327 | 36.6 | 280 | 36.1 | 0.966 |
| Normal                | 5658 | 64.5 | 1783 | 57.5 |       | 536 | 60.1 | 468 | 60.7 |       |
| Obese                 | 619 | 6.7 | 71 | 2.0 |       | 27 | 3.4 | 27 | 3.2 |       |

Table 1. Characteristics of the study population stratified by periodontitis. *Periodontitis was defined as community periodontal index codes 3 and 4. **All variables have a number of different missing values, so the total number by each variable is different. ***Continuous variables are denoted by the mean ± standard error. ****Daily use of interdental brush and dental floss. *****Impaired fasting glucose was defined as 100 mg/dL ≤ fasting blood glucose < 126 mg/dL, and diabetes was defined as fasting blood glucose ≥ 126 mg/dL or current use of antidiabetic drugs or insulin. ******Obesity status was defined as underweight (<18.5 kg/m²), normal (18.5–24.9 kg/m²), and obese (≥25.0 kg/m²).
with periodontitis did not use dental floss and an interdental toothbrush, respectively. Additionally, 11.4% of participants with periodontitis in the group with 20 or more teeth and 23.1% of participants with periodontitis in the group with less than 20 teeth brushed their teeth less than once a day.

Table 2 shows the results of the logistic regression analysis of the association between the use of interdental cleaners and periodontitis. In the group with 20 or more teeth, in models 1–4, participants who did not use dental floss had a higher adjusted odds ratio (AOR) for periodontitis (model 1 AOR: 1.55, 95% CI 1.35–1.78; model 2 AOR: 1.44, 95% CI 1.26–1.66; model 3 AOR: 1.44, 95% CI 1.25–1.66; and model 4 AOR: 1.41, 95% CI 1.22–1.64). Regarding interdental brushing, in model 4, participants who did not use an interdental brush had a significantly higher risk of periodontitis than those who used an interdental brush (model 4 AOR: 1.16, 95% CI 1.01–1.34). However, in the group with fewer than 20 teeth, there was no significant difference between groups in all models 1–4 in flossing or interdental brushing.

Table 3 shows the results of the subgroup analysis of the association between the use of interdental cleaners and periodontitis according to sex and age. In the group with 20 or more teeth, males, females, and participants in their twenties, forties, fifties, and seventies who did not use dental floss had significantly higher risks of periodontitis. Among participants who did not use interdental brushes, females and participants in their thirties and sixties had significantly higher risks of periodontitis. In the group with fewer than 20 teeth, only the male group who did not use interdental brushes had significantly lower risk of periodontitis.

Table 4 shows the results of the stratified analysis of the association between individual income and educational level and periodontitis according to the use of dental floss and interdental brushes. Participants with low and medium–low incomes who did not use both dental floss and an interdental brush were at significantly higher risk of periodontitis than those with high individual incomes. Furthermore, participants who attained...
and interdental brushes.

and a 32% decrease in plaque scores7. Combined with brushing compared with toothbrushing alone. That is, there was a 34% reduction in gingivitis pronunciation11,13,16–18. Approximately half of American adults aged over 30 years have periodontitis18,19. In Korea, tooth root resorption could be a major cause of tooth loosening with ageing and could affect oral functions such as mastication and speech19,20.

A recently published nationally representative longitudinal study revealed that frequent interdental cleaning is effective at reducing the formation of biofilms17. However, a meta-study found that the actual plaque removal rate was only 42%22.

Thus, thoroughly cleaning the interdental area where plaque mainly accumulates using a proper interdental cleaning tool is extremely effective7,25. In particular, interdental brushing is considered the most effective method for cleaning between teeth26 and reduces periodontal pathogens between teeth21. However, a meta-study found that the actual plaque removal rate was only 42%22.

Toothbrushing is a fundamental self-care behavioural activity for maintaining oral health. Frequent brushing is associated with better self-perceived oral health and less volume of gingival bleeding but less with measures of more advanced periodontal disease10. The proportion of participants who used interdental cleaners in NHANES from United States exceeded 70%. However, the fundamental background may be different from the Korean data, which show a usage rate of 10%–20% for interdental cleaners. One possibility is that more people in Korea may use interdental cleaners to remove food stuck between teeth, not dental biofilm, for prevention. Hence, we divided participants into those with ≥20 and <20 remaining teeth. Our logistic regression analysis revealed that interdental users had a higher risk of periodontal disease. This is consistent with our reasoning that interdental brushes are used for food removal rather than preventive behaviour in those who have <20 remaining teeth. Interestingly, in the male group with fewer than 20 teeth, interdental users had a higher risk of periodontal disease. This is consistent with our reasoning that interdental brushes are used for food removal rather than preventive behaviour in those who have <20 remaining teeth.

Several studies have reported that daily flossing can reduce the prevalence of gingivitis and periodontitis4,24, thereby emphasizing that interdental cleaning is extremely effective7,25. In particular, interdental brushing is considered the most effective method for cleaning between teeth26 and reduces periodontal pathogens between teeth21. In a 2015 meta-study, Sälzer found moderate evidence about the efficacy of using an interdental brush combined with brushing compared with toothbrushing alone. That is, there was a 34% reduction in gingivitis and a 32% decrease in plaque scores7.

