Abstract

The aim of this prospective cohort study was to examine whether oral hygiene knowledge, and the source of that knowledge, affect oral hygiene behavior in university students in Japan. An oral exam and questionnaire survey developed to evaluate oral hygiene knowledge, the source of that knowledge, and oral hygiene behavior, such as the frequency of tooth brushing and regular dental checkups and the use of dental floss, was conducted on university student volunteers. In total, 310 students with poor tooth brushing behavior (frequency of tooth brushing per day \(<\) once), 1,963 who did not use dental floss, and 1,882 who did not receive regular dental checkup during the past year were selected. Among these students, 50, 364, and 343 in each respective category were analyzed in over the 3-year study period (follow-up rates: 16.1%, 18.5%, and 18.2%, respectively). The odds ratios (ORs) and 95% confidence intervals (CIs) for oral hygiene behavior were calculated based on oral hygiene knowledge and the source of that knowledge using logistic regression models. The results showed that dental clinics were the most common (\(>\) 50%) source of oral hygiene knowledge, and that a more frequent use of dental floss was significantly associated with dental clinics being a source of oral hygiene knowledge (OR, 4.11; 95%CI, 1.871–9.029; \(p < 0.001\)). In addition, a significant association was seen between dental clinics being a source of oral hygiene knowledge and more frequent regular dental checkups (OR, 13.626; 95%CI, 5.971–31.095; \(p < 0.001\)). These findings suggest the existence of a relationship between dental clinics being the most common source of oral hygiene knowledge and improved oral hygiene behavior in Japanese university students.
Introduction

Appropriate oral hygiene behavior, including frequent daily tooth brushing, using dental floss, and receiving regular dental checkups, can help prevent dental caries and periodontal disease [1–6]. Oral hygiene behavior is related to a variety of factors, including oral hygiene knowledge [7–9]. In Japan, previous studies reported that university students with better oral hygiene knowledge practiced better oral hygiene behavior [10, 11]. In other countries, similar results have been reported [12–14]. Furthermore, it has been reported that students who had acquired dental knowledge during the university life improved their oral health status [15].

Various sources of oral hygiene knowledge, including television [16–18], schools [19], and dental clinics [20, 21], have been reported to be associated with oral hygiene behavior. We previously conducted a cross-sectional study to investigate the associations between oral hygiene knowledge, the source of that knowledge, and oral hygiene behavior in a group of new university students [11]. The results suggested that having better oral hygiene knowledge, as well as having dental clinics as the most common source of oral hygiene knowledge, were associated with better oral hygiene behavior. Thus, when university students have oral hygiene knowledge from dental clinics, they may improve oral hygiene behavior. However, it remains unclear whether oral hygiene knowledge and the source of that knowledge affect oral hygiene behavior in university students in Japan, and there are little prospective cohort studies.

We hypothesized that both having oral hygiene knowledge and obtaining the knowledge from dental clinics improve oral hygiene behavior in university students in Japan. The purpose of the present prospective cohort study was to investigate the relationship between oral hygiene knowledge, the source of that knowledge, and improvement of oral hygiene behavior in university students in Japan.

Materials and methods

Sample size calculation

We estimated the sample size using G*Power version 3.1.9.6 statistical software. For chi-squared test, this software computed power for a test of the null hypothesis in which the event rate in the two groups was identical. According to a previous study [11], we calculated the effect size to be 0.205 and required the minimum sample size of 187 in groups to detect significant differences in the oral hygiene behaviors with 80% power and a two-sided significance level of 5%.

Study population

Baseline data for use in this prospective cohort study were obtained from first-year Okayama university students (undergraduate students from all faculties) who had received general health and oral examinations at the Okayama University Health Service Center in April 2014. Japanese Okayama university students aged 18–24 years who fully completed a questionnaire and whose responses indicated poor oral hygiene behavior (frequency of tooth brushing per day ≤ once, no use of dental floss, and no regular dental visits) at baseline were included. All students volunteered to undergo general health and oral examinations for follow-up in April 2017, before graduation. Students who did not undergo an oral examination or provide complete questionnaire data at follow-up were excluded.

Ethics procedures and informed consent

The study protocol was approved by the ethics committees of Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences and Okayama University Hospital.
The study was conducted and reported in accordance with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines. Informed verbal consent was obtained from all participants before the study began. The verbal consent was documented by signature in the questionnaire.

**Self-questionnaires**

All students completed self-report questionnaires in Japanese language at both baseline (2014) and follow-up (2017).

