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Structural equation modeling to detect predictors of oral health-related quality of life among Japanese university students: a prospective cohort study

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Abstract

Purpose This prospective cohort study of Japanese university students aimed to identify factors that might affect oral health-related quality of life (OHRQoL) and longitudinal relationships over a period of 3 years.

Methods Students ($n = 487$) provided complete data before entering and 3 years later (before university graduation) participated in the present study. Decayed, missing, and filled teeth (DMFT) scores, community periodontal index, ratios (%) of teeth with bleeding on probing, and malocclusion were determined during oral examinations. The questionnaire addressed age, sex, self-rated oral health, oral health behavior, subjective oral symptoms, and OHRQoL determined using the oral health impact profile (OHIP)-14. Associations were analyzed using structural equation modeling (SEM).

Results The OHRQoL significantly worsened according to OHIP-14 total score ($p = 0.001$). The final model in the symptoms of SEM analysis showed that OHRQoL at follow-up positively correlated with OHRQoL at baseline. Self-rated oral health was directly associated with the OHRQoL at baseline ($p < 0.05$).

Conclusions This study determined that OHRQoL at baseline was a direct predictor, and that self-rated oral health were indirect predictors of OHRQoL at follow-up among Japanese university students.

Keywords Oral health-related quality of life · The oral health impact profile-14 · Cohort study · Self-rated oral health · Structural equation modeling

Introduction

Health-related quality of life (HRQOL) is patient-reported self-assessments and is generally regarded as a complex concept made up of physical, emotional, and other dimensions [1]. It affects human health and consists from multiple domains such as, physical, cognitive, emotional, and social health [2]. Oral health-related quality of life (OHRQoL) that specialized in oral health conditions is commonly included in oral health surveys, clinical trials, oral health needs assessment, and studies evaluating the outcomes of dental treatment [3, 4]. OHRQoL indicates the subjective experience of symptoms associated with oral status that affect well-being [5, 6]. The OHRQoL is considered a meaningful outcome measure that reveals various oral symptoms and subjective perspectives and experiences. The oral health impact profile (OHIP)-14 is an established questionnaire that can assess the relationship between oral health and quality of life [7] and determine the impact of oral status on general health from a subjective viewpoint [8].

A good OHRQoL is important for all populations, particularly university students, who are in a dynamic growth period between adolescence and adulthood [9, 10] when their health, lifestyle, and behavior can be easily changed because many are no longer under parental supervision [11]. Therefore, the present study targeted this sector of the

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population. Poor oral health behavior can easily cause poor clinical status, which leads to a vicious circle that negatively affects OHRQoL [12, 13]. On the contrary, maintaining proper oral health during this period would lead to a better OHRQoL in the future. Factors influencing OHRQoL are important to understand in order to determine effective means of caring for the well-being of university students. Our previous cross-sectional study found that factors including self-rated oral health, subjective symptoms of temporomandibular disorders (TMD), oral pain, stomatitis, and clinical status affect OHRQoL [14]. However, prospective cohort studies have not yet investigated what actually affects the OHRQoL of university students. We hypothesized that some related factors at baseline affects OHRQoL at baseline and at follow-up among university students. The present study aimed to identify factors that might affect OHRQoL and their longitudinal relationships over a three-year period among Japanese university students.

Methods

Study population

The present prospective cohort study initially collected data from first-year students who underwent oral examinations and answered the questionnaire before entering university at the Health Service Center of Okayama University in April 2014 (baseline). The inclusion criteria at baseline was Japanese first-year students who provided complete data (oral examinations and questionnaire). Among these, students who volunteered to receive oral examinations in April 2017, before graduation (follow-up), were selected. Data from students who did not complete the questionnaire at follow-up were excluded.

Ethical procedures and informed consent

The Ethics Committees at Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences and Okayama University Hospital approved the study protocols (no. 1060). All selected students provided verbal informed consent to participate in the study, which followed the STROBE guidelines.

Questionnaire

The questionnaires addressed age, sex, self-rated oral health, oral health behavior, subjective oral symptoms, and OHRQoL.

Self-rated oral health was assessed by the question: "In general, how do you consider your oral health?". The response options were very good (1), good (2), fair (3), poor (4), or very poor (5) [10]. Oral health behavior was assessed by the following items: (i) regular checkups at dental clinics: yes (1) or no (2); (ii) use of dental floss: yes (1) or no (2); and (iii) daily frequency of tooth brushing, with response choices being once (3), twice (2), or ≥ 3 times (1). Answers to questions regarding subjective oral symptoms, the presence of oral pain, and recurrent aphthous stomatitis during the past 3 months were scored as either no (1) or yes (2) [10]. We determined symptoms of TMD using the following questions: "During the past year, (i) have you noticed any sounds in your ears?" (clicking), (ii) "Have you felt pain around the temporomandibular joint (TMJ) when opening your mouth or chewing food?" (TMJ pain), and (iii) "Have you experienced difficulty opening your mouth?" (difficulty opening mouth) [15]. Answers to these questions were scored as never (1), rarely (2), sometimes (3), or frequently (4) [10, 16].