This study showed that interdental brushing and flossing were effective among young and healthy subjects. Based on the subgroup analysis according to sex and age, the female, twenties, and sixties groups were more likely to have periodontitis if they did not use interdental brushes. Interestingly, in the male group with fewer than 20 teeth, interdental users had a higher risk of periodontal disease. This is consistent with our reasoning that interdental brushes are used for food removal rather than preventive behaviour in those who have <20 remaining teeth.

Hence, the use of proper interdental hygiene tools is more important than simple use. Generally, interdental brushing is useful only for elderly individuals with enlarged spaces between teeth. However, based on the study of Carrouel25, an appropriate-diameter tool must be used according to the size of the interdental space, even among young, healthy individuals. This result is in accordance with that of our cross-sectional study.

In participants who used interdental brushes alone or both dental floss and interdental brushes, there was no significant difference in the risk of periodontitis according to socioeconomic status, particularly personal income.

### Discussion

Periodontitis is a chronic inflammatory disease in which supporting tissues around the teeth are destroyed by infection and the host immune response due to bacterial plaque accumulation16. Periodontal breakdown could be a major cause of tooth loosening with ageing and could affect oral functions such as mastication and pronunciation14,15,18–19. Approximately half of American adults aged over 30 years have periodontitis16,17. In Korea, according to counts of the frequency of outpatient treatment by the Health Insurance Review and Assessment Service (HIRA), gingivitis and periodontal disease have shown the highest rates of diseases since 201920.

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Hence, the use of proper interdental hygiene tools is more important than simple use. Generally, interdental brushing is useful only for elderly individuals with enlarged spaces between teeth. However, based on the study of Carrouel25, an appropriate-diameter tool must be used according to the size of the interdental space, even among young, healthy individuals. This result is in accordance with that of our cross-sectional study.

In participants who used interdental brushes alone or both dental floss and interdental brushes, there was no significant difference in the risk of periodontitis according to socioeconomic status, particularly personal income.

### Table 4. Multivariable association between socioeconomic status and periodontitis in the entire sample stratified by floss and interdental brush.

| Characteristic | Total | No use of floss or an interdental brush | Only floss use | Only interdental brush use | Both |
|---------------|-------|----------------------------------------|---------------|----------------------------|------|
|               | AOR (95% CI) | AOR (95% CI) | AOR (95% CI) | AOR (95% CI) | AOR (95% CI) |
| Number of Subjects | 10,009 | 6070 | 1904 | 1221 | 814 |
| Income        |       |     |     |     |     |
| Low          | 1.34 (1.12–1.60) | 1.33 (1.09–1.62) | 1.44 (0.93–2.22) | 1.42 (0.88–2.29) | 1.11 (0.62–1.99) |
| Middle low   | 1.18 (1.01–1.39) | 1.22 (1.01–1.48) | 1.18 (0.78–1.79) | 1.23 (0.75–2.04) | 0.57 (0.29–1.12) |
| Middle high  | 1.11 (0.96–1.29) | 1.11 (0.93–1.32) | 1.32 (0.88–1.97) | 1.08 (0.70–1.65) | 0.71 (0.41–1.25) |
| High         | Reference | Reference | Reference | Reference | Reference |
| Education    |       |     |     |     |     |
| c Elementary school | 1.34 (1.09–1.65) | 1.37 (1.08–1.75) | 1.52 (0.76–3.05) | 0.79 (0.40–1.55) | 1.72 (0.46–6.43) |
| Middle school | 1.26 (1.01–1.59) | 1.31 (1.01–1.69) | 1.16 (0.61–2.20) | 1.01 (0.51–1.97) | 0.86 (0.25–3.05) |
| High school  | 1.20 (1.04–1.39) | 1.15 (0.97–1.37) | 1.48 (1.06–2.07) | 0.96 (0.66–1.41) | 1.43 (0.85–2.39) |
| ≥ University or college | Reference | Reference | Reference | Reference | Reference |
and educational background, as shown in Table 4. These results could be an extension of a previous study, which shows that the use of an interdental brush alleviates periodontal health inequalities, and more detailed conclusions could be obtained by performing an analysis using dental floss as a major variable.

The current study had several limitations. That is, specific information about the use of tools, such as the frequency and duration of applying dental floss or interdental brush, was not confirmed. Additionally, as this study was cross-sectional in nature, the effect of interdental cleaning on preventing periodontal disease was not directly analysed, and the assessment of inflammation was only based on the depth of the periodontal pocket (> 3.5 mm) according to the CPI index. As the study design of Pitchika et al. was a repeated cross-sectional study, it is necessary to conduct a study with a similar design when our KNHANES data can be viewed through follow-up observation in the future.

However, the study, which performed a large-scale sample analysis representing the whole population of Korea, also had some strengths. In this study, participants were divided into those with more than 20 remaining teeth and those with less than 20 remaining teeth, thereby confirming the substantial relationship between interdental cleaning and periodontal disease. Significant results were obtained by examining the relationship between periodontitis and socioeconomic status, particularly income and educational background, according to the use of dental floss and interdental brushes.

