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ORIGINAL ARTICLE

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Functional dentition and well-being among Chilean 80-year-olds

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Background: The Decade of Healthy Aging 2021-2030 calls for a strengthening of the policies for older people in Latin America. An example of successful oral aging is the Japanese "8020" campaign, which achieved 50% of people aged 80 years having ≥20 teeth by 2016.

Objective: To evaluate the association between having a functional dentition (≥20 teeth) and cognitive health, social participation, and quality of life in people aged ≥80 years.

Methods: Cross-sectional data from 299 complete observations (weighted $N = 436\,981$) of individuals aged ≥80 years from Chile's National Health Survey 2016-2017 were included (3% of the population; total = 5520 clinical observations/weighted $N = 14\,518\,969$). Generalised structural equation models (GSEM) evaluated the association between having a functional dentition and cognitive health, measured with the Mini-mental score, between having a functional dentition and social participation, and between having a functional dentition and quality of life, measured with the EQ-5D-3L. Models included the effect of mediators (daily fruit and vegetable consumption; oral health-related quality of life score) and controlled for the exposure-induced mediator-outcome variables: sex, educational level, and location. Data were analysed using the STATA-17 survey module. Statistical significance was set at $P < .05$ (95% confidence interval [CI]).

Results: The sample was mostly female, had <8 years of education, and lived in urban areas. The prevalence of a functional dentition was 9.2% (95% CI 3.6,21.3/$n = 21$). GSEM demonstrated that the association between functional dentition and cognitive health was mediated by daily fruits and vegetables consumption ($\beta = 0.12$/95% CI 0.02,0.21/$P = .015$), with moderate strength of evidence. Additionally, there was strong evidence of an association between functional dentition and social participation frequency ($\beta = 2.76$/95% CI 0.60,4.73/$P = .009$). Finally, the association between functional dentition and quality of life was mediated by cognitive health ($\beta = 0.05$/95% CI 0.02,0.09/$P = .002$) and oral health-related quality of life ($\beta = -0.04$/95% CI −0.08 to −0.01/$P = .025$), with strong and moderate evidence, respectively.

Conclusion: Given the beneficial implications of functional dentition in social participation, nutritional benefits and quality of life and well-being of individuals aged ≥80 years.

KEYWORDS
aged, 80 and over, cognition, functional dentition, preventive dentistry, quality of life, social participation

1 | INTRODUCTION

The concept of "successful aging" was first proposed by Rowe and Kahn.[1,2] Since 2015, the World Health Organization (WHO) has used the term "healthy aging" as the "process of developing and maintaining functional capacity that enables well-being in old age".[3] Good oral health is associated with good physical and cognitive function.[4,5] Thus, the WHO, in their in the Oral Health 2020 objectives,[6] define a increasing the percentage of individuals with a functional dentition as an important component of improving older people's general health and quality of life.[7,8]

In 1989, the Japanese Ministry of Health, Labour and Welfare and the Japan Dental Association promoted a national oral health campaign, the "8020 campaign". The "80" represents the average life expectancy of Japanese people at that time, and "20" indicates the critical number of natural teeth for maintaining a good masticatory capacity and being able to eat almost any type of food, from soft to hard foods,[9] as well as maintaining an active social role and good quality of life.[10] After the evaluation of the "Basic Direction for Comprehensive Implementation of National Health Promotion", the second period of "Healthy Japan 21" covers nutrition and dietary habits, physical activity and exercise, rest, reduction of alcohol and tobacco consumption, and oral health. In the latter, an increase from 20% of people aged ≥80 years with a functional dentition (≥20 teeth) in 2005 to 50% in 2016 was achieved.[11,12]

Chile and Japan share some similarities, as the first is moving towards the second, in terms of aging and the demographic transition: Chile, in 2100, is expected to have the same population age structure as Japan does at present.[13] Chile is considered to be in an advanced demographic transition stage, and, by 2030, 35% of the population is expected to be 60 years or older,[14] while Japan is the most aged country in the world and will continue to hold this lead by 2050.[15] However, due to its successful and comprehensive public aging policies, including universal healthcare coverage, long-term care insurance, and community-based care services, Japan has a higher healthy life expectancy than Chile (74 and 69 years, respectively).[16] By contrast, Chile's public policies for older people are still developing and face challenges such as limited resources and unequal access to healthcare services.[17]

