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Removable partial denture, complete denture, and fixed partial denture use and health-related quality of life among older adults with tooth loss: A JAGES cross-sectional study

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Abstract

Purpose: To investigate the association of removable partial denture (RPD)/complete denture (CD) and fixed partial denture (FPD) use with health-related quality of life (HRQoL), evaluated using the EuroQol 5-dimension, 5-level instrument (EQ-5D-5L) among older adults with tooth loss.

Methods: Cross-sectional data from the 2022 Japan Gerontological Evaluation Study. Participants were classified as RPD/CD users, FPD users, or nonusers. Generalized linear regression models stratified by the number of teeth were used to explore the association of RPD/CD and FPD use with the HRQoL evaluated using the EQ-5D-5L. The interactions among the number of teeth, RPD/CD, and FPD use were examined.

Results: After adjusting for all covariates, RPD/CD and FPD users with 5–19 teeth had higher predicted HRQoL utility scores than nonusers (RPD/CD [n=14,297]: 0.837 vs. 0.850; FPD [n=7,476]: 0.858 vs. 0.861 [nonusers vs. users]). The interaction between number of teeth and RPD/CD and FPD use revealed that differences in HRQoL between users and nonusers were greater among those with 1–14 teeth for RPD/CD use and among those with 10–14 teeth for FPD use (RPD/CD: $\beta = -0.008$, $P < 0.01$; FPD: $\beta = -0.008$, $P = 0.183$).

Conclusions: RPD/CD and FPD users with 5–19 teeth had a higher HRQoL than nonusers, with differences appearing to depend on the number of teeth. The World Health Organization has promoted the incorporation of oral health into universal health coverage (UHC). Given the minimal HRQoL difference between CD users and nonusers among edentulous individuals, unconventional dentures may merit inclusion in UHC.

Keywords: Removable partial denture, Complete denture, Fixed partial denture, Quality of life, Patient outcome assessment

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1. Introduction

In older adults, tooth loss is a global health concern because it is highly prevalent and associated with systemic health conditions, such as noncommunicable diseases[1] and mortality[2]. Additionally, dental prosthesis (DP) use for tooth loss has been reported to affect systemic health conditions such as all-cause mortality[3], dementia[4], nutritional status, enjoyment of food[5], social participation[6], subjective happiness[7], and depressive symptoms[8].

Recently, health-related quality of life (HRQoL), a patient-reported outcome in which patients themselves subjectively report their health, quality of life, or functional status associated with healthcare or treatment[9], has gained importance from the perspective of improving the quality of healthcare and the effective utilization of healthcare resources[10]. Cost-effectiveness analyses, often using quality-adjusted life years (QALY), have been used in some countries to determine healthcare reimbursement and pricing decisions[11,12]. QALY was calculated by multiplying life-years and HRQoL util-

WHAT IS ALREADY KNOWN ABOUT THE TOPIC?

» *The association between dental prosthesis (DP) use and general health-related quality of life (HRQoL) remains controversial, and reports on the impact of DP use on HRQoL vary. The association between different types of DP and HRQoL obtained using the EuroQol 5-dimension, 5-level instrument (EQ-5D-5L) has not been reported previously.*

WHAT THIS STUDY ADDS?

» *Users of removable partial dentures (RPD), complete dentures (CD), and fixed partial dentures (FPD) with 5–19 teeth had higher HRQoL utility scores than nonusers. The differences in the HRQoL utility scores between the two groups were greater in participants with 1–14 teeth for RPD/CDs and 10–14 teeth for FPD.*

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ity scores[13,14], which are commonly measured using the EuroQol 5-dimension, 5-level instrument (EQ-5D-5L). This instrument is recommended as the initial choice in several countries, including Japan, because it enables consistency and comparability across datasets, and a national value set is available[15]. In Japan, cost-effectiveness analysis is used for post-reimbursement price adjustments for certain high-cost pharmaceuticals and medical devices[14,16].

While numerous studies have examined the association between different types of DP and oral health-related quality of life (OHRQoL)[17–22], a notable gap exists in research comparing the impact of different DP types on general HRQoL[23–26]. Notably, these studies[23–26] focused solely on patient populations, which may limit the generalizability of their findings to the broader general population. Furthermore, the results on the association between denture use and HRQoL are conflicting. Denture use has been reported to negatively affect HRQoL, primarily because of its adverse impact on social interactions[27,28]. However, positive effects on HRQoL have been reported for removable partial dentures (RPDs), complete dentures (CDs)[23,26,29], and implant-supported dentures[25]. These improvements were primarily attributed to the enhancement of appearance, oral function, and stability of the missing mandibular molar teeth[23]. Some studies have found no significant effect of RPDs[26], CDs[25,30,31], or fixed partial dentures (FPDs)[26] on HRQoL, mainly because measuring dental treatment outcomes using HRQoL is less sensitive than OHRQoL. Furthermore, few studies have explored the effects of specific denture types stratified by the number of teeth, or the interaction effects between the number of teeth and DP use. Furthermore, EQ-5D-5L has rarely been used to evaluate these associations. To address this gap, we investigated the association between DP use and HRQoL obtained by the EQ-5D-5L in a large community-dwelling older population as follows: (1) stratifying participants according to the number of teeth, (2) examining the association of RPD/CD and FPD use with HRQoL, and (3) examining the interactions between the number of teeth and the use of RPDs/CDs and FPD.