In conclusion, we found that both interdental brushing and flossing have a cross-sectionally significant periodontitis prevention and inequality alleviation effect in the population with 20 or more remaining teeth.

Methods

Data source. This study used nationwide cross-sectional data from the seventh KNHANES conducted between 2016 and 2018. KNHANES has been implemented by the Korea Centers for Disease Control and Prevention since 1998 to assess the health and nutritional status of Koreans. The target population of KNHANES is noninstitutionalized Korean citizens residing in Korea. Among them, approximately 10,000 individuals aged 19 years and over are selected annually using multistage clustered probability sampling. KNHANES collects different health and nutrition data using three types of surveys: health interviews, health examinations, and nutrition assessments. The 2016 and 2017 surveys were conducted without deliberation as they corresponded to a research conducted by the government for public welfare. The 2018 survey was performed with the approval of the institutional review board of the Korea Centers for Disease Control and Prevention with consideration of the collection of human-derived materials and the provision of raw data to a third party (IRB no.: 2018-01-03-P-A), and it was conducted according to the principles of the Declaration of Helsinki; written informed consent was obtained from all subjects. In total, 24,269 individuals participated in the seventh KNHANES. This cross-sectional study conformed to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement guidelines for the analysis of observational data. In this study, the data of 11,614 participants who were aged 19 years or older were analysed.

(1) Assessment of periodontitis (outcome variable).

The periodontal status of the participants was assessed using the community periodontal index (CPI): 0 = healthy, 1 = bleeding on probing, 2 = calculus formation, 3 = pocket measuring 4–5 mm, and 4 = pocket measuring 6 mm or more. The index teeth used in periodontal examination were the two molars in each posterior sextant, the upper right central incisor, and the lower left central incisor. A trained dentist performed periodontal examination using the World Health Organization CPI periodontal probe, and the highest score was recorded for the sextant. A CPI score of 0, 1, or 2 indicated the absence of periodontitis, and a CPI score of 3 or 4 suggested the presence of periodontitis. CPI was conducted by a trained dentist, and the kappa index ranged from 0.848 to 1.000.

(2) Assessment of interdental cleaners (explanatory variable).

A questionnaire was used to assess whether the participants used dental floss and interdental brush. For the questionnaire item “Please select all products that you use for your oral health other than toothpaste and a toothbrush,” the participants answered yes or no.

(3) Covariates.

The covariates in this study included sociodemographic factors, socioeconomic factors, oral health-related variables, and systemic health-related variables. The sociodemographic factors were age and sex, and the socioeconomic factors were individual income and educational level. Individual income was divided into four quartile groups: low (< 25%), medium–low (25%–49%), medium–high (50–74%), and high (75–100%). Educational level was classified as below elementary school, middle school, high school, and university or college.

The oral health-related variables included daily toothbrushing. Daily toothbrushing was categorized into two groups based on frequency: once or none and twice or more.

The systemic health-related variables included smoking, the presence of diabetes mellitus, and obesity. Smoking status was categorized into three groups based on smoking experience: current, past, and never. Diabetes mellitus was divided into three groups: normal, impaired fasting glucose (100 mg/dL ≤ fasting blood glucose < 126 mg/dL), and diabetes (fasting blood glucose of ≥ 126 mg/dL or the current use of antidiabetic drugs or insulin). Obesity was categorized into three groups using body mass index (BMI) based on the World Health Organization’s redefined obesity criteria for Asia-Pacific regions: underweight (< 18.5 kg/m²), normal (18.5–24.9 kg/m²), and obese (≥ 25.0 kg/m²).
Statistical analysis. Considering the complex survey design of KHNANES VII, the weighted data were analysed statistically. Age was a continuous variable, and all variables, except age, were categorical variables. The use of interdental cleaner was considered an explanatory variable, and periodontitis was considered a response variable. The characteristics of the study population were analysed according to frequency, weight proportions, and confidence interval (CI) with respect to sociodemographic factors, personal health practices, and general health status. The difference between groups with and without periodontitis according to each variable was determined using a chi-squared test.

The association between the use of interdental cleaner and periodontitis was analysed via multivariate logistic regression analysis. Regression model 1 was adjusted for age and sex. Socioeconomic variables such as individual income and educational level were added to regression model 2. Oral health-related variables, such as daily toothbrushing, were added to regression model 3. Systemic health-related variables such as smoking, diabetes mellitus, and obesity were added to regression model 4. Stratified analyses based on sex, age, individual income, and educational level were conducted to examine the association between the use of an interdental cleaner and periodontitis according to subgroups. All statistical complex sample analyses were conducted using Statistical Package for the Social Sciences version 23.0 (IBM, NY, USA). A P value of < 0.05 was considered statistically significant.

Data availability

The dataset generated and analysed during the current study and corresponding syntax are available from the first author upon reasonable request.

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Author contributions
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Competing interests
The authors declare no competing interests.

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