**Oral hygiene knowledge**

The students were asked whether they could explain a variety of dental terms (e.g., dental plaque, calculus, periodontal disease, temporomandibular disorder, dental floss, topical application of fluoride, fluoride-containing mouthwash, fissure sealant and 8020 movement (a social campaign in Japan aimed at promoting the retention of 20 or more of one’s own teeth at the age of 80 years) [10, 22] (S1 and S2 Tables).

**Source of oral hygiene knowledge**

The students were also asked where they had acquired most of their oral hygiene knowledge (e.g., internet, television, dental clinics, family, school) (S1 and S2 Tables).

**Oral hygiene behavior**

The students were also asked about their oral hygiene behavior, such as their frequency of tooth brushing per day (≥ twice/≤ once) and use of dental floss (yes/no), and whether they had received regular dental checkups during the past year (yes/no) [5, 6] (S1 and S2 Tables). Students who showed improved their oral hygiene behavior were defined as the improved group, and those who did not as the non-improved group.

**Oral examinations**

Five dentists (D.E., T.A., S.M., M.Y-T., and K.K.) assessed the students’ periodontal status using the Community Periodontal Index (CPI) version 4 [23] using a CPI probe (YDM, Tokyo, Japan). Six sites (mesiobuccal, mid-buccal, distobuccal, distolingual, mid-lingual, and mesiolingual) were examined on each tooth. For the periodontal examinations, the following 10 teeth were selected: the upper right and lower left central incisors and two molars in each posterior sextant. Among these 10 teeth, the percentage exhibiting bleeding on probing (%BOP) was also assessed because compared with probing depth, BOP is an earlier and more sensitive indicator of gingival inflammation [10, 24]. The Oral Hygiene Index-Simplified (OHI-S) [25] was used to evaluate the students’ oral hygiene status. Calibration between five dentists was performed before the oral examination, and the intra- and inter-examiner reliabilities of the CPI scores as evaluated by κ statistics were both > 0.8 (the inter-examiner reliabilities of the CPI scores κ statistics: 0.815; the intra-examiner reliabilities of the CPI scores κ statistics: 0.868–1.000).

Furthermore, in each group, we investigated the relationship between oral hygiene behavior and increased BOP (worsened %BOP), periodontal pocket depth (PPD) (worsened PPD), and OHI-S scores (worsened OHI-S).
Statistical analyses
Five dentists (A.T.T., N.T., Y.S., M.M.I, H.S.) collected the anonymous data. We used SPSS (version 25; IBM, Tokyo, Japan) for all statistical analyses, with p values < 0.05 considered to indicate statistical significance. Significant differences between the improved and non-improved oral hygiene behavior groups were determined using the fisher’s exact test and chi-square test.

Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated using logistic regression model. The onset of each type of oral hygiene behavior (frequency of daily tooth brushing and using dental floss, and having regular dental visits) was used as the dependent variable, and in accordance with a previous study, oral hygiene knowledge, the source of that knowledge, sex, and age were used as independent variables associated with outcomes in a multiple logistic regression model. Backward elimination method was used to select the final model.

Significant differences between baseline and follow-up were investigated using the McNemar-Bowker test, paired t test, or Wilcoxon signed-rank test. Changes in periodontal (%BOP, PPD) and oral hygiene status (OHI-S) from baseline to follow-up were classified into two groups: i) worsened groups, and ii) stable groups. The relationship between oral hygiene behavior and the worsening in periodontal and oral hygiene status was investigated using the chi-squared test.

Results
Study population
Baseline data (n = 2,220) were obtained from the oral examinations in April 2014. The students who met the inclusion criteria were classified into each poor oral hygiene behavior group as below. A flowchart of the participants in the present cohort study from baseline to follow-up is shown in Fig 1. Based on the baseline data, we selected 310 students with infrequent tooth brushing (frequency of tooth brushing per day [≤ once]), 1,963 who did not use dental floss, and 1,882 who did not have regular dental checkups for inclusion in the analysis. Of these students, 50, 364, and 343 in each respective category were analyzed (follow-up rates: 16.1%, 18.5%, and 18.2%, respectively). In addition, participants were examined for systemic disease. There were no systemic diseases and no significant differences in periodontal condition at baseline between the improved and non-improved groups.

The percentages of students classified into the improved group for frequent tooth brushing, using dental floss, and having regular dental visits were 44.0% (22/50), 11.8% (43/364), and 15.5% (46/343), respectively (Fig 2).

