J Prosthodont Res. 2025; **(**): ****–****

OPEN ACCESS JPR Journal of Prosthodontic Research Original article

Association between oral health and multidimensional flourishing: A cross-sectional study from Japan Gerontological Evaluation Study (JAGES)

Kewei Wang [a], Shiho Kino [b], Yusuke Matsuyama [a], Koichiro Shiba [c], Atsushi Nakagomi [d], Katsunori Kondo [d,e], Kokoro Shirai [f], Kenji Fueki [g], Jun Aida [a,h,*]

[a] Department of Dental Public Health, Institute of Science Tokyo, Tokyo, Japan, [b] Department of Preventive Oral Health Care Sciences, Institute of Science Tokyo, Tokyo, Japan, [c] Department of Epidemiology, Boston University School of Public Health, Boston, USA, [d] Center for Preventive Medical Sciences, Chiba University, Chiba, Japan, [e] Institute for Health Economics and Policy, Tokyo, Japan, [f] Department of Social Medicine, Osaka University Graduate School of Medicine, Suita, Japan, [g] Department of Masticatory Function and Health Science, Institute of Science Tokyo, Tokyo, Japan, [h] Center for Well-being Research Advancement, Institute of Science Tokyo, Tokyo, Japan

Abstract

Purpose: Human flourishing is a multidimensional concept that encompasses happiness and life satisfaction (happiness), mental and physical health (health), meaning and purpose (purpose), character and virtue (character), and close social relationships (social), which are characterized by comprehensive well-being. This cross-sectional study investigated the association of oral health, number of remaining teeth, and prosthesis use with multidimensional flourishing.

Methods: Data was sourced from the 2022 wave of the Japan Gerontological Evaluation Study, a population-based survey of independent individuals aged 65 years or older. This study utilized multilevel linear regression with multiple imputations. The covariates included sex, age, income, education, marital status, smoking status, diabetes history, instrumental activities of daily living, and depressive symptoms.

Results: This study included 87,201 participants with a mean age of 74.87 years [standard deviation (SD)=6.30], and mean±SD composite flourishing index of 6.77±1.64. Multilevel multivariable regression showed that individuals with dental prostheses or more teeth had a higher flourishing index. Among individuals without dental prostheses, those with >20 teeth showed a composite flourishing index of 0.34 units higher (95% confidence interval (95% CI): 0.26-0.42, $P < 0.001$) than those with 0-9 teeth. Among those with 0-9 teeth, individuals with dental prostheses showed 0.21 (95% CI: 0.12-0.29, $P < 0.001$) higher units compared to those without prostheses. The interaction analysis showed that dental prosthesis use was significantly associated with higher indices, especially among those with fewer teeth.

Conclusions: Teeth and prostheses were independently associated with multidimensional flourishing. Using dental prostheses may enhance multidimensional flourishing among individuals with fewer remaining teeth.

Keywords: Older people, Oral health, Flourishing, Dental prostheses

Received 10 January 2024, Accepted 18 December 2024, Available online 11 February 2025

1. Introduction

Human flourishing, a multifaceted concept that goes beyond the mere absence of illness or infirmity and includes a state of holistic well-being comprising physical, mental, and social well-being, has gained attention globally and is considered a broader range of outcomes to assess[1]. Investigating the causes and interventions that have the most significant impact on human flourishing is crucial. However, it is worth noting that studies in various fields such as medicine, public health, psychology, and economics tend to concentrate on very narrow outcomes, specifically on specific flourishing domains. In health research, approaches often address a single disease, that is, a single health domain[2,3]. Similarly, the main goal in psychological studies is usually to alleviate particular symptoms[4,5]. To effectively enhance human flourishing, empirical studies and measurements must provide a comprehensive understanding of multidimensional flourishing[6].

WHAT IS ALREADY KNOWN ABOUT THE TOPIC?

» *Having more teeth and using dental prostheses were independent predictors of enhanced flourishing in older Japanese individuals. Dental prostheses use may boost multidimensional flourishing among individuals with fewer remaining teeth.*

WHAT THIS STUDY ADDS?

» *Human flourishing is a multidimensional concept of comprehensive well-being. Previous studies have primarily examined the association between oral health and individual domains of flourishing.*

DOI: https://doi.org/10.2186/jpr.JPR_D_24_00009
***Corresponding author:** Jun Aida, Department of Dental Public Health, Graduate School of Medical and Dental Sciences, Institute of Science Tokyo, Tokyo, Japan.
E-mail address: aida.ohp@tmd.ac.jp

Table 1. Flourishing [a] measure and questions

Domain	Item	Statement (0-10)
Happiness and life satisfaction	Overall, how satisfied are you with life as a whole these days?	0 = not satisfied at all, 10 = completely satisfied
	In general, how happy or unhappy do you usually feel?	0 = extremely unhappy, 10 = extremely happy
Mental and physical health	In general, how would you rate your physical health?	0 = poor, 10 = excellent
	How would you rate your overall mental health?	
Meaning and purpose	Overall, to what extent do you feel the things you do in your life are worthwhile?	0 = not at all worthwhile, 10 = completely worthwhile
	I understand my life purpose.	0 = strongly disagree, 10 = strongly agree
Character and virtue	I always act to promote good in all circumstances, even in difficult and challenging situations.	0 = not true of me, 10 = completely true of me
	I am always able to give up some happiness now for greater happiness later.	
Close social relationships	I am content with my friendships and relationships.	0 = strongly disagree, 10 = strongly agree
	My relationships are as satisfying as I would want them to be.	

[a] The composite flourishing index (range, 0 (lowest response) -10 (highest response)) is a mean score calculated by 10 items across 5 domains, with greater values indicating higher flourishing levels

Oral health is closely determined by oral appearance, typically represented by the number of teeth and dental prosthesis use, which are two important components that can impact essential activities such as speaking and eating[7]. Deterioration of oral health, such as fewer teeth, has also been linked to feelings of embarrassment, lower self-esteem, and adverse effects on social interaction[8–11]. Oral diseases and tooth loss can substantially impact the quality of life and well-being of older adults[12]. Some studies focused on oral health with mortality, in which denture use is inversely associated with mortality among elderly individuals with tooth loss, particularly among females with fewer than 10 functional teeth[13,14]. A single domain of flourishing, such as the association between the number of teeth and happiness[1], oral health and both mental and physical health[15,16], or oral conditions and social relationships[17,18], has been the focus of previous empirical studies. However, the association between oral conditions, including the number of teeth and the use of dental prostheses, and human multidimensional flourishing still lacks a comprehensive understanding, especially in the older population.