2. Materials and Methods

2.1. Study design and participants

This study used cross-sectional data from the 2022 Japan Gerontological Evaluation Study (JAGES), an ongoing nationwide cohort study focusing on aging and health[32]. Self-administered questionnaires that included questions related to the EQ-5D-5L were mailed to 38,791 independent older adults aged ≥ 65 years who did not receive long-term care insurance benefits and lived in 70 municipalities in Japan, and available respondents were 24, 271.

2.2. Exclusion criteria

Figure 1 presents a flowchart of the individuals who participated in the analysis. The exclusion criteria were as follows: (1) invalid ID, sex, or age (n = 475); (2) had ≥ 28 teeth (complete dentition; n = 5,116); (3) had zero teeth (only for FPD use, n = 1,745); and (4) use of dental implants (RPD/CD use, n = 903; FPD use, n = 873). For RPD/CD use analysis, FPD users (n = 3,480) were excluded. For the FPD use analysis, RPD/CD users (n = 8,586) were excluded. None of the participants in this study used either RPDs/CDs or FPD.

2.3. Dependent variable

HRQoL, evaluated as the utility score of the EQ-5D-5L, was used as the dependent variable. Five items were evaluated on a 5-point scale (no, slight, moderate, severe, and extreme problems) to calculate the HRQoL utility scores for mobility, self-care, usual activity, pain/discomfort, and anxiety/depression. The responses were converted to utility scores based on the Japanese EQ-5D-5L value set[33]. For details on the questionnaire items, response options, and scoring algorithms (Ikeda *et al.* 2015)[33].

2.4. Independent variables

RPD/CD and FPD use were the independent variables. The participants were asked to select all answers that applied to their status of DP use as follows: not used, removable dentures, FPD, or dental implants. Participants who only selected removable dentures (excluding FPD) were classified as RPD/CD users, whereas those who only selected FPD (excluding removable dentures) were FPD users. Non-users (individuals who selected neither) were analyzed as RPD/CD nonusers and FPD nonusers in their respective analyses, representing the same population.

2.5. Covariates

The following variables were included in the analyses as covariates: (1) sex (male/female), (2) age (65–69, 70–74, 75–79, 80–84, or ≥85 years old), (3) equivalent income (JPY < 2.00 million, 2.00–2.99 million, 3.00–3.99 million, or ≥ 4.00 million; USD 1 = JPY 150), (4) education status (≤9, 10–12, or ≥ 13 years), (5) smoking status (current, former, or never), (6) alcohol drinking status (current, former, or never), (7) the presence or sequelae of comorbidity (yes/no), and (8) number of teeth (0, 1–4, 5–9, 10–14, 15–19, and 20–27 teeth; omitted in stratification analyses).

2.6. Statistical analysis

The analyses of RPD/CD and FPD use were conducted using separate datasets. Descriptive analyses stratified by the number of teeth (0, 1–4, 5–9, 10–14, 15–19, and 20–27) were conducted to illustrate respondent characteristics. A previous cross-sectional study using JAGES data stratified participants into groups of 0, 1–4, 5–9, 10–19, and ≥20 teeth[29]. The present study further refined the group of participants with a tooth count of 10–19 to account for finer differences in the number of teeth. Second, to obtain regression coefficients (β) and 95% confidence intervals (CIs) for RPD/CD use and FPD use, Tobit regression models (left-censoring limit = 0, right-censoring limit = 1) stratified by the number of teeth were employed for modeling censored variables[34,35]. Model 1 was crude. In model 2, sex, age, equivalent income, educational status, smoking status, alcohol consumption status, comorbidities, and the number of teeth were added to model 1. Third, after performing the Tobit regression analysis, residual diagnostics were conducted to investigate the normality (by histogram and normal Q-Q plot) and homoscedasticity (by residual vs. fitted values plot)[36] based on the results of model 2 (**Tables S1 and S2**, **Figs. S1 and S2**). As the residual diagnostics of the Tobit regression model demonstrated violations of the normality and homoscedasticity assumptions, generalized linear models (GLMs) were employed to address these issues. Comparing the Gaussian and Gamma distributions, the Gaussian distribution with a log-link function was selected based on low Akaike's Information Criteria and the Bayesian Information Criteria scores (results not shown). Fourth,