We evaluated OHRQoL using the shortened Japanese version of the OHIP, which is a valid questionnaire to measure OHRQoL [17]. It comprises 14 questions ("Appendix 1") that assess seven subscale (i) functional limitations (difficulty in pronouncing words and/or worsened sense of taste), (ii) physical pain (aching in the mouth and/or discomfort eating), (iii) psychological discomfort (feeling self-conscious and/or tense), (iv) physical disability (unsatisfactory diet and/or need to interrupt meals), (v) psychological disability (difficulty relaxing and/or being embarrassed), (vi) social disability (irritability toward others and/or difficulty performing everyday tasks), and (vii) handicap (feeling that life is not satisfying and/or feeling totally unable to function) [18]. Response options were never (0), hardly ever (1), occasionally (2), fairly often (3), or often (4) [19]. The total OHIP-14 score (range 0–56) and seven subscale scores (range 0–8) were calculated by summing the response codes to the 14 questions constituting the measure, with a lower score suggesting better impact of oral status on OHRQoL [20].

Oral examination

Five qualified dentists (S.M., T.A., K.K., M.Y.-T., and D.E.) assessed the baseline oral health status of the students. Scores for decayed, missing, and filled teeth (DMFT) scores were based on the World Health Organization diagnostic criteria for dental caries [19]. Periodontal status was assessed using the community periodontal index (CPI) [19]. Ten teeth selected for periodontal examination comprised two molars in each posterior sextant and the upper right and lower left central incisors. We used a CPI probe (YDM, Tokyo, Japan) at six sites (mesio-buccal, mid-buccal, disto-buccal, disto-lingual, mid-lingual, and mesio-lingual) per tooth. We calculated the ratio (%) of teeth that bled upon probing (%BOP:

number of BOP-positive teeth per total number of teeth) in the same teeth examined for the CPI [10].

Malocclusion was determined using a modified version of the Index of Orthodontic Treatment Need (IOTN) [21]. We previously confirmed that non-specialists could screen malocclusion for oral health surveys using the modified IOTN [22]. The dental health component of the modified IOTN is graded as either 0 or 1, with 0 and 1 representing no definite and definite need, respectively, for orthodontic treatment, with no subcategories.

Qualified dentists trained repeatedly in determining DMFT and CPI scores as well as malocclusion in three volunteers over a period of 2 weeks. Good intra- and inter-examiner agreement for the oral examination was achieved (Kappa statistic, >0.8).

Statistical analyses

Differences between OHIP-14 scores at baseline and follow-up were evaluated using Wilcoxon signed-rank tests. Longitudinal association was analyzed using structural equation modeling (SEM). Figure 1 shows an ideal model based on our hypothesis, in which OHRQoL at follow-up was considered an endogenous variable and its relationships with exogenous variables at baseline and follow-up were assessed. The present data included continuous, dichotomous, and categorical data. Therefore, weighted least-squares parameter estimates (WLSMV) was selected. The path was analyzed using Mplus version 8 (Muthén & Muthén, Los Angeles, CA, USA). Standardized coefficient (SC) interpreted according to Kline indicated that SC of about 0.10, 0.30, and >0.50 represented small, medium, and powerful effects, respectively [23]. Non-significant χ^2 findings indicated that the data did not significantly differ from the hypotheses represented by the model [14]. The goodness of fit of the model was assessed using the comparative fit index (CFI), root mean square error of approximation (RMSEA), and the Tucker–Lewis coefficient (TLI) [19, 21]. An RMSEA value <0.05 suggested adequate fit, whereas CFI and TLI represented incremental fit; values >0.95 indicated an adequate fit, whereas those >0.90 were still acceptable [23]. Non-significant paths were removed step-by-step. Values with $p < 0.05$ were considered significantly different.

Results

Figure 2 shows a flow chart of the study participants. Among 2206 students who underwent oral examinations before entering university and answered the questionnaire in 2014, 519 of them volunteered to receive oral examinations and answered the questionnaire in April 2017 (follow-up rate, 23.5%) before graduating. Among these, we selected participants with completed oral data who completed both baseline