Therefore, using data collected from an older population-based survey, this cross-sectional study aimed to explore the association between multidimensional flourishing and oral health status, including the number of remaining teeth with and without the use of dental prostheses. The research hypothesis was that there is an association between fewer remaining teeth and worse multidimensional flourishing, and dental prosthesis use would alleviate this consequence.

2. Material and Methods

2.1. Population

Cross-sectional data from the Japan Gerontological Evaluation Study (JAGES)[19,20] project, an ongoing prospective cohort study in Japan, were used. The JAGES project investigates the gerontological and social epidemiological perspectives associated with health among individuals aged 65 years or older who are not certified for long-term care insurance, which targets older people needing assistance in their daily living activities[21–25]. From November 2022 to December 2022, self-administered questionnaires were randomly delivered by mail to 338,742 community-dwelling older individuals who were 65 years and older in 76 municipalities in 23 prefectures throughout Japan (227,731 individuals responded; valid responses: 193,049). The questionnaire containing flourishing measures was randomly distributed to one in two people, and 96,340 individuals responded to the questionnaire with flourishing measures. Among them, the number of respondents without functional dependence was 88,077. Participants with missing data on age and sex were excluded; hence, data on 87,201 participants were included in this study.

2.2. Measures

2.2.1. Outcomes

Using VanderWeele's[26] multidimensional conception of flourishing as a framework, we assessed five universally desired domains of flourishing: (1) happiness and life satisfaction (happiness); (2) mental and physical health (health); (3) meaning and purpose (purpose); (4) character and virtue (character); and (5) close social relationships (social)[6]. The composite scores calculated from the average of all 10 items were considered as the composite flourishing index. Each item was assessed on a scale of 0-10 (worst to ideal). The average scores on the composite flourishing index ranged 0-10, with greater values indicating higher flourishing levels. Domain-specific scores were obtained by calculating the average of two items in each domain[27]. **Table 1** contains a complete list of items.

2.2.2. Oral health status

Oral health variables included the number of remaining teeth and dental prosthesis use, both of which were self-reported. The JAGES uses questions similar to the World Health Organization's (WHO) basic oral health survey[28]. The validity and reliability of the self-reported number of remaining teeth were established in the JAGES[29]. In JAGES 2022, we used more categories of the number of teeth, and participants selected from the following choices: 0, 1-4, 5-9, 10-14, 15-19, 20-23, 24-27, or 28-32 teeth. Dental prosthesis use was determined by a self-reported binary question: "Do you use dentures or bridges (non-removable dentures) or have dental implants?". Following a previous study[1], the self-reported number of teeth and dental prosthesis use were amalgamated and grouped into one of the following six categories: 0-9 teeth without dental prosthesis, 0-9

teeth with dental prosthesis, 10-19 teeth without dental prosthesis, 10-19 teeth with dental prosthesis, ≥20 teeth without dental prosthesis, and ≥20 teeth with dental prosthesis.

2.2.3. Covariates

The covariates were selected based on the probable association between oral health and multidimensional flourishing[30–36]. The theoretical framework of this study is shown as a directed acyclic graph in the **Supplementary Figure 1** (**Fig. S1**). Similar to previous studies, sociodemographic covariates included sex, age group, equivalized household income, educational attainment, and marital status[31]. Equivalent household income was calculated by dividing annual income by the square root of the number of household members and was categorized into three groups. Marital status was categorized as married, divorced, widowed, or single. For health-related covariates that could be associated with oral health and flourishing, smoking status, diabetes history[32,33], instrumental activities of daily living (IADLs)[34], and depressive symptoms[35,36] were considered. Smoking status was categorized as never smoking, quitting for 5 years or earlier, quitting for years or later, occasional smoking, and smoking every day[37]. IADLs were assessed using a 13-item scale (score range: 0-13) created by the Tokyo Metropolitan Institute of Gerontology[38]; a score of 13 indicated independence in higher life functions, and a score of 0-12 indicated nonindependence. For the depressive symptoms, a 15-item Geriatric Depression Scale[35] was used, and the responses were categorized into non "0-4 points," mild depressive symptoms "5-9 points," or severe depressive symptoms "10-15 points."

2.3. Statistical analysis

A descriptive analysis was conducted to examine the demographics and characteristics of the participants. In the regression analysis, we considered the structure of an individual living in a municipality because of the existence of regional differences in the distribution of dental clinics and health status. Therefore, univariable and multivariable multilevel linear regression were used to calculate the coefficient and 95% confidence intervals (95% CI) of the number of teeth and dental prostheses used in composite flourishing and each domain separately to determine the association between oral condition and multidimensional flourishing. The multilevel multivariable linear regression was adjusted for age, sex, education, marital status, smoking, diabetes, IADLs, and depressive symptoms.

To test the statistical significance of the interaction between the number of teeth and dental prosthesis use, we made models that separately included teeth and prostheses as independent variables; these were performed as supplementary analyses. An interaction model was constructed to examine the association between the number of teeth and dental prosthesis use. We created a figure (**Fig. 1**) for the composite flourishing index calculated from the interaction model results. To reduce bias due to missing responses, multiple imputation with the chained equation method were applied to create 20 imputed datasets[39]. Multiple imputation has been reported to be a robust imputation method. Complete case analyses were used for sensitivity analysis to verify the multiple imputation analyses. The statistical software program, STATA 17.0 Standard Edition (StataCorp LLC, College Station, TX, StataCorp LLC) was used for the analyses.

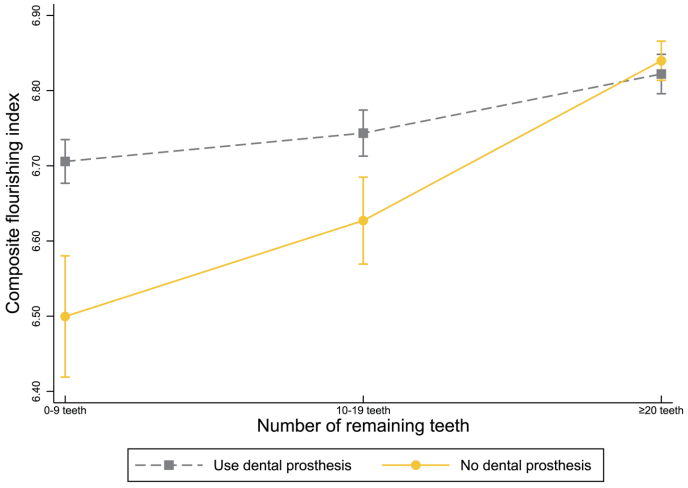

Fig. 1. Estimated composite flourishing and interaction between the number of remaining teeth, and dental prosthesis use condition, adjusted for all covariates by multilevel linear regression (age, sex, income, marital status, education, smoking, diabetes, instrumental activities of daily living, and depressive symptoms).