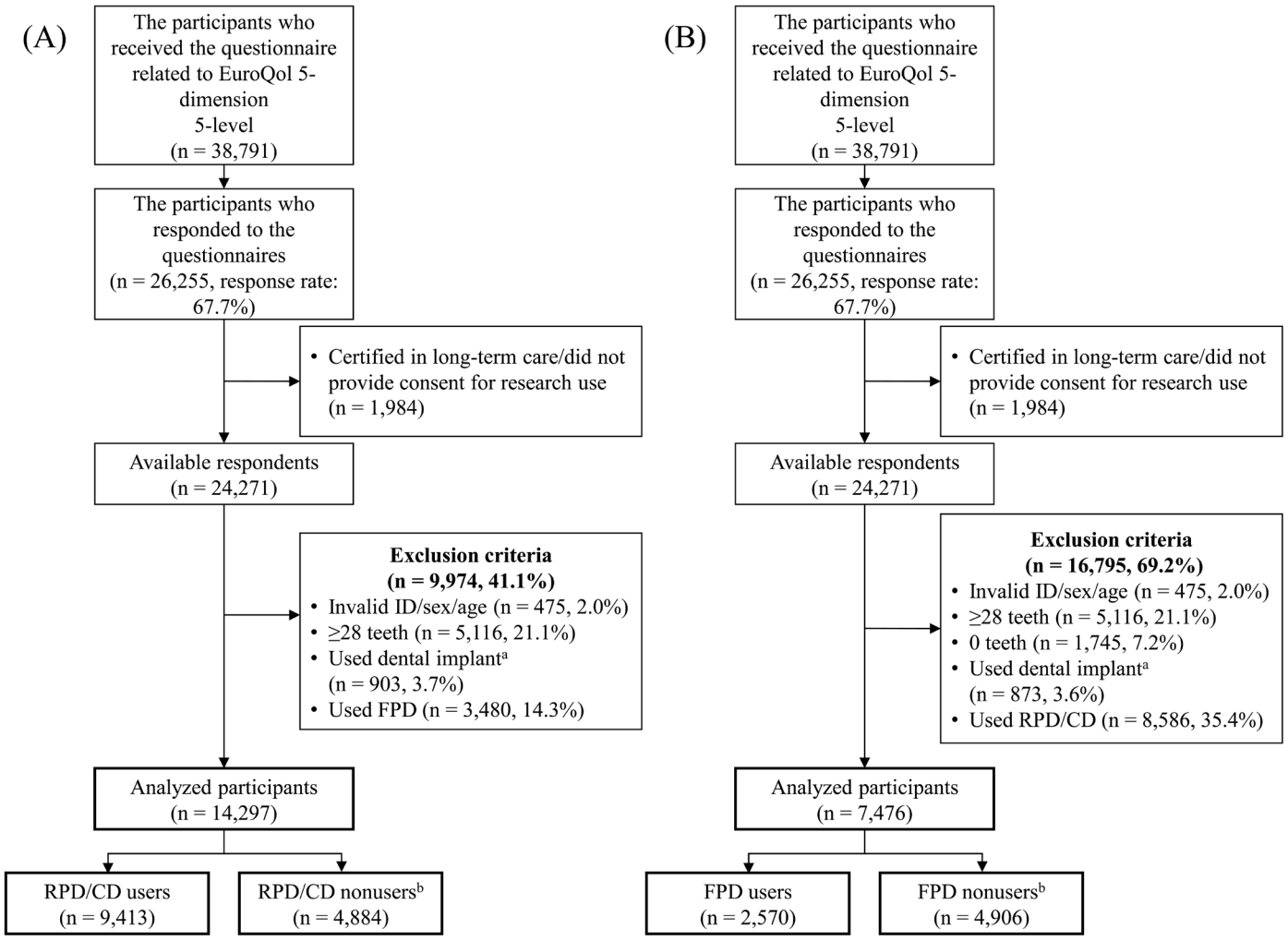

Fig. 1. The flowchart of participants included in the analyses. (A) Analysis of removable partial denture/complete denture use. (B) Analysis of fixed partial denture use. [a] Participants with dental implants were excluded because they were not covered by the current Japanese Universal Health Insurance Coverage System. [b] The analyses of RPD/CD and FPD use were conducted using separate datasets, and multiple imputations were performed separately for each dataset. Therefore, although RPD/CD and FPD nonusers refer to the same population, the sample sizes differ. RPD/CD: removable partial denture/complete denture; FPD: fixed partial denture.

to evaluate robustness against potential unmeasured confounding factors, sensitivity analyses were conducted using approximate E-values[37]. These approximate E-values were calculated based on the results from model 2 of the GLMs, applying the approximation risk ratio (RR) ≈ exp[0.91 × standardized effect sizes d (mean of the outcome variable divided by the standard deviation of the outcome)] in the E-value formula[37]. The E-value indicates the minimum strength of association that unmeasured confounders would need to have with both the exposure and outcome variables to potentially nullify the observed association potentially[37]. Furthermore, the interactions between the number of teeth and the use of RPDs/CDs and FPD were examined. Missing data were imputed using multiple imputations with chained equations[38]. Stata SE version 17 (Stata Corp.) was used for all analyses, and statistical significance was set at *P*-values < 0.05. The Strengthening the Reporting of Observational Studies in Epidemiology guidelines for cross-sectional studies were followed.

2.7. Ethics approval and consent to participate

Ethical approval for the 2022 JAGES survey was obtained from the Ethics Committee on Research of Human Subjects at Chiba University Graduate School of Medicine (No. M10460). Informed consent was obtained from all participants.

3. Results

Of the 38,791 participants, 26,255 responded (response rate: 67.7%) (**Fig. 1**). After excluding invalid responses, the analyses of RPD/CD use included 14,297 participants (mean age: 76.4 [standard deviation = 6.6]; male: 48.6%), and the analyses of FPD use included 7,476 participants (mean age: 74.5 [standard deviation = 6.2]; male: 47.1%). The distribution of the EQ-5D-5L utility scores for the RPD/CD and FPD populations is demonstrated in **Figure S3**. For both the RPD/CD and FPD groups, approximately 30% of the participants had an EQ-5D-5L utility score of 1.