Association between oral hygiene behavior and other parameters
The students with a higher frequency of daily tooth brushing (improved group) had more oral hygiene knowledge about the “8020 movement” at both baseline (p = 0.029) and follow-up (p = 0.029) than the students with a lower frequency of daily tooth brushing (non-improved group) (Table 1). Those who started using dental floss (improved group) had significantly more oral hygiene knowledge in terms of dental plaque (p = 0.005) and the topical application of fluoride (p = 0.002) at baseline, and of calculus (p = 0.008) and dental floss (p = 0.001) at follow-up; in addition, at follow-up, dental clinics (p < 0.001) were found to be the source of these students’ oral hygiene knowledge (Table 2). Those who had regular dental visits (improved group) had significantly more dental knowledge in terms of the 8020 movement (p = 0.006) at baseline, and of calculus (p = 0.015) and the topical application of fluoride (p = 0.010) or fissure sealant (p = 0.007) at follow-up; in addition, family (p = 0.032) was found
Fig 1. **Flowchart.** Students with poor oral hygiene behavior at baseline were classified into respective groups. Each group was analyzed at follow-up.

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Fig 2. **Categorization in each group.** Students with poor oral hygiene behavior at baseline were categorized into improved and non-improved groups.

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to be the source of these students’ oral hygiene knowledge at baseline, whereas television ($p = 0.010$) and dental clinics ($p < 0.001$) were found to be the sources of knowledge at follow-up (Table 3).

Multiple logistic regression analysis showed that improved change in the frequency of dental flossing was significantly associated with oral hygiene knowledge in terms of dental plaque ($p = 0.009$) and periodontal disease ($p = 0.039$) at baseline and of dental floss ($p = 0.003$) at follow-up, and when television ($p = 0.037$) and dental clinics ($p < 0.001$) were found to be the source of oral hygiene knowledge at follow-up (Table 4). Further, improved change in the frequency of regular dental visits was significantly associated with age ($p = 0.001$) and oral hygiene knowledge in terms of the 8020 movement ($p = 0.001$) at baseline and of calculus

Table 1. Associations between frequency of tooth brushing per day, oral hygiene knowledge, and source of oral hygiene knowledge at baseline and follow-up.

| Parameters                               | Improved group | Non-improved group | $p$-value$^*$ |
|------------------------------------------|----------------|-------------------|--------------|
|                                          | $n = 22$       | $n = 28$          |              |
| Sex                                      |                |                   |              |
| Male                                     | 15 (68.2)$^*$  | 22 (78.6)         | 0.406        |
| Age                                      |                |                   |              |
| 18.4 (1.1)                               | 18.3 (0.5)     | 0.714             |
| Oral hygiene knowledge                   |                |                   |              |
| Dental plaque                            | Yes            | Yes               | 0.009        |
| Calculus                                 | Yes            | Yes               | 0.084        |
| Periodontal disease                      | Yes            | Yes               | 1.000        |
| 8020 movement                            | Yes            | Yes               | 0.029        |
| Temporomandibular disorder               | Yes            | Yes               | 1.000        |
| Dental floss                             | Yes            | Yes               | 1.000        |
| Topical application of fluoride          | Yes            | Yes               | 1.000        |
| Fluoride-containing mouthwash            | Yes            | Yes               | -            |
| Fissure sealant                          | Yes            | Yes               | 1.000        |
| Source of oral hygiene knowledge         |                |                   |              |
| Internet                                 | Yes            | Yes               | 1.000        |
| Television                               | Yes            | Yes               | 0.585        |
| Dental clinic                            | Yes            | Yes               | 0.201        |
| Family                                   | Yes            | Yes               | 0.640        |
| School                                   | Yes            | Yes               | 0.773        |
| Follow-up                                |                |                   |              |
| Oral hygiene knowledge                   |                |                   |              |
| Dental plaque                            | Yes            | Yes               | 0.773        |
| Calculus                                 | Yes            | Yes               | 0.962        |
| Periodontal disease                      | Yes            | Yes               | 0.439        |
| 8020 movement                            | Yes            | Yes               | 0.029        |
| Temporomandibular disorder               | Yes            | Yes               | 0.683        |
| Dental floss                             | Yes            | Yes               | 1.000        |
| Topical application of fluoride          | Yes            | Yes               | 1.000        |
| Fluoride-containing mouthwash            | Yes            | Yes               | 0.576        |
| Fissure sealant                          | Yes            | Yes               | 1.000        |
| Source of oral hygiene knowledge         |                |                   |              |
| Internet                                 | Yes            | Yes               | 0.335        |
| Television                               | Yes            | Yes               | 0.243        |
| Dental clinic                            | Yes            | Yes               | 0.243        |
| Family                                   | Yes            | Yes               | 0.117        |
| School                                   | Yes            | Yes               | 0.246        |

*Number (%) and mean (standard deviation),

$^*$Fisher’s exact test, chi-square test or paired t test

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(p = 0.043) at follow-up, and when family (p = 0.028) and dental clinics (p < 0.001) were found to be the sources of oral hygiene knowledge at baseline and follow-up, respectively. On the other hand, no significant associations were identified between the improved frequency of daily tooth brushing and other parameters.