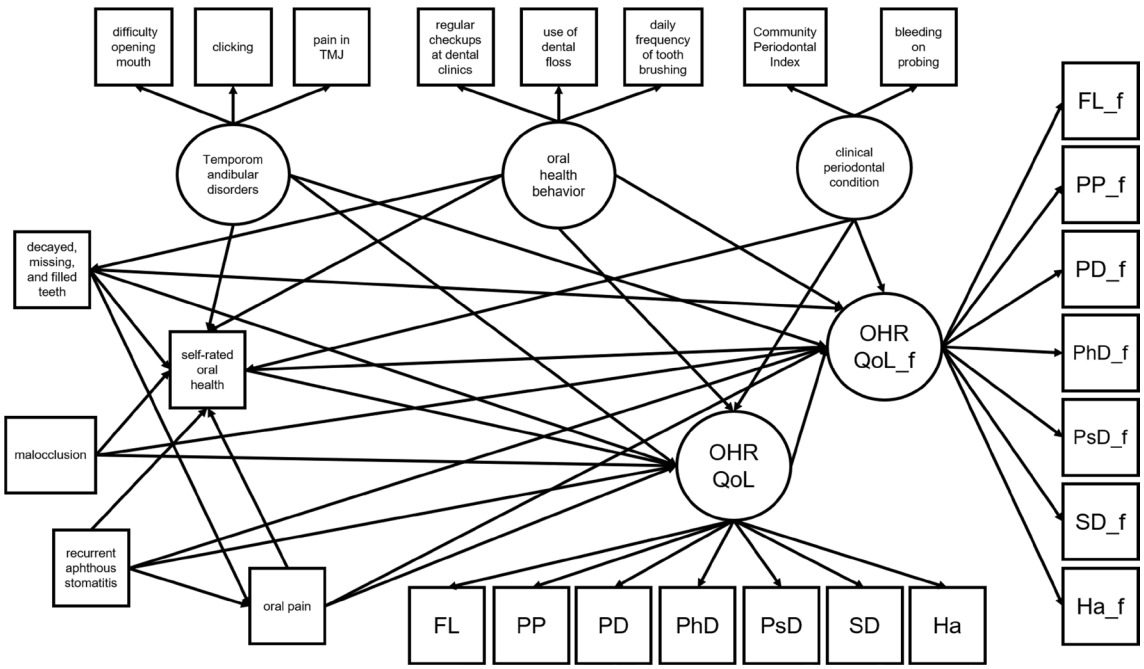

Fig. 1 Ideal model. Ideal model shows the associations among self-rated oral health, subjective symptoms, clinical status, oral health behavior, and OHRQoL. Rectangles and ovals indicate observed and latent variables, respectively. Values with single-head arrows indicate standardized coefficients. *f* follow-up, *FL* functional limitation, *Ha* handicap, *OHRQoL* oral health-related quality of life, *PD* psychological discomfort, *PhD* physical disability, *PP* physical pain, *PsD* Psychological disability, *SD* social disability

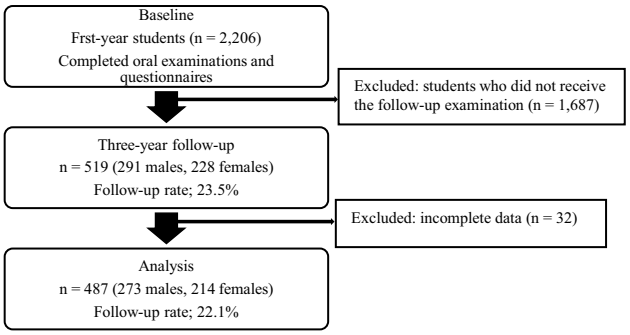

Fig. 2 Flow chart of the study participants

and follow-up questionnaires. After excluding incomplete data ($n = 32$), we analyzed data from 487 (273 males, 214 females) students aged 18.23 ± 0.53 years at baseline (follow-up rate, 22.1%).

Table 1 shows the characteristics of the 487 participants. Overall, the prevalence of poor and very poor self-rated oral health was 11.3% and 2.5%, respectively. The prevalence of self-reported recurrent aphthous stomatitis was 22.0%. The mean DMFT score was 1.91 ± 2.79. The prevalence of malocclusion was 23.0%.

Table 2 shows that total OHIP-14 scores significantly increased or worsened ($p = 0.001$). The number of students showing above 0 of total OHIP-14 scores at baseline and follow-up was 148 (30.4%) and 185 (38.0%), respectively. Significant differences were observed between the baseline and follow-up. Subscales of OHIP-14 also worsened significantly except for physical pain.

Figure 3 shows the parameters estimated for the final structural model. The χ^2 value was not significant ($\chi^2 = 156.168$; df = 131; $p = 0.0661$). The CFI, TLI, and RMSEA values indicated good model-data fit (0.999, 0.999, and 0.020, respectively). The model showed that OHRQoL at follow-up positively correlated with OHRQoL at baseline and that self-rated oral health was directly associated with the OHRQoL at baseline. All pathways were significant ($p < 0.05$). Clinical periodontal conditions, oral health behavior, TMD, and oral pain were excluded from the final model. "Appendix 2" shows change in OHRQoL from baseline to follow-up.