2.4. Ethical issues

JAGES 2022 was reviewed and granted ethical approval by the Ethics Committee of the Chiba University (M10460) and the Ethics Committee of the Tokyo Medical and Dental University (D2022-040-01). This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies. Informed consent was obtained from the questionnaire, we asked about participation in the survey, and the data from the responses of those who agreed were used in the analysis.

3. Results

This study enrolled 87,201 participants with a mean age of 74.87 (SD=6.30; 47.8% of the participants were men (n=41,683) and 52.2% were women (n=45,518). Descriptive statistics, mean scores of composite flourishing, and each domain are displayed in **Table 2**. The proportion of respondents with 0-9 teeth and no dental prosthesis, 0-9 teeth and used a dental prosthesis,10-19 teeth and no dental prosthesis, 10-19 teeth and used a dental prosthesis, ≥20 teeth and no dental prosthesis, and ≥20 teeth and used a dental prosthesis were 1.7%, 19.0%, 2.9%, 15.8%, 31.4%, and 29.2%, respectively. The mean composite flourishing index score ± SD was 6.77 ± 1.64. Those with 0-9 teeth and no dental prosthesis showed the lowest composite flourishing score (5.93±1.83), and the group with more than 20 teeth and without dental prostheses showed the highest composite flourishing score (6.90±1.60). This trend was also observed in all domains of the flourishing scores. Regarding covariates, the flourishing index score of respondents was higher with a higher number of remaining teeth who used a dental prosthesis, except for those with ≥20 remaining teeth, women, with age and self-reported income increasing, with higher educational attainment, not single, with independence in higher life functions, without diabetes and depressive symptoms.

Table 2. Descriptive statistics of participants by using multiple imputations (N=87,201)

	Respondent, N (%)	Flourishing, Mean (SD)	Domain of flourishing, mean (SD)				
			Happiness	Health	Purpose	Character	Social
Total	87,201(100.0)	6.77(1.64)	7.09(1.73)	6.86(1.74)	6.76(1.92)	6.48(1.93)	6.67(2.02)
Number of teeth and dental pro							
0-9 teeth and no dental prosthesis	1,449(1.7)	5.93(1.83)	6.18(1.97)	6.20(1.90)	5.85(2.09)	5.74(2.13)	5.66(2.27)
0-9 teeth and use dental prosthesis	16,580(19.0)	6.60(1.71)	6.93(1.81)	6.62(1.81)	6.54(1.99)	6.39(2.01)	6.51(2.10)
10-19 teeth and no dental prosthesis	2,547(2.9)	6.35(1.72)	6.61(1.83)	6.46(1.80)	6.33(1.99)	6.12(1.99)	6.21(2.11)
10-19 teeth and use dental prosthesis	13,755(15.8)	6.71(1.64)	7.03(1.72)	6.77(1.74)	6.69(1.91)	6.46(1.94)	6.63(2.01)
≥20 teeth and no dental prosthesis	27,405(31.4)	6.90(1.60)	7.23(1.68)	7.03(1.70)	6.91(1.88)	6.56(1.89)	6.79(1.97)
≥20 teeth and use dental prosthesis	25,465(29.2)	6.87(1.59)	7.20(1.67)	6.97(1.68)	6.87(1.88)	6.55(1.88)	6.76(1.95)
Age							
65-69	19,858(22.8)	6.64(1.64)	6.96(1.76)	6.84(1.73)	6.67(1.95)	6.27(1.89)	6.43(2.04)
70-74	25,952(29.8)	6.74(1.64)	7.04(1.73)	6.89(1.72)	6.75(1.93)	6.40(1.91)	6.61(2.01)
75-79	20,344(23.3)	6.82(1.63)	7.12(1.70)	6.87(1.74)	6.80(1.90)	6.55(1.91)	6.75(1.98)
80-84	1,3898(15.9)	6.85(1.65)	7.19(1.72)	6.82(1.76)	6.77(1.91)	6.64(1.95)	6.81(2.00)
≥85	7,149(8.2)	7.02(1.65)	7.39(1.70)	6.89(1.77)	6.91(1.91)	6.87(2.00)	7.04(1.99)
Sex							
Male	41,683(47.8)	6.64(1.63)	6.96(1.72)	6.76(1.73)	6.65(1.90)	6.35(1.89)	6.47(2.00)
Female	45,518(52.2)	6.90(1.65)	7.21(1.73)	6.96(1.74)	6.86(1.94)	6.60(1.95)	6.86(2.01)
Income							
Low	43,314(49.7)	6.49(1.72)	6.79(1.81)	6.62(1.80)	6.44(1.99)	6.24(2.00)	6.37(2.10)
Middle	33,699(38.6)	6.96(1.52)	7.30(1.59)	7.03(1.64)	6.97(1.80)	6.63(1.82)	6.88(1.88)
High	10,188(11.7)	7.35(1.47)	7.72(1.50)	7.34(1.60)	7.42(1.76)	7.00(1.82)	7.27(1.83)
Education							
≤9 years	18,932(21.7)	6.52(1.77)	6.87(1.87)	6.59(1.84)	6.44(2.03)	6.30(2.07)	6.41(2.18)
10-12 years	38,247(43.9)	6.73(1.63)	7.04(1.71)	6.85(1.72)	6.71(1.90)	6.43(1.91)	6.63(1.99)
>13years	30,022(34.4)	6.99(1.55)	7.30(1.63)	7.05(1.66)	7.03(1.85)	6.66(1.84)	6.88(1.91)
Marital status							
Married	63,737(73.1)	6.84(1.59)	7.18(1.67)	6.91(1.71)	6.85(1.87)	6.53(1.88)	6.72(1.95)
Widowed	16,384(18.8)	6.82(1.69)	7.10(1.78)	6.87(1.77)	6.73(1.98)	6.58(2.00)	6.82(2.06)
Divorced	4,114(4.7)	6.21(1.82)	6.36(1.95)	6.53(1.86)	6.19(2.17)	5.98(2.11)	5.98(2.28)
Single	2,956(3.4)	5.93(1.76)	6.12(1.87)	6.32(1.85)	5.88(2.08)	5.68(2.04)	5.67(2.25)
Smoking							
Every day	7,747(8.9)	6.39(1.72)	6.65(1.84)	6.61(1.78)	6.33(2.04)	6.10(1.98)	6.25(2.12)
Occasionally	1,056(1.2)	6.44(1.75)	6.71(1.86)	6.61(1.91)	6.36(2.06)	6.22(1.99)	6.29(2.12)
Quit 4 years or later	2,364(2.7)	6.28(1.68)	6.66(1.78)	6.35(1.81)	6.25(1.93)	6.00(1.94)	6.15(2.05)
Quit 5 years or earlier	24,893(28.5)	6.62(1.59)	6.96(1.68)	6.75(1.70)	6.62(1.88)	6.30(1.86)	6.44(1.96)
Never	51,142(58.6)	6.94(1.63)	7.25(1.70)	6.99(1.73)	6.92(1.90)	6.66(1.93)	6.87(1.99)
Diabetes							
No	74,750(85.7)	6.81(1.64)	7.12(1.72)	6.92(1.73)	6.79(1.92)	6.50(1.93)	6.70(2.01)
Yes	12,451(14.3)	6.57(1.66)	6.92(1.74)	6.51(1.72)	6.57(1.94)	6.35(1.94)	6.48(2.05)
IADLs*, 13 items							
13	19,687(22.6)	7.38(1.48)	7.57(1.56)	7.35(1.60)	7.41(1.73)	7.12(1.78)	7.42(1.75)
0-12	67,514(77.4)	6.60(1.65)	6.95(1.75)	6.72(1.75)	6.57(1.93)	6.30(1.93)	6.45(2.03)
Depressive symptom							
None	66,202(75.9)	7.24(1.40)	7.59(1.45)	7.29(1.54)	7.27(1.68)	6.89(1.77)	7.19(1.75)
Mild	16,771(19.2)	5.56(1.33)	5.85(1.48)	5.75(1.56)	5.44(1.63)	5.43(1.74)	5.32(1.79)
Severe	4,228(4.8)	4.22(1.41)	4.32(1.58)	4.59(1.59)	3.99(1.73)	4.31(1.92)	3.86(1.90)