### Relationship between oral hygiene behavior and oral condition

Among the 50 students with infrequent tooth brushing, the 364 who did not use dental floss, and the 343 who did not receive regular dental checkups, %BOP (p = 0.011, p = 0.001, p < 0.001, respectively), PPD (p < 0.001, p = 0.004, p = 0.001, respectively), and OHI-S scores

### Table 2. Associations between the use of dental floss, oral hygiene knowledge, and source of oral hygiene knowledge at baseline and follow-up.

| Parameters | Improved group | Non-improved group | p-value† |
|------------|----------------|--------------------|----------|
|            | n = 43         | n = 321            |          |
| Sex        |                |                    |          |
| Male       | 19 (44.2)      | 190 (59.2)         | 0.062    |
| Baseline   |                |                    |          |
| Age        | 18.3 (0.5)     | 18.2 (0.5)         | 0.539    |
| Oral hygiene knowledge | | | |
| Dental plaque | Yes | 23 (53.5) | 102 (31.8) | 0.005 |
| Calculus    | Yes | 14 (32.6) | 100 (31.2) | 0.852 |
| Periodontal disease | Yes | 8 (18.6) | 69 (21.5) | 0.663 |
| 8020 movement | Yes | 15 (34.9) | 71 (22.1) | 0.064 |
| Temporomandibular disorder | Yes | 7 (16.3) | 38 (11.8) | 0.406 |
| Dental floss | Yes | 2 (4.7) | 22 (6.9) | 0.753 |
| Topical application of fluoride | Yes | 5 (11.6) | 4 (1.2) | 0.002 |
| Fluoride-containing mouthwash | Yes | 0 (0.0) | 1 (0.3) | 1.000 |
| Fissure sealant | Yes | 0 (0.0) | 5 (1.6) | 1.000 |
| Source of oral hygiene knowledge | | | |
| Internet | Yes | 8 (18.6) | 50 (15.6) | 0.610 |
| Television | yes | 12 (27.9) | 98 (30.5) | 0.725 |
| Dental clinic | Yes | 27 (62.8) | 169 (52.6) | 0.210 |
| Family | Yes | 7 (16.3) | 75 (23.4) | 0.296 |
| School | Yes | 15 (34.9) | 138 (43.0) | 0.312 |
| Follow-up | | | |
| Oral hygiene knowledge | | | |
| Dental plaque | Yes | 18 (41.9) | 89 (27.7) | 0.056 |
| Calculus | Yes | 23 (53.5) | 106 (33.0) | 0.008 |
| Periodontal disease | Yes | 13 (30.2) | 79 (24.6) | 0.426 |
| 8020 movement | Yes | 12 (27.9) | 66 (20.6) | 0.270 |
| Temporomandibular disorder | Yes | 8 (18.6) | 62 (19.3) | 0.912 |
| Dental floss | Yes | 10 (23.3) | 21 (6.5) | 0.001 |
| Topical application of fluoride | Yes | 4 (9.3) | 11 (3.4) | 0.087 |
| Fluoride-containing mouthwash | Yes | 3 (7.0) | 9 (2.8) | 0.158 |
| Fissure sealant | Yes | 2 (4.7) | 3 (0.9) | 0.108 |
| Source of oral hygiene knowledge | | | |
| Internet | Yes | 14 (32.6) | 113 (35.2) | 0.733 |
| Television | yes | 12 (27.9) | 85 (26.5) | 0.842 |
| Dental clinic | Yes | 24 (55.8) | 84 (26.2) | <0.001 |
| Family | Yes | 1 (2.3) | 28 (8.7) | 0.228 |
| School | Yes | 4 (9.3) | 50 (15.6) | 0.277 |

*Number (%) and mean (standard deviation),
†Fisher’s exact test, chi-square test or paired t test

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(p < 0.001, p < 0.001, p < 0.001, respectively) were significantly higher at follow-up than at baseline (paired t test, chi-squared test, Wilcoxon signed-rank test) (S3 Table).