The information provided in Chile's National Health Survey (ENS)[18] is vital for the development of prevention plans, care, and health policies for the population.[19] Some 22.6% of older Chileans report poor or very poor oral health, and only 18.3% have a functional dentition.[18] Although Chile has a life expectancy at birth of around 80 years,[20] the population group that has grown the most in the last 20 years is the 80 years and older, which grew from 214 000 in 2001 to 561 000 in 2021, an increase of 162%.[21] Thus, it is important to study and characterise the so-called group of survivors, who they are and under what conditions they overcome their life expectancy at birth (~55 years in 1950).[20]

The United Nations (UN) has recently declared the "Decade of Healthy Aging, 2021-2030", and stated that the complex problem of aging should involve an interdisciplinary and multifactorial approach that encompasses the entire life course. In this sense, the evaluation of the maintenance or loss of functionality is one of the indicators recommended by the WHO to improve the health and quality of life of older people.[22,23] Accordingly, the objective of this study was to determine, using data from the ENS 2016-2017, the beneficial associations of having a functional dentition for people aged ≥80, particularly in terms of cognitive health, social participation, and quality of life.

2 | METHODS

This study was a secondary analysis of epidemiological data obtained from a National Health Survey conducted in 2016-2017 (ENS 2016-2017). This report follows the STROBE guidelines for cross-sectional studies.[24]

2.1 | National Health Survey 2016-2017

The NHS was a cross-sectional, probabilistic, population-based survey, stratified by conglomerate (multi-stage), whose target population was persons 15 years of age and older who usually reside in privately occupied housing, located in the urban and rural areas of 15 regions of Chile. Thirty strata were formed by crossing regions and locations, including municipalities with more than 30 000 inhabitants, to select census blocks (urban areas) or localities (rural areas), dwellings, and 1 individual at random per dwelling. A total sample of 6233 respondents aged 15 years and over was obtained, which utilising the survey weights corresponded to an expanded sample of $N = 14\,518\,969$ individuals. The response rate was 66%, and the non-response rate of was 9.8%. Interviews were conducted at home, using a tablet, by an interviewer or nurse according to the type of

form. The fieldwork was done between August 2016 and March 2017. In addition, a random subgroup of 5520 individuals underwent laboratory tests, with a sampling error of 2.6% nationwide due to the design effect of 1797 estimates with 95% confidence and a relative error of <30%.

This project was supported by the Scientific Ethical Committee of the Faculty of Medicine of the Pontificia Universidad Católica de Chile (project no. 16-019). Informed consent was obtained from the population aged ≥18 years. Assent and informed consent from a representative were required for those aged under 18. For detailed information on the evaluation methods, please visit the following web page http://epi.minsal.cl/encuesta-ens-descargable/.

2.2 | Data collection

During the first home visit, the following information was recorded.

2.2.1 | Sociodemographic data

Age, sex, educational level (years of schooling approved), occupation, household income, location (urban/rural), and health insurance system were recorded.

2.2.2 | Oral health

Self-reported data on oral health and the last dental appointment were recorded. The questionnaire also included 5 oral health-related quality of life questions,[25] covering discomfort when communicating and eating, pain, interference with daily activities, and social relations as a result of the dental or denture condition. The higher the scale score, the poorer the respondent's oral health-related quality of life.

2.2.3 | Cognitive function

The shortened version of the Mini-Mental Questionnaire (MMSE), a screening instrument used to detect cognitive alterations, was used. It evaluates the aspects of orientation, attention, recent memory, and language. This version contains 6 questions, with a maximum score of 19 points, and the cut-off point used to determine cognitive health was a score greater than or equal to 13 points.[26]

2.2.4 | Risk and protective indicators

Self-reported smoking was recorded. The Global Physical Activity Questionnaire (GPAQ)[27] was applied, with the objective to measure the physical activity level, whether at work, leisure time or transportation. The physical activity levels were low, moderate, and high. For alcohol use, the AUDIT questionnaire was used,[28] with 10 questions focused on the risk of alcohol abuse. It consists of a score from 0 to 40 points and considers the categories of low-risk consumption (0-7 points), hazardous or harmful alcohol consumption (8-15 points), and the likelihood of alcohol dependence (16 points or more). For fruit and vegetable consumption, the self-reported monthly and weekly frequencies were recorded.