N: number, SD: standard deviation, IADLs: instrumental activities of daily living scale

Table 3. Multilevel linear regression analysis of the association between the number of teeth with and without dental prosthesis with composite flourishing by using multiple imputations (N=87,201)

	Univariable model				Fully adjusted model†			
	Coefficient*	95% CI		*P*	Coefficient*	95% CI		*P*
Number of teeth and dental prosthesis								
0-9 teeth and no dental prosthesis	Ref.				Ref.			
0-9 teeth and use dental prosthesis	0.67	0.57	0.76	<0.001	0.21	0.12	0.29	<0.001
10-19 teeth and no dental prosthesis	0.42	0.31	0.53	<0.001	0.13	0.03	0.22	<0.01
10-19 teeth and use dental prosthesis	0.77	0.68	0.87	<0.001	0.24	0.16	0.33	<0.001
≥20 teeth and no dental prosthesis	0.95	0.86	1.05	<0.001	0.34	0.26	0.42	<0.001
≥20 teeth and use dental prosthesis	0.92	0.83	1.01	<0.001	0.32	0.24	0.40	<0.001
Age								
65-69	Ref.				Ref.			
70-74	0.09	0.06	0.12	<0.001	0.12	0.10	0.15	<0.001
75-79	0.16	0.13	0.19	<0.001	0.24	0.22	0.27	<0.001
80-84	0.19	0.16	0.23	<0.001	0.32	0.28	0.35	<0.001
≥85	0.38	0.33	0.42	<0.001	0.56	0.52	0.60	<0.001
Sex								
Male	Ref.				Ref.			
Female	0.27	0.24	0.29	<0.001	0.10	0.07	0.12	<0.001
Income								
Low	Ref.				Ref.			
Mid	0.47	0.44	0.49	<0.001	0.23	0.21	0.26	<0.001
High	0.85	0.81	0.88	<0.001	0.51	0.48	0.54	<0.001
Education								
≤9 years	Ref.				Ref.			
10-12 years	0.20	0.17	0.23	<0.001	0.07	0.05	0.10	<0.001
>13years	0.44	0.41	0.47	<0.001	0.22	0.19	0.25	<0.001
Marital status								
Married	Ref.				Ref.			
Widowed	-0.01	-0.04	0.02	0.595	-0.04	-0.06	-0.01	<0.01
Divorced	-0.63	-0.68	-0.58	<0.001	-0.24	-0.28	-0.19	<0.001
Single	-0.91	-0.97	-0.85	<0.001	-0.43	-0.49	-0.38	<0.001
Smoking								
Every day	-0.55	-0.59	-0.51	<0.001	-0.15	-0.19	-0.11	<0.001
Occasionally	-0.50	-0.60	-0.40	<0.001	-0.17	-0.25	-0.08	<0.001
Quit 4 years or later	-0.66	-0.72	-0.59	<0.001	-0.27	-0.33	-0.21	<0.001
Quit 5 years or earlier	-0.33	-0.36	-0.31	<0.001	-0.16	-0.19	-0.14	<0.001
Never	Ref.				Ref.			
Diabetes								
No	Ref.				Ref.			
Yes	-0.23	-0.27	-0.20	<0.001	-0.10	-0.13	-0.07	<0.001
IADLs, 13 items								
13	0.79	0.76	0.81	<0.001	0.42	0.40	0.45	<0.001
0-12	Ref.				Ref.			
Depressive symptoms								
None	Ref.				Ref.			
Mild	-1.68	-1.70	-1.65	<0.001	-1.54	-1.57	-1.52	<0.001
Severe	-3.02	-3.07	-2.98	<0.001	-2.78	-2.83	-2.73	<0.001

IADLs: instrumental activities of daily living scale, CI: confidence interval. * The coefficient indicates the difference in composite flourishing from the reference category coef. Positive: Composite flourishing is higher than the reference category coef. Negative: Composite flourishing was lower than the reference category. †Adjusted for all covariates (age, sex, education, marital status, smoking, diabetes, IADLs, and depressive symptoms).