Discussion

To the best of our knowledge, this is the first prospective cohort study to apply the SEM approach to determine relationships between self-rated oral health, oral health behaviors, subjective symptoms, clinical status, and OHRQoL in a group of Japanese university students. The SEM analysis showed that OHRQoL at follow-up associated directly with that at baseline and indirectly with self-related oral health at baseline. In addition, DMFT, recurrent aphthous stomatitis, and malocclusion directly affected self-rated oral health at baseline. Japanese school health authorities have recently started to promote health [14], and understanding predictors of OHRQoL is important to ensure the health of young adults. The present study identified self-related oral health as predictors of OHRQoL.

Self-rated oral health was directly associated with OHRQoL at baseline; that is, better self-rated oral health resulted in a better OHRQoL, which concurred with the findings of our previous cross-sectional study [14]. Associations between self-rated oral health and OHRQoL have also been investigated among dental students in India [24]. Self-rated oral health is generally used to determine oral health status in epidemiological studies [10], because dental information can quite easily be collected for large-scale surveys [25, 26]. Self-rated oral health might be a useful predictor of changes in epidemiological studies of OHRQoL in younger populations.

The present study found that clinical status (DMFT score and malocclusion) and subjective symptoms of recurrent aphthous stomatitis were associated directly with self-rated oral health and indirectly with OHRQoL. That is, participants with high DMFT scores, malocclusion, and recurrent aphthous stomatitis felt that their self-rated oral health was unsatisfactory. The results of our previous cross-sectional study of university students were similar [10]. A high DMFT score correlated with anxiety [27], which affects self-rated oral health [10]. Thus, anxiety associated with caries might influence self-rated oral health. Although DMFT and OHRQoL were indirectly related in the present study, previous findings have suggested that DMFT score is a primary factor for low OHRQoL in children [28]. Dental treatment can improve oral health status, anxiety, and OHRQoL [29]. Therefore, a decreased DMFT score can be an effective way to improve OHRQoL. Oral mucosal diseases can seriously impair various aspects [30], and recurrent aphthous stomatitis affects the quality of life [31]. A previous control study has suggested an association between recurrent aphthous stomatitis and levels of anxiety as well as salivary cortisol that indicates stress resulting from persistent and recurrent episodes of burning pain [32]. The psychological impact of recurrent aphthous stomatitis might indirectly affect OHRQoL. Malocclusion has physical, psychological, and social effects [33], and negatively impacts performance, which might add to psychological stress among young adults [22]. Taken together, DMFT score, malocclusion, and recurrent aphthous stomatitis indirectly contribute to a poor OHRQoL. Therefore, control of these factors might be important for improving OHRQoL in young populations.

Oral pain and TMD did not fit the final model, though others have reported associations between these factors

Table 1 Characteristics of participants ($n = 487$)