2.2.5 | Social well-being and quality of life

Self-reported social participation and monthly social participation frequency were recorded. For quality of life, the EQ-5D-3L questionnaire was used[29]; it is a descriptive instrument comprising 5 dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each dimension has 3 levels: no problems, some problems, and extreme problems. The digits for each dimension can be combined in a 5-digit number that represents a health state (HS). There was a social value for each HS, according to whether a given state is better or worse than death, bounded between −1 and 1, where negative values indicate that the person prefers to die rather than live in their current HS for 10 years. For this study, the higher the social rating for a certain HS, the better was the health-related quality of life according to the population preference.[29]

2.2.6 | Oral health examination

In a second home visit, clinical information was sought. Nurses were trained by 9 dentists, through a demonstration, a dental examination practice, and a final test with 20 clinical cases. The test average score was 50.0 (SD 2.7), and inter-rater reliability was substantial (kappa = 0.85). The oral health questionnaire encompassed the use of dentures, total number of remaining teeth (range, 1-16 per arch), anterior missing teeth, and cavitated carious lesions in the maxilla and mandible. It also indicates whether anterior missing teeth is resolved by the use of dentures. This survey considered the WHO definition appraising the functional dentition as the presence of ≥20 teeth, regardless of their location.[30] For detailed information on the evaluation methods, please visit the following website http://epi.minsal.cl/encuesta-ens-descargable/.

2.2.7 | Non-communicable disease screening

In respect of non-communicable diseases, hypertension, diabetes and metabolic syndrome were assessed. Detailed evaluation and diagnostic criteria are available in Table S1.

2.3 | Statistical analysis

Operationalization of the variables and statistical analysis used the survey module for complex samples in STATA 17 (StataCorp. 2021.

StataCorp LLC., College Station, TX, USA). A comprehensive categorization and description of the variables is presented in Table S1. A total of 299 participants with complete observations were available (341 observations in total, 42 missing data). For the descriptive analysis, frequency and prevalence with 95% confidence intervals (CI) were estimated using the corresponding weights for each variable through frequency tables.

In the first exploratory stage, cross-tabulations used the chi-squared test, and means were compared using the *t*-test. Subsequently, the crude association between variables was determined by the multivariable modelling guided by a theoretical model.[10,31–41] An association matrix was constructed, which showed associations with their putative directions (Table S2).

The second stage consisted of an exploratory path analysis using Generalised Structural Equation Modelling (GSEM), which was performed exclusively on observed rather than latent variables. GSEM had desirable advantages for the present analysis because it allows the modelling of several types of variables. Although GSEM cannot be used to determine causality, this method allows the determination and evaluation of the plausibility of the direction of an association, as well as the eventual mediation role of a variable. The hypotheses to be evaluated were as follows:

- Having a functional dentition has a beneficial impact on the MMSE score. Daily consumption of fruits and vegetables and social participation frequency mediate this association, after adjusting for sociodemographic characteristics such as sex, educational level, and location.
- Having a functional dentition has a beneficial impact on quality of life, as measured by the social value of HSs of the EQ-5D-3L. This association is mediated by oral health-related quality of life and MMSE, adjusting for sociodemographic covariates such as sex, educational level, and location.