Table 3 presents the results of multilevel linear regression analysis of the imputed data for composite flourishing. Compared to those with 0-9 teeth and no dental prosthesis, those with more than 20 teeth and no dental prosthesis showed a 0.95 (95% CI: 0.86 to 1.05, $P < 0.001$) higher index in the univariable model. After adjusting for covariates, some of the variance previously attributed to the

Table 4. Multilevel linear regression analysis of the association between the number of remaining teeth with and without dental prosthesis with each domain of flourishing by using multiple imputations (N=87,201)

	Happiness †		Health †		Purpose†		Character †		Social †	
	Coef. * (95%CI)	*P*	Coef. *(95%CI)	*P*	Coef.* (95% CI)	*P*	Coef.* (95% CI)	*P*	Coef.* (95% CI)	*P*
Number of teeth and dental prosthesis										
0-9 teeth and no dental prosthesis	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
0-9 teeth and use dental prosthesis	0.24(0.16;0.33)	<0.001	0.07(-0.02;0.16)	0.108	0.22(0.12;0.32)	<0.001	0.20(0.09;0.30)	<0.001	0.30(0.20;0.40)	<0.001
10-19 teeth and no dental prosthesis	0.12(0.02;0.22)	<0.01	0.01(-0.09;0.12)	0.835	0.15(0.04;0.27)	<0.05	0.13(0.01;0.25)	<0.05	0.22(0.10;0.34)	<0.001
10-19 teeth and use dental prosthesis	0.27(0.19;0.36)	<0.001	0.12(0.03;0.21)	<0.01	0.26(0.16;0.36)	<0.001	0.22(0.12;0.33)	<0.001	0.34(0.24;0.44)	<0.001
≥20 teeth and no dental prosthesis	0.37(0.29;0.45)	<0.001	0.27(0.18;0.36)	<0.001	0.36(0.26;0.46)	<0.001	0.27(0.17;0.37)	<0.001	0.43(0.33;0.53)	<0.001
≥20 teeth and use dental prosthesis	0.36(0.27;0.44)	<0.001	0.23(0.15;0.32)	<0.001	0.34(0.24;0.44)	<0.001	0.27(0.17;0.37)	<0.001	0.41(0.31;0.51)	<0.001

CI: confidence interval, Coef: coefficient. * Coefficients indicate the differences in each domain of flourishing from the reference category coefficient. Positive: Flourishing is higher than the reference category Coef. Negative: Flourishing scored lower than the reference category. †Adjusted for all covariates (age, sex, education, marital status, smoking, diabetes, instrumental activities of daily living scale, and depressive symptoms).

independent variable in the univariable model was explained by the confounders. It was then reduced to 0.34 (95% CI: 0.26 to 0.42, $P < 0.001$) in the fully adjusted model, shown as the coefficient. In addition, an increased coefficient of composite flourishing index for those who used a dental prosthesis who had the same number of teeth and did not use a dental prosthesis was observed, except for those with ≥20 remaining teeth ($P < 0.001$) in both univariable and fully adjusted models. In the fully adjusted model, individuals with 10-12 years of education presented a higher index of 0.07 (95% CI: 0.05 to 0.10, $P < 0.001$) compared to the reference category (individuals with an education of <9 years). For individuals with 0-9 teeth who use dental prostheses and those with 10-19 teeth who use dental prostheses when compared to those with 0-9 teeth without using dental prostheses, this difference was more particularly pronounced, which presented a higher index of 0.21 (95% CI: 0.12 to 0.29, $P < 0.001$) and 0.24 (95% CI: 0.16 to 0.33, $P < 0.001$), respectively. In the multivariable model, municipality-level variance was 0.006, and individual-level variance was 1.793. This indicated that after adjusting for individual factors, most of the variance was observed between individuals rather than municipalities.

Table 4 shows the results of the fully adjusted model of the multilevel linear regression analyses for each flourishing domain. In the domain of happiness, those with ≥20 teeth and no dental prosthesis showed a 0.37 (95% CI: 0.29-0.45, $P < 0.001$) higher score than the group of 0-9 teeth and no dental prosthesis; the coefficient was 0.27 (95% CI: 0.18-0.36, $P < 0.001$) in the health domain; 0.36 (95% CI: 0.26-0.46, $P < 0.001$) in the purpose domain; 0.27 (95% CI: 0.17-0.37, $P < 0.001$) in the character domain; 0.43 (95% CI: 0.33-0.53, $P < 0.001$) in the domain of social relationship. An increased coefficient of multidimensional flourishing scores for those who used a dental prosthesis with the same number of remaining teeth compared to those who did not use a dental prosthesis was observed, except for those with ≥20 remaining teeth ($P < 0.001$). **Table S1** contains the results for all covariates.

Supplementary analyses using the variables of the number of teeth and dental prosthesis use separately showed a significant interaction ($P < 0.05$) between the number of remaining teeth and dental prosthesis use on composite flourishing (**Table S2**).

Figure 1 presents the estimated composite flourishing index obtained from the interaction model. Without dental prosthesis, individuals with 10-19 teeth showed an index of 6.63 (95%CI: 6.57-6.68, $P < 0.001$), those with 0-9 teeth had a lower index of 6.50(95% CI: 6.42-6.58, $P < 0.001$). Individuals with 0-9 teeth had lower indices than those with 10-19 teeth. The estimated composite flourishing index of those who use dental prostheses was 6.74 (95% CI: 6.71-6.77, $P < 0.001$) when the number of remaining teeth was 10-19, those with 0-9 teeth had a lower index of 6.71 (95% CI:6.68-6.73, $P < 0.001$). The significant interaction indicated that the reduction in the composite flourishing index among those with fewer teeth was more prominent among those who did not use dental prostheses. Complete case analyses were performed as sensitivity analyses, showing a similar result to the imputed analyses (**Tables S3, and S4, and Fig. S2**).

4. Discussion

To the best of our knowledge, this is the first study to determine the association between oral health and multidimensional flourishing. These findings indicate that individuals with a limited number of teeth showed lower flourishing levels; however, prosthesis use attenuated this association.

4.1. Comparison with previous studies

Our results are consistent with those of previous studies; however, many empirical studies have focused on the association between oral health and very narrow outcomes, with a single domain flourishing. One study reported that dental prostheses have shown substantial benefits in enhancing the happiness of older individuals with fewer than 20 remaining teeth[1]. Other studies have indicated that the main predictors of reduced social interaction and social isolation are tooth loss and lack of dental prostheses[17,18]. Moreover, having less than 20 teeth correlated with adverse physical and cognitive health outcomes[16,40]. Furthermore, a significant correlation existed between oral health-related factors and the experience of happiness[1,41,42]. A holistic assessment of human flourishing, encompassing diverse indicators beyond singular domains, is pivotal in shaping future public health priorities by revealing areas over-or underemphasized in policies and agendas[30]. Our study used human flourishing, which comprises a broad range of states, as an outcome.

Regarding the influence of age on multidimensional flourishing, consistent with prior research[43], life satisfaction and happiness were positively correlated with age. It is plausible that as individuals age, they experience a reduction in stress stemming from life events and economic concerns while concurrently exhibiting an increase in positive emotions and the stability of emotional experiences[43,44]. Simultaneously, evidence indicates that a higher positive effect is associated with reduced mortality risk among both healthy and diseased populations residing in the community[45], especially in older adults[46]. Therefore, our results, which are consistent with flourishing trends, tend to increase with age, particularly in older individuals. This might be attributed to older adults enhancing their attention and retention of positive information relative to negative information[47]. Their goals become more realistic and easier to achieve, thereby leading to heightened flourishing[48].