A significant increase in OHI-S scores was seen in the non-improved group compared with the improved group regarding the use of dental floss (chi-squared test; p < 0.001) (S4 Table). Significant increases in %BOP and OHI-S scores were also seen in the non-improved group regarding frequent dental visits (chi-squared test; p = 0.022, p = 0.030, respectively) (S4 Table). On the other hand, no significant differences in oral condition were observed between the improved and non-improved groups regarding daily tooth brushing frequency (%BOP: p = 0.217, PPD: p = 0.615, OHI-S: p = 0.907).

Table 3. Associations between receiving regular dental checkups, oral hygiene knowledge, and the source of that knowledge at baseline and follow-up.

| Parameters | Improved group | Non-improved group | p-value* |
|------------|---------------|-------------------|----------|
|            | n = 46        | n = 297           |          |
| Sex        |               |                   |          |
| Male       | 21 (45.7)†    | 172 (57.9)        | 0.119    |
| Baseline   |               |                   |          |
| Age        | 18.4 (0.5)    | 18.2 (0.6)        | 0.035    |
| Oral hygiene knowledge |       |                   |          |
| Dental plaque | Yes         | 17 (37.0)        | 104 (35.0) | 0.798    |
| Calculus   | Yes           | 14 (30.4)        | 91 (30.6) | 0.978    |
| Periodontal disease | Yes   | 6 (13.0)        | 72 (24.2) | 0.092    |
| 8020 movement | Yes         | 17 (37.0)        | 57 (19.2) | 0.006    |
| Temporomandibular disorder | Yes   | 7 (15.2)        | 37 (12.5) | 0.603    |
| Dental floss | Yes           | 2 (4.3)         | 24 (8.1)  | 0.552    |
| Topical application of fluoride | Yes | 1 (2.2)         | 10 (3.4)  | 1.000    |
| Fluoride-containing mouthwash | Yes     | 0 (0.0)         | 1 (0.3)   | 1.000    |
| Fissure sealant | Yes            | 1 (2.2)        | 2 (0.7)   | 0.352    |
| Source of oral hygiene knowledge |       |                   |          |
| Internet   | Yes           | 7 (15.2)        | 54 (18.2) | 0.625    |
| Television | Yes           | 13 (28.3)       | 95 (32.0) | 0.613    |
| Dental clinic | Yes         | 25 (54.3)       | 149 (50.2)| 0.598    |
| Family     | Yes           | 5 (10.9)        | 75 (25.3) | 0.032    |
| School     | Yes           | 15 (32.6)       | 130 (43.8)| 0.154    |
| Follow-up  |               |                   |          |
| Oral hygiene knowledge |       |                   |          |
| Dental plaque | Yes         | 20 (43.5)       | 98 (33.0) | 0.164    |
| Calculus   | Yes           | 25 (54.3)       | 106 (35.7)| 0.015    |
| Periodontal disease | Yes   | 16 (34.8)       | 79 (26.6) | 0.248    |
| 8020 movement | Yes         | 13 (28.3)       | 58 (19.5) | 0.174    |
| Temporomandibular disorder | Yes   | 10 (21.7)       | 60 (20.2) | 0.810    |
| Dental floss | Yes           | 6 (13.0)        | 29 (9.8)  | 0.442    |
| Topical application of fluoride | Yes | 7 (15.2)        | 13 (4.4)  | 0.010    |
| Fluoride-containing mouthwash | Yes     | 2 (4.3)         | 12 (4.0)  | 1.000    |
| Fissure sealant | Yes            | 4 (8.7)        | 3 (1.0)   | 0.007    |
| Source of oral hygiene knowledge |       |                   |          |
| Internet   | Yes           | 12 (26.1)       | 118 (39.7)| 0.076    |
| Television | Yes           | 5 (10.9)        | 86 (29.0) | 0.010    |
| Dental clinic | Yes         | 34 (73.9)       | 67 (22.6) | <0.001   |
| Family     | Yes           | 2 (4.3)         | 25 (8.4)  | 0.555    |
| School     | Yes           | 5 (10.9)        | 47 (15.8) | 0.383    |

*Number (%) and mean (standard deviation), †Fisher’s exact test, chi-square test or paired t test
Discussion

Based on the results of our previous cross-sectional study [11], we conducted a prospective cohort study focused on the relationship between oral hygiene knowledge, the source of that knowledge, and oral hygiene behavior. We found a significant association between improved oral hygiene behavior, in terms of the use of dental floss and having regular dental visits, and having dental clinics as the source of oral hygiene knowledge in a group of Japanese university students. As the result, it was suggested that obtaining knowledge from dental clinics could improve oral health behavior. To our knowledge, the present prospective cohort study is the first to report this longitudinal association.