Table 1 shows the descriptive statistics of the participants stratified according to the number of teeth with multiple imputations. When stratified by the number of teeth, the mean HRQoL utility scores were higher among RPD/CD or FPD users than among nonusers in all groups, except for the zero and 20–27 teeth groups in the RPD/CD use analysis and the 1–4 teeth group in the FPD use analysis.

Tables 2 and 3 reveal the results of the GLMs with multiple imputations used to investigate the association between RPD/CD use and HRQoL. After adjusting for all covariates, the HRQoL utility scores were higher for users than for nonusers in all groups (total, $P < 0.001$; 0 teeth, $P = 0.321$; 1–4 teeth, $P = 0.065$; 5–9 teeth, $P < 0.01$; 10–14 teeth, $P < 0.01$; 15-19 teeth, $P = 0.173$; and 20–27 teeth, $P = 0.181$). In the FPD use analysis, similar trends were observed in the 5–19 teeth groups, whereas opposite trends were found in the other groups (total, $P = 0.455$; 1–4 teeth, $P = 0.680$; 5–9 teeth, $P = 0.570$; 10–14 teeth, $P < 0.05$; 15–19 teeth, $P = 0.606$; and 20–27 teeth, $P = 0.757$) (**Tables 4 and 5**).

Table S3 lists the estimated approximate E-values. Approximate E-values ranged 1.00–1.97 for the point estimates and 1.00–1.49 for confidence limits across the different outcomes.

Table S4 and Figure 2 (A) reveal the interaction between RPD/CD use and the number of teeth, whereas **Table S5 and Figure 2 (B)** illustrate the interaction for FPD use. The HRQoL difference between RPD/CD users and nonusers was greater in groups with 1–14 teeth than in all other groups (**Fig. 2 (A)**; $\beta = -0.008$, $P < 0.01$). For FPD users and nonusers, the difference was greater in groups with 10–14 teeth than in all other groups (**Fig. 2 (B)**, $\beta = -0.008$, $P = 0.183$).

4. Discussion

In the present study, RPD/CD and FPD users with 5–19 teeth had higher HRQoL utility scores than those without. A statistically significant difference was observed between those with 5–14 teeth for RPD/CD use and those with 10–14 teeth for FPD use. The interaction effect demonstrated that the difference was greater in groups with 1–14 teeth for RPD/CD use and 10–14 teeth for FPD use.

These results were partially consistent with those of previous studies. For example, a previous cross-sectional study reported that among those with ≤ 19 teeth, RPD/CD users revealed higher HRQoL utility scores obtained by EQ-5D-5L than nonusers[29]. Conversely, a previous study examining RPD/CD and FPD treatments reported that treatment with any DP significantly enhanced certain components of the Short Form-36 (SF-36) across all participants. However, no significant association was observed between RPDs/CDs and FPDs[26]. Our study demonstrated a positive association when analyzed separately, and the FPD results were novel of the present study.

Possible explanations for these results are as follows: A previous study reported that DP use exerted protective effects on functional disability, intellectual ability, frequency of going out, and dietary lifestyle among older adults with ≤ 19 teeth[39]. Another study revealed that DP use mitigated the association between tooth loss and risk of depressive symptoms among those with ≤ 9 teeth[8]. In the present study, the mitigating effects of RPDs/CDs and FPD on the negative impact of tooth loss on HRQoL were comparable, indicating that the protective effect of RPDs/CDs and FPD, as described in previous studies, had a positive impact on HRQoL utility scores, regardless of the type.

The increase in HRQoL scores due to RPD/CD and FPD use, particularly among those with 1–14 teeth for RPD/CDs and 10–14 teeth for FPD, was approximately 0.03–0.04. Although the Minimal Important Difference (MID)—the smallest change in a measure that patients perceive as beneficial—in EQ-5D varies depending on the disease and situation, a previous study reported that it was 0.044 ± 0.004 for the Japanese population[40]. Regarding MID in the oral and maxillofacial region, a study in the United States reported a value of 0.04 for treatment of chronic rhinosinusitis[41]. The present results for RPD/CD and FPD use were the same extent as these values. Further research is required to clarify the denture treatment-specific MID in the EQ-5D.

Regarding the difference in the effect sizes of RPDs/CDs and FPDs according to the number of teeth, the difference in HRQoL utility scores between the use and non-use of RPDs/CDs and FPDs was very small in the group with 15–27 teeth. Notably, in the 20–27 teeth group, nonusers tended to have a higher HRQoL, although this difference was not statistically significant. A possible explanation for this is the higher HRQoL utility scores of the group with 15–27 teeth, which may have a ceiling effect on the protective effects of RPDs/CDs and FPD on HRQoL. Conversely, among those with 1–4 teeth, FPD users exhibited a non-significant trend toward lower HRQoL than nonusers. This may be attributable to the insufficient restoration of functional occlusion attained by FPD alone. Additionally, for CDs, the difference in HRQoL was minimal in the zero-teeth group, consistent with previous studies reporting nonsignificant HRQoL improvements with CD treatment[25]. One possible explanation for this is the unsatisfactory improvement in the chewing ability of CDs[42]. Meanwhile, studies from Canada[25] and the Netherlands[43] reported that implant dentures enhanced the HRQoL among edentulous older adults compared to traditional CDs.