Variable	n (%)/mean ± standard deviation (SD)	OHIP-14			
		Mean ± SD	95% confidence interval	Baseline n (%) above 0	Follow-up n (%) above 0
Male	273 (56.1)	2.2 ± 6.9	1.2–3.1	83 (17.0)	102 (20.9)
Female	214 (43.9)	1.8 ± 5.4	1.1–2.5	65 (13.3)	83 (17.0)
Self-rated oral health					
Very good	67 (13.8)	1.4 ± 7.5	–0.4–3.2	10 (2.1)	21 (4.3)
Good	118 (24.2)	1.9 ± 6.0	0.8–3.0	36 (7.4)	41 (8.4)
Fair	235 (48.2)	1.8 ± 4.5	1.2–2.3	73 (15.0)	91 (18.6)
Poor	55 (11.3)	2.6 ± 4.8	1.3–3.8	21 (4.3)	26 (5.3)
Very poor	12 (2.5)	9.4 ± 15.7	–0.6–19.4	8 (1.6)	6 (1.2)
Oral health behavior					
Regular dental checks					
Yes	82 (16.8)	1.9 ± 6.9	0.3–3.4	24 (4.9)	26 (5.3)
No	405 (83.2)	2.1 ± 5.7	1.5–2.6	124 (25.5)	159 (32.6)
Dental floss					
Yes	66 (13.6)	3.6 ± 8.6	1.4–5.7	22 (4.5)	27 (5.5)
No	421 (86.4)	1.8 ± 5.4	1.3–2.3	126 (25.9)	158 (32.4)
Daily frequency of tooth brushing					
≤ 1	61 (12.5)	1.3 ± 2.5	0.6–1.9	17 (3.5)	27 (5.5)
2	371 (76.2)	2.2 ± 6.5	1.5–2.8	115 (23.6)	139 (28.5)
≥ 3	55 (11.3)	1.8 ± 4.8	0.6–3.1	16 (3.3)	19 (3.9)
Subjective oral symptoms					
Oral pain					
Yes	15 (3.1)	2.1 ± 2.5	0.7–3.4	8 (1.6)	7 (1.4)
No	472 (96.9)	2.0 ± 6.0	1.5–2.6	140 (28.7)	178 (36.6)
Recurrent aphthous stomatitis					
Yes	107 (22.0)	2.7 ± 7.2	1.4–4.1	40 (8.2)	48 (9.9)
No	380 (78.0)	1.8 ± 5.6	1.3–2.4	108 (22.2)	137 (28.1)
Temporomandibular disorders					
Temporomandibular joint pain					
Never	377 (77.4)	1.9 ± 5.8	1.4–2.5	112 (23.0)	136 (27.9)
Rarely	73 (15.0)	2.8 ± 7.6	1.0–4.6	26 (5.3)	34 (7.0)
Sometimes	29 (6.0)	1.5 ± 3.4	0.2–2.7	8 (1.6)	13 (2.7)
Frequently	8 (1.6)	1.1 ± 2.5	–0.9–3.2	2 (0.4)	2 (0.4)
Clicking					
Never	273 (56.0)	2.0 ± 6.3	1.3–2.8	85 (17.5)	99 (20.3)
Rarely	90 (18.5)	2.5 ± 7.3	1.0–4.0	26 (5.3)	34 (7.0)
Sometimes	65 (13.3)	1.8 ± 3.8	0.8–2.7	20 (4.1)	24 (4.9)
Frequently	59 (12.1)	1.7 ± 3.8	0.7–2.6	17 (3.5)	28 (5.7)
Difficulty opening mouth					
Never	386 (79.3)	2.1 ± 6.4	1.4–2.7	111 (22.8)	145 (29.8)
Rarely	49 (10.0)	1.8 ± 3.4	0.8–2.7	19 (3.9)	19 (3.9)
Sometimes	40 (8.2)	2.4 ± 4.6	0.9–3.9	16 (3.3)	17 (3.5)
Frequently	12 (2.5)	0.3 ± 0.6	–0.1–0.6	2 (0.4)	4 (0.8)
Clinical status					
Decayed, missing, and filled teeth (DMFT) (number)					
0	226 (46.4)	1.1 ± 2.8	0.6–1.6	64 (13.1)	84 (17.2)
≥ 1	261 (53.6)	1.9 ± 6.4	0.8–3.1	84 (17.2)	101 (20.7)
Community periodontal index					
0	70 (14.4)	1.4 ± 3.4	0.6–2.2	21 (4.3)	30 (6.2)
1	103 (21.1)	2.7 ± 7.3	1.3–4.1	35 (7.2)	39 (8.0)

Table 1 (continued)

Variable	*n* (%)/mean ± standard deviation (SD)	OHIP-14			
		Mean ± SD	95% confidence interval	Baseline *n* (%) above 0	Follow-up *n* (%) above 0
2	242 (49.7)	2.1 ± 6.3	1.3–2.9	71 (14.6)	90 (18.5)
3	71 (14.6)	1.6 ± 4.2	0.6–2.6	21 (4.3)	25 (28.7)
4	1 (0.2)	–	–	–	1 (0.2)
Ratio (%) of bleeding on probing					
0	117 (24.0)	2.5 ± 7.0	1.2–3.8	41 (8.4)	49 (10.0)
≥ 10	370 (76.0)	1.3 ± 2.9	0.8–1.8	107 (22.0)	136 (27.9)
Malocclusion					
Yes	112 (23.0)	1.8 ± 4.3	1.0–2.6	37 (7.6)	49 (10.0)
No	375 (77.0)	2.1 ± 6.4	1.4–2.7	111 (22.8)	136 (27.9)

Table 2 Changes between baseline and follow-up in oral health impact profile-14 ($n = 487$)

Oral health impact profile-14	Mean ± standard deviation (SD)	Baseline		Follow-up			p^a
		95% confidence interval (CI)	*n* (%) above 0	Mean ± SD	95% CI	*n* (%) above 0	
Total	2.0 ± 6.0	1.5–2.6	148 (30.4)	4.1 ± 10.8	3.1–5.0	185 (38.0)	0.001
Subscale							
Functional limitation	0.2 ± 0.9	0.1–0.3	45 (9.2)	0.5 ± 1.6	0.4–0.7	84 (17.2)	< 0.001
Physical pain	0.4 ± 1.2	0.3–0.5	82 (16.8)	0.6 ± 1.7	0.5–0.8	98 (20.1)	0.207
Psychological discomfort	0.4 ± 1.1	0.3–0.5	80 (16.4)	0.6 ± 1.7	0.5–0.8	101 (20.7)	0.018
Physical disability	0.2 ± 0.9	0.1–0.3	36 (7.4)	0.5 ± 1.6	0.4–0.7	80 (16.4)	< 0.001
Psychological disability	0.2 ± 0.9	0.1–0.3	36 (7.4)	0.6 ± 1.7	0.5–0.8	94 (19.3)	0.002
Social disability	0.2 ± 0.9	0.2–0.3	47 (9.7)	0.6 ± 1.6	0.4–0.7	80 (16.4)	< 0.001
Handicap	0.2 ± 0.9	0.2–0.3	45 (9.2)	0.5 ± 1.6	0.4–0.7	66 (13.6)	< 0.001