Two models were evaluated: a full model, which was built based on evidence[10,31–41] complemented with the information obtained from the association matrix; and an adjusted model, where associations with little or no evidence ($P > .1$) were removed from the path analysis. The integration method for the random-effects model was Laplacian approximation with 7 squaring points (default).[42] Coefficients were reported with a 95% CI based on a linearized error estimate for survey data. Since the GSEM was run using the survey module, it was not possible to estimate the goodness-of-fit of the model or to compute the direct and indirect effects. Thus, the existence of mediation was considered using the causal-steps approach reviewed by Hayes,[43] controlling for mediators and exposure-induced mediator-outcome confounders. A heat map for functional dentition regional prevalence was made using the statistical software R 4.2.2 (2022, R Foundation for Statistical Computing, Vienna, Austria), using the packages *ggplot2* y *chilemapas*. Continuous measures of statistical evidence (*P*-values) were interpreted using the framework proposed by Muffler et al that 'there was no ($P \geq .1$)/weak ($P < .1$)/moderate ($P < .05$)/strong ($P < .01$)/very strong evidence ($P < .001$)' for a certain finding according to the approximate ranges into which the p-value fell.[44]

3 | RESULTS

The 299 complete observations of the NHS yielded a nationally representative sample which corresponds to 436 981 individuals aged ≥80. Most were female, had <8 years of schooling, were not employed, with a household income between $20 000 and $200 000 CLP (US$25.2-US$251.8 approx.), and were located in urban areas. A high percentage (89.3%) reported belonging to the national health public insurance fund, FONASA. Slightly more than half of the included population did not have metabolic syndrome (Table 1).

3.1 | Oral health

Table 1 shows the descriptive distribution of the included variables. The majority reported very good/good oral health (42.2% [95% CI 31.5-53.8]), with a relatively low average oral health-related quality of life (7.7 [95% CI 6.9-8.4]) out of a minimum of 5, demonstrating a largely good oral health-related quality of life. Clinical examination showed a 9.2% prevalence of functional dentition (95% CI 3.6-21.3), with very strong evidence of differences between males and females (17.5 vs 2.1, respectively). The regional prevalence of functional dentition (Figure 1) ranged from 4.9% (95% CI 0.6-28.9%) in Region VI to a maximum of 24.6% (95% CI 5.0-66.9%) in Region I. On the other hand, Regions II, III, IV, and IV had the highest prevalence of a functional dentition (Figure 1). By contrast, regions II, IV, IX, X, X, XI, and XIV lacked observations of persons with a functional dentition. Additionally, more than 70% of the population with a functional dentition were caries-free, denture wearers (maxillary and/or mandibular), or reported having a dental appointment less than 1 year previously (Table 1).

3.2 | Cognitive health

In relation to cognitive health, the mean MMSE score was 14.3 (95% CI 13.6-15.0, with 76.2% MMSE ≥13). For quality of life, the mean score was 0.5 (95% CI 0.4-0.6), with very strong evidence of differences between men and women (0.6 and 0.4). On the other hand, the majority reported not participating in social activities (63.9%). However, among those who did, the majority reported doing so 2 or more times per week (61.0%), with a sex difference (~60% more for women).

3.3 | Risk and protective indicators

The level of physical activity was low (Table 1), with moderate evidence of sex differences ($P < .05$). Most (>50%) reported consuming

TABLE 1 Characteristics of the population aged ≥80 years, according to ENS 2016-2017.