This study reaffirms the clinical significance of RPD/CD and FPD treatments from the perspective of restoring oral function and improving HRQoL. For example, Japanese guidelines recommend evaluating a patient's systemic health[44] and OHRQoL[45] before denture treatment. Incorporating HRQoL evaluations would provide a more comprehensive assessment of the patient status and treatment impact. Additionally, the World Health Organization has advocated incorporating oral health care into universal health coverage (UHC)[46], ensuring that all people have access to the full range of quality health services they need, when and where they need them, without facing financial hardship[47]. Given that edentulous individuals have lower HRQoL and higher all-cause mortality risks than dentate individuals[2], considering unconventional dentures for UHC inclusion is worthwhile to enhance their utilization and mitigate these risks[48,49]. Further EQ-5D-5L evaluations and cost-effectiveness analyses are required to guide global policy decisions regarding the inclusion of various DP types in UHC.

This study had some limitations. First, its cross-sectional design limited the ability to draw causal inferences. Lower HRQoL may have led participants to avoid using RPDs/CDs and FPD. Longitudinal studies are required to reduce the risk of reverse causation. Second, although the self-reported number of teeth has been validated in the Japanese population[50,51], the use of self-reported data may have caused misclassification. The patients may not have fully understood or reported the type of DP used. Moreover, although our study focused on independent older adults who provided valid ID, sex, and age information, the self-reported nature of our survey raised concerns regarding the data quality. Without information on question-

Table 1. Descriptive statistics of participants stratified by the number of teeth with multiple imputation