4.2. Strengths

The significance of this study cannot be overstated, especially for those who have lost a moderate-to-significant number of teeth. Loss of teeth is likely to result in functional impairment, such as difficulty chewing and esthetics, which may eventually lower the quality of life[8]. This study further contributes to clinical relevance, which can be considered a strength of this study. In comparison to the education variable categories, which have a three-year difference in educational attainment, the disparities observed in the composite flourishing index are more pronounced with respect to the variables of tooth and dental prosthesis use when compared to their respective reference categories. This finding highlights the potential significance of focusing clinical attention on dental health indicators such as tooth count and dental prosthesis use to promote flourishing among older adults. The use of dental prosthetics can significantly improve the ability to eat and speak correctly, leading to a marked improvement in the overall quality of life[49]. This finding underscores the crucial role of oral health in multidimensional flourishing. This suggests that maintaining natural teeth and using dental prostheses may positively affect the functioning of all flourishing domains including happiness and life satisfaction, mental and physical health, meaning and purpose, character and virtue, close social relationships, and financial and material stability. The inclusion of dental care in health coverage can potentially enhance the well-being of the older population.

The strengths of this study include the use of a relatively large sample size, which improved the statistical power and precision of the estimates. The findings were robust because of the adjustment for broad and essential covariates, such as symptoms of depression and IADLs. In addition, multiple imputation of the missing data reduced the possibility of selection bias.

4.3. Limitations:

The limitations of this study must be considered cautiously. First, it had a cross-sectional design, and there was a possibility of reverse causation. Moreover, some covariates may be related to the pathways linking oral health and flourishing; further longitudinal studies are required to address this limitation. Second, the nature of the observational study could not clarify causality. Although several confounding factors were considered, unmeasured confounders may exist. Third, because we used self-report questions, there may have been information bias. If misclassification systematically occurred for both teeth and flourishing scores, the observed association was seriously biased. The self-reported number of teeth has been reported to be valid and reliable in the JAGES[21]. In addition, selection bias is possible as we excluded participants with invalid information on age and sex (n=876); however, the magnitude of such selection bias is considered minimal as these excluded individuals constituted only 1% of the original sample. Finally, this study did not analyze variations in the effects of different types of prosthetic devices on multidimensional health outcomes. Further research is required to evaluate the variations related to the types of dental prostheses.

4.4. Implications and future research directions

In Japan, a universal health care insurance system that encompasses conventional dental prosthetic procedures has been established[50,51]. Several studies have indicated that Japanese and foreign residents enjoy discounted services with reduced out-of-pocket payments under the universal healthcare insurance system. The system has enhanced accessibility to dental prosthetic treatments and increased dental procedures and oral health checkup visits[52,53]. However, many problems remain in Japan, such as regional inequalities in oral health and total healthcare costs, especially in older populations[50]. In an aging world, not only in Japan, but also in middle-income countries, raising revenues or making payments for healthcare for older people is a serious problem[54]. These studies indicate that it is crucial to maintain and expand the range of discounted dental treatment services that are essential to maintaining flourishing in the older population. Future research should include longitudinal studies to assess the temporal dynamics of oral health status and multidimensional flourishing. Additionally, incorporating a mediation analysis into studies is necessary to determine the mediating mechanisms of this relationship. In addition, cross-national comparative research is vital for a global assessment of the association between oral status and multidimensional flourishing.

5. Conclusions

This study reported that having a greater number of teeth and using a dental prosthesis were separately linked to multidimensional flourishing even after controlling for all relevant covariates. These findings suggest that the use of dental prostheses may enhance multidimensional flourishing in individuals with fewer remaining teeth.

Ethics Committee approval

Japan Gerontological Evaluation Study (JAGES) 2022 was reviewed and granted ethical approval by the Ethics Committee of the Chiba University (M10460) and the Ethics Committee of the Tokyo Medical and Dental University (D2022-040-01). This study adhered to the STROBE guidelines for cross-sectional studies.

Acknowledgments

This study used data from JAGES (the Japan Gerontological Evaluation Study). JAGES was supported by Japan Society for the Promotion of Science (JSPS) KAKENHI Grant Number (15H01972, 19H03860, 19H03861, 21K19635, 23H03117), Health Labor Sciences Research Grant (H28-Choju-Ippan-002, 19FA1012, 19FA2001, 21DA1002, H30-Jyunkankinado-Ippan-004, 22FA2001, 22FA1007, 22FA1010, 22FA0601, 23FA1022), Japan Agency for Medical Research and Development (AMED) (JP18dk0110027, JP18ls0110002, JP18le0110009, JP20dk0110034, JP21lk0310073, JP21dk0110037), Open Innovation Platform with Enterprises, Research Institute and Academia (OPERA,

JPMJOP1831) from the Japan Science and Technology (JST), a grant from Innovative Research Program on Suicide Countermeasures (1-4), a grant from Sasakawa Sports Foundation, a grant from Japan Health Promotion & Fitness Foundation, a grant from Chiba Foundation for Health Promotion & Disease Prevention, the 8020 Research Grant for fiscal 2019 from the 8020 Promotion Foundation (adopted number: 19-2-06), and grants from Meiji Yasuda Life Foundation of Health and Welfare and the Research Funding for Longevity Sciences from National Center for Geriatrics and Gerontology (29-42, 30-22, 20-19, 21-20).

Conflict of interest statement

No declarations.

References

[1] Abbas H, Aida J, Kondo K, Osaka K. Association among the number of teeth, dental prosthesis use, and subjective happiness: A cross-sectional study from the Japan Gerontological Evaluation study (JAGES). J Prosthet Dent. 2024;131:871–7. https://doi.org/10.1016/j.prosdent.2022.02.014, PMID:35459542

[2] Doss BD, Cicila LN, Georgia EJ, Roddy MK, Nowlan KM, Benson LA, *et al.* A randomized controlled trial of the web-based OurRelationship program: effects on relationship and individual functioning. J Consult Clin Psychol. 2016;84:285–96. https://doi.org/10.1037/ccp0000063, PMID:26999504

[3] Kashner TM, Rosenheck R, Campinell AB, Surís A, Crandall R, Garfield NJ, *et al.* Impact of work therapy on health status among homeless, substance-dependent veterans: a randomized controlled trial. Arch Gen Psychiatry. 2002;59:938–44. https://doi.org/10.1001/archpsyc.59.10.938, PMID:12365881

[4] Diener E. Subjective well-being: the science of happiness and a proposal for a national index. Am Psychol. 2000;55:34–43. https://doi.org/10.1037/0003-066X.55.1.34, PMID:11392863

[5] Seligman MEP. Flourish: A visionary new understanding of happiness and well-being. New York, NY, US: Free Press; 2011.