[a]Wilcoxon signed-rank tests

and OHRQoL [31, 34–37]. Few students had experienced oral pain within the past 3 months or TMD in the present study population. Most participants reported never having had TMD symptoms, namely, clicking (56.0%), TMJ pain (77.4%), and difficulty opening the mouth (79.3%). Thus, oral pain and TMD might have had less impact on OHRQoL than other factors and were thus excluded from the pathways.

Oral health behavior such as frequency of tooth brushing or using dental floss were also excluded from the final model, although others have suggested an association between oral health behavior and OHRQoL. For example, a cross-sectional study of Brazilian orthodontic patients aged 14–30 years showed an association between using dental floss and OHRQoL [38]. In another cross-sectional study, Spanish persons aged 18–87 years who regularly attended dental clinics had significantly better dental and periodontal status and better oral well-being than those who did not, indicated by the mean total summary scores of OHIP-14 and the oral satisfaction scale [39]. The inconsistency of these two studies might be due to differences in study design, race, and age. Since the direct association is still unclear, further cohort studies are required.

Clinical periodontal conditions (CPI score and %BOP) were also excluded from the final model. A previous cross-sectional study involving the OHIP-14 found little impact of clinical oral health status on quality of life of dental students in India [24]. On the contrary, others have suggested a correlation between OHRQoL and clinical status in patients with obvious symptoms of periodontitis [40–42]. Generally, the frequency or degree of severe oral problems and the inability to perceive such problems are low among younger populations [10, 43]. Thus, university students have few symptoms of periodontal diseases. That is, the frequency of adverse or severe oral conditions that exert considerable impact on OHRQoL, such as periodontal disease or tooth loss, was low in this age group, which might explain the exclusion of these factors from the final model.

Slade and Spencer (1994) developed the OHIP-14 to measure disability and discomfort due to oral status and this has become one of the most popular OHRQoL tools [18]. It comprises 14 items that were derived from the original

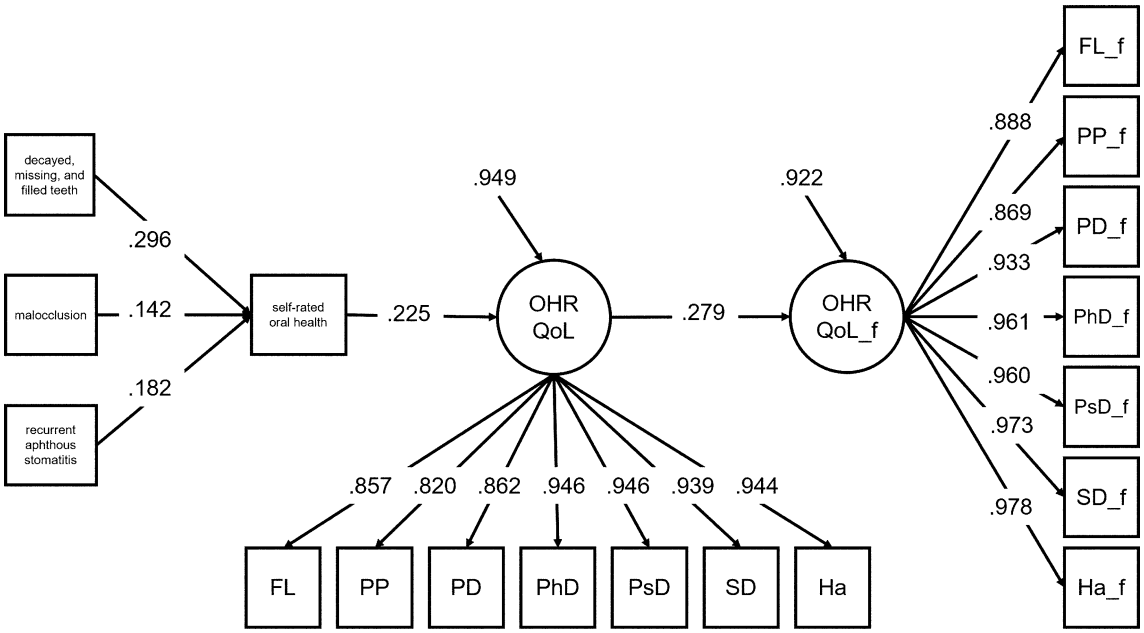

Fig. 3 Final structural model. Rectangles and ovals indicate observed and latent variables. Values for single-head arrows indicate standardized coefficients. All pathways are significant ($p < 0.05$). Follow-up OHRQoL is directly associated with that at baseline and indirectly associated with self-related oral health, stomatitis, DMFT, and malocclusion. *f* follow-up, *FL* functional limitation, *Ha* handicap, *OHRQoL* oral health-related quality of life, *PD* psychological discomfort, *PhD* physical disability, *PP* physical pain, *PsD* Psychological disability, *SD* social disability

49-item version [18]. We selected the OHIP-14 as an indicator of OHRQoL because it can detect psychosocial impact on individuals and groups, and it closely matches the main criteria for measuring OHRQoL [37, 44]. The OHIP-14 is also less time-consuming and more practical than the full version for epidemiological investigations of OHRQoL.