	RPD/CD use							FPD use					
	Total	0 teeth	1–4 teeth	5–9 teeth	10–14 teeth	15–19 teeth	20–27 teeth	Total	1–4 teeth	5–9 teeth	10–14 teeth	15–19 teeth	20–27 teeth
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Total	14,297 (100.0)	1,813 (100.0)	1,299 (100.0)	1,706 (100.0)	1,758 (100.0)	1,688 (100.0)	6,033 (100.0)	7,476 (100.0)	208 (100.0)	331 (100.0)	513 (100.0)	794 (100.0)	5,631 (100.0)
RPD/CD or FPD use													
No	4,884 (34.2)	137 (7.6)	162 (12.4)	201 (11.8)	287 (16.4)	464 (27.5)	3,634 (60.2)	4,906 (65.6)	176 (84.5)	218 (65.9)	306 (59.6)	482 (60.7)	3,724 (66.1)
Yes	9,413 (65.8)	1,676 (92.4)	1,137 (87.6)	1,505 (88.2)	1,470 (83.6)	1,224 (72.5)	2,400 (39.8)	2,570 (34.4)	32 (15.5)	113 (34.1)	207 (40.4)	312 (39.3)	1,907 (33.9)
Sex													
Male	6,943 (48.6)	975 (53.8)	711 (54.7)	837 (49.1)	859 (48.8)	806 (47.7)	2,756 (45.7)	3,518 (47.1)	135 (65.1)	196 (59.2)	297 (57.9)	393 (49.6)	2,496 (44.3)
Female	7,354 (51.4)	838 (46.2)	588 (45.3)	869 (50.9)	899 (51.2)	882 (52.3)	3,277 (54.3)	3,958 (52.9)	72 (34.9)	135 (40.8)	216 (42.1)	401 (50.4)	3,134 (55.7)
Age (years)													
65–69	2,364 (16.5)	135 (7.4)	131 (10.1)	221 (12.9)	279 (15.9)	300 (17.8)	1,300 (21.5)	1,813 (24.3)	41 (19.5)	62 (18.7)	110 (21.5)	182 (22.9)	1,419 (25.2)
70–74	3,816 (26.7)	354 (19.5)	302 (23.2)	453 (26.6)	462 (26.3)	452 (26.8)	1,794 (29.7)	2,312 (30.9)	54 (26.2)	107 (32.4)	165 (32.1)	241 (30.3)	1,745 (31.0)
75–79	3,424 (23.9)	384 (21.2)	280 (21.6)	411 (24.1)	434 (24.7)	449 (26.6)	1,466 (24.3)	1,657 (22.2)	47 (22.6)	71 (21.5)	109 (21.3)	174 (21.9)	1,256 (22.3)
80–84	2,861 (20.0)	478 (26.4)	314 (24.1)	363 (21.3)	375 (21.3)	323 (19.1)	1,008 (16.7)	1,125 (15.0)	35 (16.9)	50 (15.2)	82 (15.9)	127 (15.9)	831 (14.8)
≥85	1,832 (12.8)	463 (25.5)	273 (21.0)	259 (15.2)	208 (11.9)	165 (9.8)	465 (7.7)	569 (7.6)	31 (14.8)	40 (12.2)	47 (9.2)	71 (8.9)	380 (6.7)
Equivalent income (JPY)													
<2 million	7,908 (55.3)	1,183 (65.3)	812 (62.5)	1,081 (63.4)	1,039 (59.1)	904 (53.6)	2,889 (47.9)	3,839 (51.3)	145 (69.9)	235 (71.1)	319 (62.2)	425 (53.5)	2,715 (48.2)
2–2.99 million	3,140 (22.0)	331 (18.2)	250 (19.3)	315 (18.5)	355 (20.2)	385 (22.8)	1,504 (24.9)	1,752 (23.4)	38 (18.5)	54 (16.2)	110 (21.5)	187 (23.6)	1,362 (24.2)
3–3.99 million	1,864 (13.0)	162 (8.9)	141 (10.9)	170 (9.9)	212 (12.1)	225 (13.4)	954 (15.8)	1,104 (14.8)	16 (7.5)	16 (4.9)	49 (9.6)	101 (12.7)	922 (16.4)
≥4 million	1,385 (9.7)	138 (7.6)	96 (7.4)	141 (8.3)	151 (8.6)	173 (10.2)	687 (11.4)	782 (10.5)	9 (4.1)	26 (7.8)	34 (6.7)	81 (10.2)	632 (11.2)
Education status (years)													
≤9	4,038 (28.2)	818 (45.1)	486 (37.4)	589 (34.5)	488 (27.7)	410 (24.3)	1,248 (20.7)	1,642 (22.0)	81 (39.2)	106 (32.0)	148 (28.9)	208 (26.2)	1,098 (19.5)
10–12	6,192 (43.3)	637 (35.1)	518 (39.9)	705 (41.3)	800 (45.5)	778 (46.1)	2,754 (45.6)	3,411 (45.6)	82 (39.6)	150 (45.3)	224 (43.6)	379 (47.7)	2,577 (45.8)
≥13	4,067 (28.4)	358 (19.7)	295 (22.7)	412 (24.1)	470 (26.7)	501 (29.7)	2,031 (33.7)	2,423 (32.4)	44 (21.3)	75 (22.6)	141 (27.5)	207 (26.1)	1,956 (34.7)
Smoking status													
Current	1,724 (12.1)	307 (16.9)	194 (14.9)	237 (13.9)	249 (14.1)	180 (10.7)	558 (9.3)	803 (10.7)	52 (25.2)	70 (21.1)	88 (17.1)	107 (13.5)	486 (8.6)
Former	4,441 (31.1)	614 (33.8)	465 (35.8)	554 (32.4)	543 (30.9)	548 (32.5)	1,717 (28.5)	2,168 (29.0)	67 (32.3)	109 (32.8)	166 (32.4)	236 (29.7)	1,590 (28.2)
Never	8,132 (56.9)	892 (49.2)	640 (49.3)	916 (53.7)	966 (55.0)	960 (56.9)	3,758 (62.3)	4,505 (60.3)	88 (42.5)	153 (46.1)	259 (50.4)	451 (56.8)	3,555 (63.1)
Alcohol drinking status													
Current	5,578 (39.0)	568 (31.3)	468 (36.0)	666 (39.0)	739 (42.1)	677 (40.1)	2,459 (40.8)	2,991 (40.0)	75 (36.0)	127 (38.3)	213 (41.6)	321 (40.4)	2,256 (40.1)
Former	1,957 (13.7)	308 (17.0)	206 (15.9)	244 (14.3)	233 (13.3)	226 (13.4)	740 (12.3)	981 (13.1)	39 (18.9)	62 (18.8)	74 (14.5)	122 (15.4)	683 (12.1)
Never	6,762 (47.3)	937 (51.7)	625 (48.1)	796 (46.7)	785 (44.7)	785 (46.5)	2,835 (47.0)	3,504 (46.9)	94 (45.1)	142 (42.9)	225 (44.0)	350 (44.1)	2,693 (47.8)
Comorbidity													
No	2,446 (17.1)	271 (15.0)	228 (17.6)	254 (14.9)	296 (16.9)	283 (16.8)	1,114 (18.5)	1,428 (19.1)	54 (25.9)	57 (17.3)	103 (20.1)	134 (16.8)	1,081 (19.2)
Yes	11,851 (82.9)	1,542 (85.0)	1,071 (82.4)	1,452 (85.1)	1,461 (83.1)	1,405 (83.2)	4,920 (81.5)	6,048 (80.9)	154 (74.1)	274 (82.7)	409 (79.9)	660 (83.2)	4,550 (80.8)
	Mean EQ-5D-5L							Mean EQ-5D-5L					
RPD/CD or FPD use	0.846	0.805	0.819	0.829	0.840	0.852	0.868	0.859	0.792	0.797	0.830	0.848	0.869
No	0.858	0.807	0.808	0.803	0.820	0.846	0.870	0.857	0.794	0.790	0.816	0.846	0.869
Yes	0.839	0.805	0.821	0.832	0.844	0.854	0.866	0.862	0.784	0.811	0.850	0.853	0.869

RPD/CD: removable partial denture/complete denture; FPD: fixed partial denture. Each response is the average of 20 imputed datasets. Analyses of RPD/CD and FPD use were conducted using separate datasets and multiple imputations were performed separately for each dataset. Therefore, although RPD/CD and FPD nonusers referred to the same population, the sample sizes and mean EQ-5D-5L differed.