In the two improved groups (use of dental floss and having regular dental visits), dental clinics were the most common source of oral hygiene knowledge (about 60%) during university life at both baseline and follow-up. Similar to the present findings, previous studies have reported that > 60% of adults obtain their oral hygiene knowledge from dentists or dental clinics [26, 27]. On the other hand, in the non-improved groups that did not use dental floss or receive regular dental checkups, the Internet was the most common source of dental knowledge. Owing to the rapid spread of the Internet in recent years, young adults have unlimited chances to obtain information on oral hygiene. However, such information from online sources can vary greatly depending on the digital literacy of the individual [28], and inaccurate information is sometimes obtained [29]. Therefore, oral hygiene knowledge obtained from
Internet may not necessarily contribute to improved oral hygiene behavior, even among young adults.

Some researchers have reported on the relationship between oral hygiene knowledge and oral hygiene behavior. Muralidharan et al., reported that Indian students having oral hygiene knowledge of topical fluorides was significantly associated with good oral hygiene behavior [14]. Yao et al., reported that dental students in China had better oral hygiene behavior than medical students [15]. Márquez-Arrico et al., reported that use of dental floss was associated with good dental knowledge, however, frequency of tooth brushing did not present significant associations with levels of oral health knowledge in Spanish adult population [30]. Although it cannot be concluded, there is a general agreement that good dental knowledge and good oral health behavior are generally correlated.

In this study, having the knowledge of the 8020 movement was significantly associated with improved regular dental visit. The 8020 movement is a Japanese social campaign aiming to retain 20 or more of one’s own teeth at the age of 80. The participants who had the knowledge of the 8020 movement may be willing to do regular dental visit to retain 20 or more of one’s own teeth at the age of 80. The previous study also shows that the dental knowledge including the 8020 movement is significantly associated with regular dental visit [10] and supports our study.

No significant association was found between the frequency of tooth brushing and the source of oral hygiene knowledge; this finding supports that of our previous study [11].

On the other hand, it has been reported that the frequency of tooth brushing was associated with sex [31] or knowledge of topical fluoride [14], these results contradicted the present study. However, we should pay attention to the number of participants. Many students (86.3%) regularly brushed their teeth more than twice a day, so there might not have been much room for improvement, thereby creating a type of ceiling effect. Further, in this study the minimum sample size was 187. In the case of improved tooth brushing, the number of analyzed participants was less than the required number. The results of this analysis need to be interpreted with caution.

Not using dental floss was associated with lower OHI-S scores, and not receiving regular dental checkups was associated with lower OHI-S scores and %BOP (S3 Table); these findings suggest that the students with poor oral hygiene behavior also had poor oral hygiene and/or periodontal status, which supports the findings of previous studies [6, 10, 11]. Therefore, acquiring oral hygiene knowledge from dental clinics may be effective for improving oral hygiene behavior, thereby contributing to the achievement and maintenance of good periodontal status.

In the present study, the prevalences of frequent tooth brushing (≥ twice/day), dental floss use, and regular dental visits among all participants at baseline were 86.3%, 13.3%, and 17.0%, respectively. According to the Japanese Survey of Dental Diseases (2016) (https://www.mhlw.go.jp/toukei/list/62-28.html), the prevalences of frequent tooth brushing (≥ twice/day) and dental floss use among young people (age 20–24 years) were 77.0% and 20.4%, respectively; these data were similar to those in the present study. On the other hand, according to the Japanese National Health and Nutrition Survey (2016) (https://www.mhlw.go.jp/stf/houdou/0000177189.html), the prevalence of receiving regular dental checkups among young people aged 20–29 years was 43.3%. Okayama University students may have a lower rate of regular dental checkups. Therefore, the participants in this study should be carefully evaluated.

This study did have some limitations. First, other possible confounders, such as lifestyle, stress and education levels, and socioeconomic status, were not included in the analysis. Second, given the low follow-up rate (16.1–18.5% of all eligible students), there is a possibility of a selection bias. Third, we did not assess the effects of other variables that might affect oral
hygiene behavior, such as the frequency of obtaining information from the given source, the interactions between knowledge and knowledge sources, the frequency of dental floss use, the recall interval for dental checkups, and dental visit patterns, or the relation between oral health status and dental visit patterns. Forth, we could not test participants’ knowledge on preventive measures actually because we could only include the questionnaire during the routine oral health examination. Therefore, we could not investigate whether participants have the correct knowledge. Finally, because all participants were recruited from the same university in Japan, caution is needed in extrapolating these findings to the general population of younger people.