	Total % [95% CI], *n*	Male % [95% CI], *n*	Female % [95% CI], *n*	*P*
Age (mean)	84.38 [83.68-85.07], 299	84.29 [83.11-85.47], 106	84.45 [83.65-85.25], 193	>.1
Sex		45.8 [35.5-56.5], 106	54.2 [43.5-64.5], 193	—
Educational level				
<8 years	71.9 [60.8-80.8], 210	63.1 [44.2-78.7], 66	79.2 [68.0-87.2], 144	.01
8-12 years	21.7 [14.8-30.7], 69	24.1 [13.7-38.8], 31	19.7 [11.9-31.0], 38	
13 or more years	6.4 [1.7-21.1], 12	12.8 [3.1-40.0], 7	1.1 [0.3-3.6], 5	
Occupation				
Occupied	3.4 [1.1-9.9], 7	7.2 [2.3-20.7], 5	0.2 [0.0-0.9], 2	<.001
Not occupied	96.6 [90.1-98.9], 292	92.8 [79.3-97.7], 101	99.8 [99.1-99.9], 191	
Household income by quintile (in CLP)				
20000-200000	37.4 [27.6-48.4], 118	33.8 [19.2-52.3], 30	40.5 [29.5-52.6], 88	.46
207000-291000	14.8 [9.3-22.8], 33	12.0 [5.9-23.0], 13	17.2 [9.6-28.8], 20	
292008-400000	26.5 [16.1-40.4], 48	29.3 [12.1-55.6], 22	24.1 [14.4-37.4], 26	
415000-600000	14.3 [6.6-28.5], 25	20.8 [7.5-46.3], 14	8.7 [2.9-23.4], 11	
>600000	7.0 [2.9-15.7], 22	4.1 [1.4-11.0], 7	9.5 [3.1-25.3], 15	
Location				
Urban	82.0 [74.7-87.5], 237	74.8 [61.4-84.7], 74	88.1 [79.7-93.3], 163	.035
Rural	18.0 [12.5-25.3], 62	25.2 [15.3-38.6], 32	11.9 [6.7-20.3], 30	
Health insurance system				
FONASA A	20.8 [14.8-28.3], 77	16.7 [8.9-29.2], 22	24.3 [16.5-34.3], 55	—
FONASA B	40.1 [30.8-50.1], 121	27.1 [16.5-41.1], 38	51.4 [39.8-62.8], 83	
FONASA C	2.1 [0.9-4.5], 10	2.7 [0.9-8.2], 4	1.5 [0.5-4.2], 6	
FONASA D	1.6 [0.7-3.5], 10	2.8 [1.0-7.1], 6	0.6 [0.2-2.1], 4	
FONASA (unknown group)	24.7 [15.3-37.3], 54	32.2 [16.1-54.1], 24	18.2 [10.2-30.4], 30	
Armed Forces	1.5 [0.5-4.9], 8	2.2 [0.4-10.9], 4	0.9 [0.3-2.9], 4	
ISAPRE	8.9 [3.2-22.6], 8	16.3 [5.1-41.1], 6	2.5 [0.4-14.8], 2	
None	0.3 [0.1-1.2], 3	-	0.6 [0.2-2.2], 3	
Metabolic syndrome				
Yes	47.5 [34.5-60.9], 98	30.7 [15.4-51.8], 31	57.6 [43.0-71.1], 67	.032
No	52.5 [39.1-65.5], 81	69.3 [48.2-84.6], 29	42.4 [29.0-57.0], 52	
Oral health				
Self-report				
Very bad/bad	24.8 [18.0-33.22, 80	21.3 [12.3-34.3], 32	27.8 [18.4-39.7], 48	.73
Average	33.0 [25.1-41.9], 109	35.4 [22.0-51.7], 39	30.8 [21.7-41.8], 70	
Very good/good	42.2 [31.5-53.8], 110	43.3 [25.5-62.9], 35	41.4 [30.0-53.7], 75	
Oral health-related quality of life (best 5-worst 25) (mean)	7.65 [6.87-8.44], 299	7.37 [6.15-8.60], 106	7.89 [6.89-8.90], 193	.522
Functional dentition (≥20 teeth)				
Yes	9.2 [3.6-21.33], 21	17.5 [6.3-40.3], 13	2.1 [0.9-4.9], 8	<.001
No	90.8 [78.7-96.4], 278	82.5 [59.7-93.8], 93	97.9 [95.1-99.1], 185	
Cavitated caries lesions				
Cavity-free	70.7 [62.2-78.0], 207	62.4 [45.9-76.4], 64	77.8 [68.7-84.8], 143	.073
≥1 cavity	29.3 [22.0-37.8], 92	37.6 [23.6-54.1], 42	22.2 [15.2-31.3], 50	
Denture wearer				
Yes	71.3 [60.4-80.1], 208	63.3 [44.8-78.6], 63	78.0 [67.2-86.0], 145	.12
No	28.7 [19.9-39.6], 91	36.7 [21.4-55.2], 43	22.0 [14.0-32.8], 48	

(Continues)