Table 2. Association between removable partial denture/complete denture use and EQ-5D-5L utility scores by generalized linear regression analyses with multiple imputations (n = 14,297)

	Total		0 teeth		1–4 teeth		5–9 teeth		10–14 teeth		15–19 teeth		20–27 teeth	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
RPD/CD use (Ref: No)														
Yes	−0.022 (−0.029, −0.016)***	0.016 (0.009, 0.023)***	−0.002 (−0.046, 0.043)	0.021 (−0.021, 0.063)	0.016 (−0.027, 0.060)	0.037 (−0.002, 0.077)	0.036 (−0.003, 0.074)	0.051 (0.015, 0.086)**	0.028 (−0.002, 0.057)	0.046 (0.019, 0.074)**	0.009 (−0.012, 0.030)	0.014 (−0.006, 0.033)	−0.005 (−0.014, 0.004)	0.006 (−0.003, 0.014)

When the independent variable and covariates increased by one unit, the EQ-5D-5L utility score was interpreted as an increase of that coefficient × 100%. RPD/CD: removable partial denture/complete denture; EQ-5D-5L: EuroQol 5-dimension, 5-level instrument; β: regression coefficient; CI: confidence interval; Ref: reference. Model 1: Crude; Model 2: Model 1 + sex, age, equivalent income, educational status, smoking status, alcohol consumption status, comorbidities, and number of teeth (omitted from the stratification analyses). * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 3. Difference in the predicted mean EQ-5D-5L utility scores between with and without removable partial denture/complete denture use calculated by the results of generalized linear regression analyses with multiple imputations (n = 14,297)

	Total			0 teeth			1–4 teeth			5–9 teeth			10–14 teeth			15–19 teeth			20–27 teeth		
	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference
RPD/CD use	No	Yes		No	Yes		No	Yes		No	Yes		No	Yes		No	Yes		No	Yes	
Model 1	0.858	0.839	−0.019	0.870	0.866	−0.004	0.870	0.866	−0.004	0.870	0.866	−0.004	0.870	0.866	−0.004	0.870	0.866	−0.004	0.870	0.866	−0.004
Model 2	0.837	0.850	0.014	0.790	0.807	0.017	0.793	0.823	0.030	0.793	0.834	0.041	0.808	0.846	0.038	0.843	0.855	0.012	0.866	0.871	0.005

RPD/CD: removable partial denture/complete denture; EQ-5D-5L: EuroQol 5-dimension, 5-level instrument. Model 1: Crude; Model 2: Model 1 + sex, age, equivalent income, educational status, smoking status, alcohol consumption status, comorbidities, and number of teeth (omitted from the stratification analyses).

Table 4. Association between fixed partial denture use and EQ-5D-5L utility scores by generalized linear regression analyses with multiple imputations (n = 7,476)

	Total		1–4 teeth		5–9 teeth		10–14 teeth		15–19 teeth		20–27 teeth	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
FPD use (Ref: No)												
Yes	0.006 (−0.003, 0.015)	0.003 (−0.005, 0.011)	−0.013 (−0.128, 0.102)	−0.022 (−0.126, 0.083)	0.026 (−0.027, 0.079)	0.014 (−0.034, 0.061)	0.040 (0.001, 0.079)*	0.045 (0.006, 0.083)*	0.008 (−0.020, 0.037)	0.007 (−0.019, 0.032)	0.000 (−0.009, 0.010)	−0.001 (−0.010, 0.008)

When the independent variables and covariates increased by one unit, the EQ-5D-5L utility score was interpreted as an increase in that coefficient by 100%. FPD: fixed partial denture; EQ-5D-5L: EuroQol 5-dimension, 5-level instrument; β: regression coefficient; CI: confidence interval; Ref: reference. Model 1: Crude; Model 2: Model 1 + sex, age, equivalent income, educational status, smoking status, alcohol consumption status, comorbidities, and number of teeth (omitted from the stratification analyses). * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 5. Difference in the predicted mean EQ-5D-5L utility scores between with and without fixed partial denture use calculated by the results of generalized linear regression analyses with multiple imputations (n = 7,476)

	Total			1–4 teeth			5–9 teeth			10–14 teeth			15–19 teeth			20–27 teeth		
	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference	Predicted mean utility scores		Difference
FPD use	No	Yes		No	Yes		No	Yes		No	Yes		No	Yes		No	Yes	
Model 1	0.857	0.862	0.005	0.794	0.784	−0.010	0.790	0.811	0.021	0.816	0.850	0.033	0.846	0.853	0.007	0.869	0.869	0.000
Model 2	0.858	0.861	0.003	0.795	0.778	−0.017	0.794	0.805	0.011	0.815	0.852	0.037	0.846	0.852	0.006	0.869	0.868	−0.001

FPD: fixed partial denture; EQ-5D-5L: EuroQol 5-dimension, 5-level instrument. Model 1: Crude; Model 2: Model 1 + sex, age, equivalent income, educational status, smoking status, alcohol consumption status, comorbidities, and number of teeth (omitted from the stratification analyses).

naire completion time, we could not fully assess the accuracy and reliability of the responses. Third, the dental occlusion status, defect morphology, number of DP units, and location were not ascertained in the questionnaire survey. Owing to limited information, those who used both RPD/CD and FPD were excluded from the analyses in this study because it was difficult to stratify the number of teeth based on the assumption of the occlusion status of the cases. Moreover, we were unable to determine the number of FPD units that would theoretically require multiple units for adequate restoration in an individual with fewer teeth. Previous research has found that having occlusal contact units (CU) of RPD/CD with or without natural teeth and having ≥10 natural teeth with occlusal CU were associated with higher HRQoL[52]. As our study did not consider occlusal CU, some RPD/CD and FPD users may not have attained sufficient