[6] VanderWeele TJ. Outcome-wide Epidemiology. Epidemiology. 2017;28:399–402. https://doi.org/10.1097/EDE.0000000000000641, PMID:28166102

[7] Larsson P, Bondemark L, Häggman-Henrikson B. The impact of oro-facial appearance on oral health-related quality of life: A systematic review. J Oral Rehabil. 2021;48:271–81. https://doi.org/10.1111/joor.12965, PMID:32196720

[8] Gerritsen AE, Allen PF, Witter DJ, Bronkhorst EM, Creugers NHJ. Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. Health Qual Life Outcomes. 2010;8:126. https://doi.org/10.1186/1477-7525-8-126, PMID:21050499

[9] Glick M, Williams DM, Kleinman DV, Vujicic M, Watt RG, Weyant RJ. A new definition for oral health developed by the FDI World Dental Federation opens the door to a universal definition of oral health. J Public Health Dent. 2017;77:3–5. https://doi.org/10.1111/jphd.12213, PMID:28276588

[10] Schierz O, Baba K, Fueki K. Functional oral health-related quality of life impact: A systematic review in populations with tooth loss. J Oral Rehabil. 2021;48:256–70. https://doi.org/10.1111/joor.12984, PMID:32333415

[11] Sato Y, Aida J, Takeuchi K, Ito K, Koyama S, Kakizaki M, *et al.* Impact of loss of removable dentures on oral health after the great East Japan earthquake: a retrospective cohort study. J Prosthodont. 2015;24:32–6. https://doi.org/10.1111/jopr.12210, PMID:25219566

[12] Henschke C, Winkelmann J, Eriksen A, Orejas Pérez E, Klingenberger D. Oral health status and coverage of oral health care: A five-country comparison. Health Policy. 2023;137:104913. https://doi.org/10.1016/j.healthpol.2023.104913, PMID:37757534

[13] Hayasaka K, Tomata Y, Aida J, Watanabe T, Kakizaki M, Tsuji I. Tooth loss and mortality in elderly Japanese adults: effect of oral care. J Am Geriatr Soc. 2013;61:815–20. https://doi.org/10.1111/jgs.12225, PMID:23590405

[14] Fukai K, Takiguchi T, Ando Y, Aoyama H, Miyakawa Y, Ito G, *et al.* Mortality rates of community-residing adults with and without dentures. Geriatr Gerontol Int. 2008;8:152–9. https://doi.org/10.1111/j.1447-0594.2008.00464.x, PMID:18821998

[15] Tiwari T, Kelly A, Randall CL, Tranby E, Franstve-Hawley J. Association between mental health and oral health status and care utilization. Front Oral Health. 2022;2:732882. https://doi.org/10.3389/froh.2021.732882, PMID:35199101

[16] Albani V, Nishio K, Ito T, Kotronia E, Moynihan P, Robinson L, *et al.* Associations of poor oral health with frailty and physical functioning in the oldest old: results from two studies in England and Japan. BMC Geriatr. 2021;21:187. https://doi.org/10.1186/s12877-021-02081-5, PMID:33736595

[17] Koyama S, Saito M, Cable N, Ikeda T, Tsuji T, Noguchi T, *et al.* Examining the associations between oral health and social isolation: A cross-national comparative study between Japan and England. Soc Sci Med. 2021;277:113895. https://doi.org/10.1016/j.socscimed.2021.113895, PMID:33882441

[18] Hajek A, König HH. The association between oral health-related quality of life, loneliness, perceived and objective social isolation-results of a nationally representative survey. Int J Environ Res Public Health. 2021;18:12886. https://doi.org/10.3390/ijerph182412886, PMID:34948495

[19] Japan Gerontological Evaluation Study, https://www.jages.net/; 2024[accessed 25 June 2024].

[20] Kondo K. Progress in aging epidemiology in Japan: the JAGES Project. J Epidemiol. 2016;26:331–6. https://doi.org/10.2188/jea.JE20160093, PMID:27349200

[21] Kondo K, Rosenberg M. World Health O. Advancing universal health coverage through knowledge translation for healthy ageing: lessons learnt from the Japan gerontological evaluation study. Geneva: World Health Organization; 2018.

[22] Yamamoto T, Kondo K, Aida J, Fuchida S, Hirata Y, Grp J; JAGES group. Association between the longest job and oral health: Japan Gerontological Evaluation Study project cross-sectional study. BMC Oral Health. 2014;14:130. https://doi.org/10.1186/1472-6831-14-130, PMID:25345714

[23] Ito K, Aida J, Yamamoto T, Ohtsuka R, Nakade M, Suzuki K, *et al.*; JAGES Group. Individual- and community-level social gradients of edentulousness. BMC Oral Health. 2015;15:34. https://doi.org/10.1186/s12903-015-0020-z, PMID:25884467

[24] Kondō K. Health Inequalities in Japan: An Empirical Study of Older People: Trans Pacific Press; 2010.

[25] Yamamoto T, Kondo K, Hirai H, Nakade M, Aida J, Hirata Y. Association between self-reported dental health status and onset of dementia: a 4-year prospective cohort study of older Japanese adults from the Aichi Gerontological Evaluation Study (AGES) Project. Psychosom Med. 2012;74:241–8. https://doi.org/10.1097/PSY.0b013e318246dffb, PMID:22408130

[26] VanderWeele TJ. On the promotion of human flourishing. Proc Natl Acad Sci USA. 2017;114:8148–56. https://doi.org/10.1073/pnas.1702996114, PMID:28705870

[27] Shiba K, Cowden RG, Gonzalez N, Lee MT, Lomas T, Lai AY, *et al.* Global trends of mean and inequality in multidimensional wellbeing: analysis of 1.2 million individuals from 162 countries, 2009-2019. Front Public Health. 2022;10:824960. https://doi.org/10.3389/fpubh.2022.824960, PMID:35237554

[28] Petersen PE, Baez RJ. World Health O. Oral health surveys: basic methods. 5th ed. Geneva: World Health Organization; 2013.

[29] Yamamoto T. Validity of self-reported oral health variables: Aichi Gerontological Evaluation Study (AGES) project. Health Sci Health Care. 2012;12:4–12.