TABLE 1 (Continued)

	Total % [95% CI], *n*	Male % [95% CI], *n*	Female % [95% CI], *n*	*P*
Last dental appointment				
More than a year ago	27.3 [18.7-38.0], 70	31.4 [16.9-50.8], 28	23.8 [15.9-34.0], 42	.42
Less than a year ago	72.7 [62.0-81.3], 229	68.6 [49.2-83.1], 78	76.2 [66.0-84.1], 151	
Cognitive health				
MMSE score (mean)	14.31 [13.59-15.02], 299	14.79 [13.76-15.82], 106	13.9 [12.89-14.91], 193	.237
MMSE <13	23.8 [17.2-32.0], 82	19.4 [11.0-32.0], 28	27.5 [18.8-38.4], 54	.28
MMSE ≥13	76.2 [68.0-82.8], 217	80.6 [68.0-89.0], 78	72.5 [61.6-81.2], 139	
Quality of Life and Social welfare				
EQ-5D-3L				
Social value of health states (−0.4 a 1)	0.50 [0.44-0.56]	0.61 [0.54-0.68]	0.41 [0.32-0.50]	<.001
Social participation				
Yes	36.1 [26.0-47.5], 91	30.1 [14.4-52.4], 23	41.1 [29.9-53.3], 68	.36
No	63.9 [52.5-74.0], 208	69.9 [47.6-85.6], 83	58.9 [46.7-70.1], 125	
Social participation frequency				
Twice or more times a month	61.0 [38.0-80.0], 61	24.5 [7.8-55.5], 9	83.6 [69.5-91.9], 52	<.001
Once a month	10.6 [5.3-20.3], 17	11.2 [3.5-30.4], 8	10.3 [4.1-23.4], 9	
Less than once a month	24.8 [8.0-55.5], 9	62.8 [28.6-87.7], 5	1.3 [0.3-4.8], 4	
Never	3.6 [1.2-10.1], 4	1.5 [0.2-11.6], 1	4.8 [1.4-14.9], 3	
Physical activity				
GPAQ				
Low	71.9 [59.9-81.4], 218	61.6 [41.5-78.3], 69	80.6 [71.3-87.5], 149	.02
Moderate	19.5 [11.0-32.2], 44	30.4 [14.6-52.8], 24	10.3 [5.9-17.3], 20	
High	8.6 [4.6-15.6], 29	8.0 [3.2-19.0], 9	9.1 [4.4-17.8], 20	
Healthy nutrition				
Daily consumption of fruits				
Yes	51.7 [40.9-62.4], 149	43.6 [27.3-61.4], 47	58.6 [46.0-70.2], 102	.17
No	48.3 [37.6-59.1], 150	56.4 [38.6-72.7], 59	41.4 [29.8-54.0], 91	
Daily consumption of vegetables				
Yes	52.7 [42.0-63.2], 172	49.0 [31.6-66.7], 46	54.2 [42.0-66.0], 112	.77
No	47.3 [36.8-58.0], 127	51.0 [33.3-68.4], 60	45.8 [34.0-58.1], 81	
Daily fruits and vegetables consumption				
Yes	35.2 [25.9-45.9], 108	33.1 [18.7-51.5], 36	37.1 [26.3-49.4], 72	.70
No	64.8 [54.2-74.1], 191	66.9 [48.5-81.3], 70	62.9 [50.6-73.7], 121	
Smoking (self-reported)				
Yes	7.19 [2.3-20.6], 14	13.3 [3.5-39.1], 8	2.0 [0.6-6.4], 6	.02
No	92.81 [79.4-97.7], 285	86.7 [61.0-96.5], 98	98.0 [93.6-99.4], 187	
Alcohol abuse (AUDIT)				
Low risk consumption	43.7 [33.5-54.5], 115	58.3 [40.3-74.3], 56	31.4 [22.0-42.6], 59	.009
Hazardous or harmful alcohol consumption	0.6 [0.1-3.9], 1	1.2 [0.2-8.3], 1	-	
Likelihood of alcohol dependence	55.7 [45.0-65.9], 183	40.5 [24.7-58.6], 49	68.6 [57.4-78.0], 134	

fruit or vegetable daily. On the other hand, those who reported the daily consumption fruit and vegetables in combination were 35.2% (95% CI 25.9-45.9). For smoking, 92.8% did not consume tobacco or cigarettes at that time, but there was a higher prevalence of smoking in men. By contrast, there was a high prevalence of likelihood of alcohol dependence in this population (55.7%), with a strong sex difference.