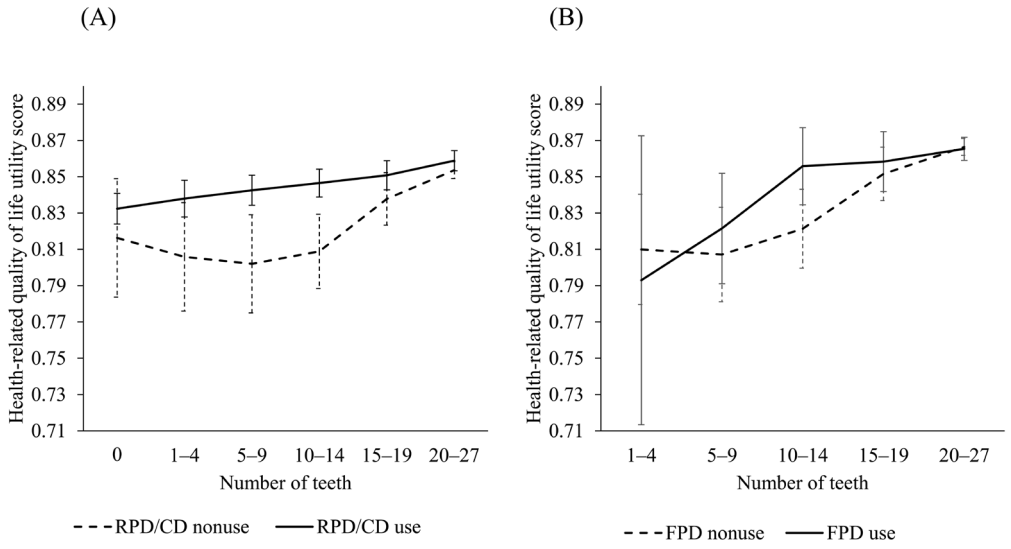

Fig. 2. Interaction between removable partial denture/complete denture use (A), and fixed partial denture use (B) and the number of teeth obtained by generalized linear regression analysis with multiple imputations after adjusting for all covariates. (A): The HRQoL difference between RPD/CD users and nonusers was greater in groups with 1–14 teeth than in all other groups. (B): The HRQoL difference between FPD users and nonusers was greater in groups with 10–14 teeth than in all other groups. A significant interaction effect was only observed for RPD/CD ((A) $P < 0.01$; (B) $P = 0.183$). RPD/CD: removable partial denture/complete denture; FPD: fixed partial denture.

restoration of occlusal CUs. Therefore, the results may have been underestimated compared with those obtained if occlusal CUs were considered. Further studies that consider occlusal CUs are warranted. Fourth, we could not consider the differences between the RPD/CD and FPD types. However, only conventional RPDs/CDs and FPDs are currently covered by the Japanese Universal Health Insurance Coverage System (JUHICS); therefore, we assumed that most participants used conventional devices. Fifth, although the reliability and validity of the EQ-5D-5L have been verified in numerous countries[53], validation studies specific to the Japanese version are lacking[33]. This limitation raises concerns regarding the applicability and accuracy of the instrument for assessing HRQoL among Japanese participants. Further studies are warranted to validate the Japanese version of EQ-5D-5L in the general population. Sixth, the EQ-5D-5L, while improved from the EuroQol 5-dimension, 3-level instrument, still shows ceiling effects among the general population due to its focus on capturing ill health[53]. Moreover, although the participants were informed that their anonymity was assured, social desirability bias could have affected the ceiling effects. Therefore, the results may have been underestimated due to these factors. Seventh, despite adjusting for possible confounders, unknown confounding variables may have influenced the results. Approximate E-values were used to assess the robustness of our findings, which revealed moderate resistance to potentially unmeasured confounding factors. Although many diseases, particularly chronic conditions, have been reported to affect HRQoL[54–56], this study only adjusted for the presence or sequelae of comorbidities. This limitation arose because the questionnaire used in this study could not specify the details of the diseases associated with HRQoL. Future studies with careful adjustment for these factors are warranted. Eighth, the generalizability of our findings is limited because the utility scores of HRQoL differed among countries and regions; the use of RPDs/CDs and FPD was covered by JUHICS (i.e., all participants had free access to dental institutions and could be treated at a relatively low cost), and the target population was limited to functionally independent community-dwelling older adults.

5. Conclusions

RPD/CD and FPD users with 5–19 teeth had higher HRQoL utility scores than nonusers, with the differences appearing to depend on the number of teeth. Because the difference among edentulous individuals was small, considering unconventional dentures for UHC inclusion is worthwhile. Further EQ-5D-5L evaluations and cost-effectiveness analyses for various DP types are required to guide policy decision-making.

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Author contributions

Conceptualization: M.H.H., K.T., T.K., J.A., H.E., and K.O.; data curation: J.A. and K.O.; formal analysis: M.H.H., K.T., T.K., J.A., and K.O.; funding acquisition: M.H.H., K.T., T.K., J.A., and K.O.; investigation: M.H.H., K.T., T.K., J.A., H.E., and K.O.; methodology: M.H.H., K.T., T.K., J.A., H.E., and K.O.; project administration: M.H.H., K.T., T.K., J.A., H.E., and K.O.; resources: M.H.H., K.T., T.K., J.A., and K.O.; software: M.H.H., K.T., T.K., J.A., and K.O.; supervision: M.H.H., K.T., T.K., J.A., H.E., and K.O.; writing–original draft: M.H.H.; writing—review and editing: K.T., T.K., J.A., H.E., and K.O. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest statement

The authors declare no conflict of interest.

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