**Conclusion**

The results of the present 3-year cohort study suggest that having oral hygiene knowledge and obtaining knowledge from dental clinics among Japanese university students could improve oral health behavior in terms of the use of dental floss and regular dental visits. Acquiring oral hygiene knowledge from dental clinics may be effective for contributing to the achievement and maintenance of good periodontal status.

**Supporting information**

S1 Table. Questionnaire list in English.
(PDF)

S2 Table. Questionnaire list in Japanese.
(PDF)

S3 Table. Differences in periodontal status and oral hygiene at baseline and follow-up.
(PDF)

S4 Table. Differences in worsened periodontal status and oral hygiene between the improved and the non-improved groups.
(PDF)

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References

1. Lertpimoonchai A, Rattanasiri S, Arj-Ong Vallibhakara S, Attia J, Thakkins tian A. The association between oral hygiene and periodontitis: a systematic review and meta-analysis. Int Dent J. 2017; 67 (6):332–343. https://doi.org/10.1111/idj.12317 PMID: 28646499.

2. Davies RM, Davies GM, Ellwood RP. Prevention. Part 4: Toothbrushing: what advice should be given to patients? Br Dent J. 2003; 195: 135–141. https://doi.org/10.1038/sj.bdj.4810396 PMID: 12907975.

3. Sheiham A. Dietary effects on dental diseases. Public Health Nutr. 2001; 4(2B): 569–591. https://doi.org/10.1079/phn2001142 PMID: 11683551.

4. Sham AS, Cheung LK, Jin LJ, Corbet EF. The effects of tobacco use on oral health. Hong Kong Med J. 2003; 9(4): 271–277. PMID: 12904615.

5. Mizutani S, Ekuni D, Furuta M, Tomofuji T, Irie K, Azuma T, et al. Effects of self-efficacy on oral health behaviours and gingival health in university students aged 18- or 19-years-old. J Clin Periodontol. 2012; 39(9): 844–849. https://doi.org/10.1111/j.1600-051X.2012.01919.x PMID: 22780323.

6. Lang WP, Farghaly MM, Ronis DL. The relation of preventive dental behaviours to periodontal health status. J Clin Periodontol. 1994; 21(3): 193–198. https://doi.org/10.1038/sj.bdj.4810396 PMID: 10540935.

7. Deinzer R, Micheelis W, Granrath N, Hoffmann T. More to learn about: periodontitis-related knowledge and its relationship with periodontal health behaviour. J Clin Periodontol. 2009; 36(9): 756–764. https://doi.org/10.1111/j.1600-051X.2009.01452.x PMID: 19659893.

8. Ostberg AL, Halling A, Lindblad U. Gender differences in knowledge, attitude, behavior and perceived oral health among adolescents. Acta Odontol Scand. 1999; 57(4): 231–236. https://doi.org/10.1080/000163599428832 PMID: 10540935.

9. Fukai K. Statistical Analysis of Cognitions of Oral Health and Acceptance of Dental Care in Japanese Adult Population. J Dent Hlth. 1998; 48(1): 120–142 (in Japanese). https://doi.org/10.5834/jdh.48.1_120

10. Furuta M, Ekuni D, Irie K, Azuma T, Tomofuji T, Ogura T, et al. Sex differences in gingivitis relate to interaction of oral health behaviors in young people. J Periodontol. 2011; 82(4): 558–565. https://doi.org/10.1902/jop.2010.100444 PMID: 20936916.

11. Taniguchi-Tabata A, Ekuni D, Mizutani S, Yamane-Takeuchi M, Kataoka K, Azuma T, et al. Associations between dental knowledge, source of dental knowledge and oral health behavior in Japanese university students: A cross-sectional study. PLoS One. 2017; 12(6):e0179298. https://doi.org/10.1371/journal.pone.0179298 PMID: 28594914.

12. Tiwari T, Rai NK, Wilson AR, Gansky SA, Albino J. What Can We Learn from Parents of Caries-Free and Caries-Active Hispanic Children? JDR Clin Trans Res. 2020; 10:2380084420904043. https://doi.org/10.1177/2380084420904043 PMID: 32040929

13. Linjawi AI, Bahaziq AM, Qari AH, Baashen HA, Hassan AH. Impact of Dental Visits on Oral Health Awareness in Saudi Arabia. J Contemp Dent Pract. 2019; 20(7):783–788. PMID: 31597796

14. Muralidharan D, Pocha S, Paul A. Topical fluoride use: Knowledge, attitudes and practices of undergraduate dental students of three Dental Colleges in South India. Eur J Dent Educ. 2018; 22(3):e444–e450. https://doi.org/10.1111/eje.12323 PMID: 29396903