Most participants (69.6%) in the present study had a total OHIP-14 score of 0. The mean and standard deviation of the total OHIP-14 score at baseline was 2.02 ± 5.95, which was lower than the means determined in previous studies of Brazilian dental students [45], young adults in Hong Kong [46], and dental students in India (4.5, 6.3, and 13.4, respectively) [24]. The participants in this study tended to have a better OHRQoL compared to the similar generations in other countries. The inconsistency might be due to differences in study design or race. On the other hand, comparison of OHIP-14 using the mean and standard deviation must be considered carefully. The number of students with 0 scores of OHIP-14 was large in this study. Therefore, the mean value might not represent the population characteristics correctly. When using OHIP-14 for population who have good oral conditions, we need to be aware of these facts.

Evaluation of the OHRQoL depended on individual experience, which is affected by social, psychological, socioeconomic, demographic, and other cultural factors [32]. For example, socioeconomic factors such as low income and schooling can affect OHRQoL [47, 48]. Socioeconomic factors might not have varied very much in the present study compared with other countries [48, 49], because only national university students were recruited. Thus, the low score in this study might have been minimally affected by such factors compared with previous studies in other countries. However, we did not investigate socioeconomic status. Further studies are needed to determine such effects in Japan.

This study has several limitations. The follow-up rate was low (22.1%) because oral examinations are not mandatory at Japanese universities. A possible impact of differences between the group that was followed up and those who were not should be considered because some bias may lead to under- or overestimation. However, our findings did not significantly differ between the 487 participants who were followed up and 1719 individuals who were not, except for age, %BOP, and malocclusion ("Appendix 3"). Furthermore, all participants were recruited from Okayama University. Thus, extrapolating our findings to a general young Japanese population might be limited.

Conclusions

OHRQoL at baseline was a direct predictor, and self-rated oral health was indirect predictors of OHRQoL at follow-up in a three-year prospective cohort study of Japanese university students.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflicts of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethics Committees at Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences and at Okayama University Hospital, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Appendix 1: Question items of oral health impact profile-14

Subscale	Question item
Functional limitation	Have you had trouble pronouncing any words because of problems with your teeth, mouth or dentures?
	Have you felt that your sense of taste has worsened because of problems with your teeth, mouth or dentures?
Physical pain	Have you had painful aching in your mouth?
	Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth or dentures?
Psychological discomfort	Have you felt self-conscious because of problems with your teeth, mouth or dentures?
	Have you felt tense because of problems with your teeth, mouth or dentures?
Physical disability	Has your diet been unsatisfactory because of problems with your teeth, mouth or dentures?
	Have you had to interrupt meals because of problems with your teeth, mouth or dentures?
Psychological disability	Have you found it difficult to relax because of problems with your teeth, mouth or dentures?
	Have you been a bit embarrassed because of problems with your teeth, mouth or dentures?
Social disability	Have you been a bit irritable with other people because of problems with your teeth, mouth or dentures?
	Have you had difficulty doing your usual jobs because of problems with your teeth, mouth or dentures?
Handicap	Have you felt that life in general was less satisfying because of problems with your teeth, mouth or dentures?
	Have you been totally unable to function because of problems with your teeth, mouth or dentures?