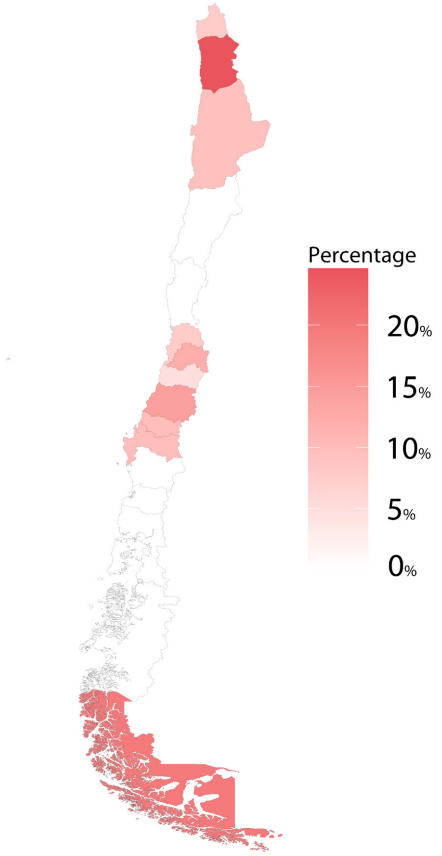

FIGURE 1 Regional distribution of functional dentition prevalence in people aged ≥80 years.

3.4 | Bivariate analysis

The educational level was lower in females than males (Table 1), and in the bivariate analysis (Table S2), being male was strongly associated with a higher educational level. Additionally, strong to very strong evidence of differences between men and women was observed, favouring males for functional dentition and in quality of life (EQ-5D-3L social value of HSs), and favouring women for social participation frequency. Likewise, there was moderate evidence of an association between rural area and educational level social participation frequency. Similarly, there were moderate to very strong evidence of differences between educational level (13 or more years) and location (urban) in functional dentition, oral health-related quality of life, MMSE score, quality of life, and daily consumption of fruits and vegetables ($P < .05$). Functional dentition was associated with MMSE score (very strong evidence), oral health-related quality of life (very strong evidence), social participation frequency (moderate evidence), quality of life (moderate evidence), and daily fruit consumption (strong evidence). There was very strong evidence that the MMSE score was associated with quality of life and moderate evidence that it was associated with daily vegetable consumption. Social participation frequency was also moderately associated with quality of life. There was strong evidence of an association between oral health-related quality of life and quality of life. A full model was constructed based on these associations and complementing those with the literature.

3.5 | Generalised structural equation model

Table 2 shows moderate evidence of associations of sex and location with educational level, and moderate to very strong evidence of an association of sex, educational level (13 or more years) and location with functional dentition. Secondly, moderate evidence suggests an association between functional dentition and daily consumption of fruits and vegetables, adjusted for sex and location; strong evidence of association of evidence of functional dentition and sex with social participation frequency, adjusted for educational level and location; and moderate evidence of association between functional dentition and educational level (13 years or more) with oral health-related quality of life. There was, moderate to strong evidence for an association of daily consumption of fruits and vegetables and educational level (13 or more years) with MMSE score, and moderate to strong evidence for an association of MMSE score and oral health-related quality of life with quality of life.

The results of the exploratory path analysis are shown in Figure 2. There was a strong association between having a functional dentition and social participation frequency ($\beta = 2.8$, 95% CI 0.6-4.7, $P = .009$), adjusting for sex, educational level, and location. However, there was no evidence of social participation frequency predicting MMSE score, ruling out its potential mediating effect. On the other hand, there was moderate evidence that a functional dentition was associated with higher daily consumption of fruits and vegetables ($\beta = 1.9$, 95% CI 0.1-3.7, $P = .038$), adjusted for sex and location, and moderate evidence of an association of daily consumption of fruits and vegetables with MMSE score ($\beta = 0.1$, 95% CI 0.02-0.2, $P = .015$), adjusted for educational level. Consequently, the association between the presence of functional dentition and a better MMSE score was explained by the subsequent daily consumption of fruits and vegetables.