15. Yao K, Yao Y, Shen X, Lu C, Guo Q. Assessment of the oral health behavior, knowledge and status among dental and medical undergraduate students: a cross-sectional study. BMC Oral Health. 2019; 19(1):26. https://doi.org/10.1186/s12903-019-0716-6 PMID: 30696440

16. Gholami M, Pakdaman A, Montazeri A, Virtanen JI. Evaluation of the impact of a mass media campaign on periodontal knowledge among Iranian adults: a three-month follow-up. PLoS One. 2017; 12(1): e0169668. https://doi.org/10.1371/journal.pone.0169668 PMID: 28609599.
Gholami M, Pakdaman A, Montazeri A, Jafari A, Virtanen JI. Assessment of periodontal knowledge following a mass media oral health promotion campaign: a population-based study. BMC Oral Health. 2014; 14: 31. https://doi.org/10.1186/1472-6831-14-31 PMID: 24708753.

Märtensson C, Söderfeldt B, Halling A, Renvert S. Knowledge on periodontal disease before and after a mass media campaign. Swed Dent J. 2004; 28(4): 165–171. PMID: 15779493.

d’Almeida HB, Kagami N, Maki Y, Takaesu Y. Self-reported oral hygiene habits, health knowledge, and sources of oral health information in a group of Japanese junior high school students. Bull Tokyo Dent Coll. 1997; 38(2): 123–131. PMID: 9566129.

Iwamoto A, Ishikawa Y, Yagi M, Ohuchi A, Sato T, Fukai K, et al. Changing patterns of behavior related to oral health in dental health examination program for adults that gives priority to risk-funding and health-guidance. J Dent Hlth. 2012; 62(1): 33–40 (in Japanese).

Hugoson A, Koch G, Göthberg C, Helkimo AN, Lundin SA, Norderyd O, et al. Oral health of individuals aged 3–80 years in Jönköping, Sweden during 30 years (1973–2003). I. Review of findings on dental care habits and knowledge of oral health. Swed Dent J. 2005; 29(4): 125–38. PMID: 16463569.

Ishii T. The meaning and problem of the 8020 movement in Japan. Nihon Hotetsu Shika Gakkai Zasshi. 2005; 49: 168–178 (in Japanese). https://doi.org/10.2186/jjps.49.168 PMID: 15858312.

Ainamo J, Barmes D, Beagrie G, Cutress T, Martin J, Sardo-Infirri J. Development of the World Health Organization (WHO) community periodontal index of treatment needs (CPITN). Int Dent J. 1982; 32(3): 281–291. PMID: 6958657.

Greenstein G. The role of bleeding upon probing in the diagnosis of periodontal disease. A literature review. J Periodontol. 1984; 55(12): 684–688. https://doi.org/10.1902/jop.1984.55.12.684 PMID: 6394735.

Greene JC, Vermillion JR. The Simplified Oral Hygiene Index. J Am Dent Assoc. 1964; 68:7–13. https://doi.org/10.14219/jada.archive.1964.0034 PMID: 14076341.

Roberts-Thomson KF, Spencer AJ. Public knowledge of the prevention of dental decay and gum diseases. Aust Dent J. 1999; 44: 253–258. https://doi.org/10.1111/j.1834-7819.1999.tb00229.x PMID: 10687234.

Isman R. Public views on fluoridation and other preventive dental practices. Community Dent Oral Epidemiol. 1983; 11(4): 217–223. https://doi.org/10.1111/j.1600-0528.1983.tb01881.x PMID: 6576880.

Tam A, Yue O, Atchison KA, Richards JK, Holtzman JS. The association of patients’ oral health literacy and dental school communication tools: a pilot study. J Dent Educ. 2015; 79(5):530–8. PMID: 25941146.

ElKarmi R, Hassona Y, Taimeh D, Scully C. YouTube as a source for parents’ education on early childhood caries. Int J Paediatr Dent. 2017; 27(6):437–443. https://doi.org/10.1111/ijd.12277 PMID: 27882621.

Márquez-Arrico CF, Almerich-Silla JM, Montiel-Company JM. Oral health knowledge in relation to educational level in an adult population in Spain. J Clin Exp Dent. 2019; 11(12):e1143–e1150. https://doi.org/10.4317/jced.56411 PMID: 31824595.

Zhao Q, Wang SB, Xu G, Song Y, Han X, Liu Z, et al. Periodontal health: A national cross-sectional study of knowledge, attitudes and practices for the public oral health strategy in China. J Clin Periodontol. 2019; 46(4):406–419. https://doi.org/10.1111/jcpe.13082 PMID: 30768801.