[30] Lee MT, Kubzansky LD, VanderWeele TJ. Measuring Well-Being: Interdisciplinary Perspectives from the Social Sciences and the Humanities. Lee MT, Kubzansky LD, VanderWeele TJ, editors. New York, NY: Oxford University Press; 2021.

[31] Aida J, Kondo K, Yamamoto T, Saito M, Ito K, Suzuki K, *et al.* Is social network diversity associated with tooth loss among older Japanese adults? PLoS One. 2016;11:e0159970. https://doi.org/10.1371/journal.pone.0159970, PMID:27459102

[32] Hilding A, Shen C, Östenson CG. Social network and development of prediabetes and type 2 diabetes in middle-aged Swedish women and men. Diabetes Res Clin Pract. 2015;107:166–77. https://doi.org/10.1016/j.diabres.2014.09.057, PMID:25458340

[33] Taylor JJ, Preshaw PM, Lalla E. A review of the evidence for pathogenic mechanisms that may link periodontitis and diabetes. J Periodontol. 2013;84:S113–34. https://doi.org/10.1902/jop.2013.134005, PMID:23631573

[34] Mori Y, Tsuji T, Watanabe R, Hanazato M, Chen YR, Kondo K. Built environments and frailty in older adults: The JAGES longitudinal study using mediation analysis. J Am Med Dir Assoc. 2023;24:1677–82. https://doi.org/10.1016/j.jamda.2023.06.023, PMID:37541649

[35] Mandelli L, Nearchou FA, Vaiopoulos C, Stefanis CN, Vitoratou S, Serretti A, *et al.* Neuroticism, social network, stressful life events: association with mood disorders, depressive symptoms and suicidal ideation in a community sample of women. Psychiatry Res. 2015;226:38–44. https://doi.org/10.1016/j.psychres.2014.11.001, PMID:25677396

[36] Araújo MM, Martins CC, Costa LCM, Cota LOM, Faria RLAM, Cunha FA, *et al.* Association between depression and periodontitis: a systematic review and meta-analysis. J Clin Periodontol. 2016;43:216–28. https://doi.org/10.1111/jcpe.12510, PMID:26743451

[37] Niino N. A Japanese translation of the geriatric depression scale. Clin Gerontol. 1991;10:85–7.

[38] Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. Gerontologist. 1969;9:179–86. https://doi.org/10.1093/geront/9.3_Part_1.179, PMID:5349366

[39] Azur MJ, Stuart EA, Frangakis C, Leaf PJ. Multiple imputation by chained equations: what is it and how does it work? Int J Methods Psychiatr Res. 2011;20:40–9. https://doi.org/10.1002/mpr.329, PMID:21499542

[40] Kino S, Tamada Y, Takeuchi K, Nakagomi A, Shiba K, Kusama T, *et al.* Exploring the relationship between oral health and multiple health conditions: an outcome-wide approach. J Prosthodont Res. 2023;68:415–24. https://doi.org/10.2186/jpr.JPR_D_23_00091, PMID:37574274

[41] Yoon HS, Kim HY, Patton LL, Chun JH, Bae KH, Lee MO. Happiness, subjective and objective oral health status, and oral health behaviors among K orean elders. Community Dent Oral Epidemiol. 2013;41:459–65. https://doi.org/10.1111/cdoe.12041, PMID:23398395

[42] Tuchtenhagen S, Ortiz FR, Ardenghi TM, Antunes JLF. Oral health and happiness in adolescents: A cohort study. Community Dent Oral Epidemiol. 2021;49:176–85. https://doi.org/10.1111/cdoe.12589, PMID:33135221

[43] An HY, Chen W, Wang CW, Yang HF, Huang WT, Fan SY. The Relationships between physical activity and life satisfaction and happiness among young, middle-aged, and older adults. Int J Environ Res Public Health. 2020;17:4817. https://doi.org/10.3390/ijerph17134817, PMID:32635457

[44] Carstensen LL, Turan B, Scheibe S, Ram N, Ersner-Hershfield H, Samanez-Larkin GR, *et al.* Emotional experience improves with age: evidence based on over 10 years of experience sampling. Psychol Aging. 2011;26:21–33. https://doi.org/10.1037/a0021285, PMID:20973600

[45] Chida Y, Steptoe A. Positive psychological well-being and mortality: a quantitative review of prospective observational studies. Psychosom Med. 2008;70:741–56. https://doi.org/10.1097/PSY.0b013e31818105ba, PMID:18725425

[46] Zhang Y, Han B. Positive affect and mortality risk in older adults: A meta-analysis. PsyCh J. 2016;5:125–38. https://doi.org/10.1002/pchj.129, PMID:27113246

[47] Carstensen LL, DeLiema M. The positivity effect: a negativity bias in youth fades with age. Curr Opin Behav Sci. 2018;19:7–12. https://doi.org/10.1016/j.cobeha.2017.07.009. , PMID:30327789

[48] McMahan EA, Estes D. Age-related differences in Lay conceptions of well-being and experienced well-being. J Happiness Stud. 2012;13:79–101. https://doi.org/10.1007/s10902-011-9251-0

[49] Azevedo MS, Correa MB, Azevedo JS, Demarco FF. Dental prosthesis use and/or need impacting the oral health-related quality of life in Brazilian adults and elders: Results from a National Survey. J Dent. 2015;43:1436–41. https://doi.org/10.1016/j.jdent.2015.10.016, PMID:26523347

[50] Zaitsu T, Saito T, Kawaguchi Y. The oral healthcare system in Japan. Healthcare (Basel). 2018;6:79. https://doi.org/10.3390/healthcare6030079, PMID:29996547

[51] Aida J, Fukai K, Watt RG. Global neglect of dental coverage in universal health coverage systems and Japan's broad coverage. Int Dent J. 2021;71:454–7. https://doi.org/10.1016/j.identj.2020.12.027, PMID:33618834

[52] Cooray U, Aida J, Watt RG, Tsakos G, Heilmann A, Kato H, *et al.* Effect of copayment on dental visits: a regression discontinuity analysis. J Dent Res. 2020;99:1356–62. https://doi.org/10.1177/0022034520946022, PMID:32735476

[53] Ando M, Takaku R. Affordable false teeth: the effects of patient cost sharing on denture utilization and subjective chewing ability. BE J Econ Anal Policy. 2016;16:1387–438. https://doi.org/10.1515/bejeap-2015-0194

[54] Preker AS, Cotlear D, Kwon S, Atun R, Avila C. Universal health care in middle-income countries: lessons from four countries. J Glob Health. 2021;11:16004. https://doi.org/10.7189/jogh.11.16004, PMID:34912557