Appendix 2: Change in OHRQoL from baseline to follow-up

Oral health impact profile-14	Self-rated oral health																	
	Total			Very good			Good			Fair			Poor			Very poor		
	Mean ± standard deviation (SD)	95% confidence interval (CI)	Median	Mean ± SD	95% CI	Median	Mean ± SD	95% CI	Median	Mean ± SD	95% CI	Median	Mean ± SD	95% CI	Median	Mean ± SD	95% CI	Median
Total	2.0 ± 12.1	1.0–3.1	0.0	1.9 ± 12.4	1.2–4.9	0.0	1.7 ± 12.1	0.5–3.9	0.0	3.1 ± 12.8	1.5–4.8	0.0	0.3 ± 5.5	1.2–0.8	0.0	−6.8 ± 13.2	−15.2– 1.5	−2.5
Subscale																		
Functional limitation	0.3 ± 1.8	0.2–0.5	0.0	0.3 ± 1.8	−0.3–0.6	0.0	0.2 ± 1.9	−0.2–0.5	0.0	0.5 ± 1.8	0.3–0.7	0.0	0.3 ± 0.9	0.0–0.5	0.0	−1.2 ± 2.4	−2.7– 0.4	0.0
Physical pain	0.2 ± 2.0	0.0–0.4	0.0	0.2 ± 1.9	−0.3–0.6	0.0	0.2 ± 0.9	−0.1–0.6	0.0	0.3 ± 2.2	0.1–0.6	0.0	−0.1 ±1.5	−0.5–0.3	0.0	−1.4 ± 2.8	−3.2–0.4	0.0
Psychological discomfort	0.2 ± 2.0	0.1–0.4	0.0	0.2 ± 2.0	−0.2–0.8	0.0	0.2 ± 2.0	−0.2–0.6	0.0	0.4 ± 2.0	0.2–0.7	0.0.	−0.3 ± 1.5	−0.7–0.1	0.0	−1.3 ± 2.5	−2.9–0.3	−0.5
Physical disability	0.3 ± 1.8	0.2–0.5	0.0	0.3 ± 2.0	−0.2–0.7	0.0	0.3 ± 1.8	0.0–0.6	0.0	0.5 ± 2.0	0.2–0.7	0.0	0.2 ± 0.8	0.0–0.4	0.0	−0.4 ± 0.0	−1.8–1.0	0.0
Psychological disability	0.4 ± 1.9	0.3–0.6	0.0	0.5 ± 2.0	0.0–0.9	0.0	0.4 ±1.9	0.0–0.7	0.0	0.6 ± 2.0	0.3–0.8	0.0	0.3 ± 1.0	0.0–0.5	0.0	−0.6 ± 2.4	−2.1–0.9	0.0
Social disability	0.3 ± 1.8	0.2–0.5	0.0	0.3 ± 1.7	−0.2–0.7	0.0.	0.3 ± 1.8	0.0–0.6	0.0	0.5 ± 2.0	0.2–0.7	0.0	0.2 ± 1.0	−0.1–0.5	0.0	−0.4 ± 1.6	−1.4–0.6	0.0
Handicap	0.3 ± 1.8	0.1–0.5	0.0	0.2 ± 1.8	−0.2–0.7	0.0	0.2 ± 1.7	−0.1–0.5	0.0	0.5 ± 1.9	0.2–0.7	0.0	−0.2 ± 1.1	−0.2–0.4	0.0	−0.9 ± 1.8	−2.0–0.2	0.0

The values were obtained by subtracting the baseline value from the follow-up value

Appendix 3: Baseline data comparison between follow-up and non-follow-up students

Variable	Follow-up students (n = 487) n (%)/mean ± standard deviation (SD)	Non-follow-up students (n = 1719) N (%)/mean ± SD	p[a]
Male	273 (56.1)	1001 (58.2)	0.391
Age (years)	18.23 ± 0.53	18.58 ± 2.23	< 0.001
Self-rated oral health			
≥ Good	185 (38.0)	612 (35.3)	
≤ Fair	302 (62.0)	1107 (64.4)	0.333
Oral health behavior			
Regular dental checks			
Yes	82 (16.8)	294 (17.1)	0.891
Dental floss			
Yes	66 (13.6)	227 (13.2)	0.842
Daily frequency of tooth brushing			
≤ 1	61 (12.5)	239 (13.9)	
≥ 2	426 (87.5)	1480 (86.1)	0.434
Subjective oral symptoms			
Oral pain			
Yes	15 (3.1)	45 (2.6)	0.580
Recurrent aphthous stomatitis			
Yes	107 (22.0)	352 (20.5)	0.473
Temporomandibular disorders			
Temporomandibular joint pain			
≤ Rarely	450 (92.4)	1568 (91.2)	
≥ Sometimes	37 (7.6)	151 (8.8)	0.408
Clicking			
≤ Rarely	363 (74.5)	1277 (74.3)	
≥ Sometimes	124 (25.5)	442 (25.7)	0.911
Difficulty opening mouth			
≤ Rarely	435 (89.3)	1551 (90.2)	
≥ Sometimes	52 (10.7)	168 (9.8)	0.557
Clinical status			
Decayed, missing, and filled teeth (number)	1.91 ± 2.79	2.17 ± 3.05	0.122
Community periodontal index			
≤ 1	173 (35.5)	605 (35.2)	
≥ 2	314 (64.5)	1114 (64.8)	0.893
Ratio (%) of bleeding on probing	31.15 ± 27.77	34.42 ± 28.17	0.016
Malocclusion	112 (23.0)	490 (28.5)	0.012
The total score of OHIP-14	2.02 ± 5.95	2.04 ± 5.77	0.900

[a]Mann–Whitney U test, χ^2 test

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