For quality of life, there was moderate evidence of an association between having a functional dentition and oral health-related quality of life ($\beta = -0.3$, 95% CI −0.5 to −0.1, $P = .012$), adjusted for educational level, and moderate evidence of an association between oral health-related quality of life and quality of life ($\beta = -0.04$, 95% CI −0.08 to −0.01, $P = .025$). Similarly, there was strong evidence of an association between MMSE score and quality of life ($\beta = 0.1$, 95% CI 0.02-0.1, $P = .002$).

4 | DISCUSSION

This investigation found that a functional dentition was associated with a higher consumption of fruits and vegetables, and consequently, better cognitive health, with higher social participation frequency, and better quality of life as a result of better cognitive health and better oral health-related quality of life, after adjusting for sex, educational

TABLE 2 Set of structural equations for adjusted generalised linear models.

Number of strata = 30 Number of PSUs = 255		Number of obs = 299 Population size = 436 981.53 Design df = 225				
Outcomes/endogenous variables (family, link function)	**Predictors/exogenous variables**	**Coefficient**	**Linearized standard error**	***t***	***P*>|*t*|**	**95% confidence interval**
Educational level (ordinal, logit)	Sex (ref. male)	−1.12	0.57	−1.97	**.050**	−2.25 to 0.00
	Location (ref. urban)	−1.55	0.63	−2.44	**.015**	−2.80 to −0.30
Functional dentition (binomial, logit)	Sex (ref. male)	−1.75	0.69	−2.53	**.012**	−3.12 to −0.39
	Educational level (ref. <8 years)					
	8-12 years	1.45	0.78	1.85	.065	−0.09 to 2.98
	13 or more years	4.77	0.97	4.90	**<.001**	2.85-6.69
	Location (ref. location)	−1.48	0.71	−2.07	**.04**	−2.88 to −0.07
Daily fruits and vegetables consumption (binomial, logit)	Functional dentition (ref. not functional)	1.90	0.91	2.09	**.038**	0.11-3.70
	Sex (ref. male)	0.54	0.42	1.28	.203	−0.29 to 1.37
	Location (ref. urban)	0.18	0.45	0.40	.692	−0.72 to 1.08
MMSE score (Gaussian, log)[a]	Functional dentition (ref. not functional)	0.02	0.05	0.37	.712	−0.08 to 0.12
	Daily fruits and vegetables consumption (ref. no)	0.12	0.05	2.46	**.015**	0.02-0.21
	Educational level (ref. <8 years)					
	8-12 years	0.14	0.05	2.71	**.007**	0.04-0.23
	13 or more years	0.12	0.06	2.10	**.036**	0.01-0.24
Social participation frequency (ordinal, logit)	Functional dentition (ref. not functional)	2.76	1.05	2.64	**.009**	0.60-4.73
	Sex (ref. male)	2.75	0.99	2.79	**.006**	0.81-4.70
	Educational level (ref. <8 years)					
	8-12 years	0.20	0.79	0.25	.803	−1.36 to 1.75
	13 or more years	0.12	0.80	0.15	.880	−1.45 to 1.70
	Location (ref. urban)	−1.32	1.06	−1.25	.213	−3.40 to 0.76
Oral health-related Quality of Life (negative binomial, mean log)	Functional dentition (ref. not functional)	−0.28	0.11	−2.54	**.012**	−0.49 to 0.06
	Educational level (ref. <8 years)					
	8-12 years	−0.09	0.11	−0.86	.391	−0.29 to 0.12
	13 or more years	−0.25	0.10	−2.55	**.011**	−0.44 to −0.06
Quality of Life (EQ-5D-3L health states social value) (Gaussian, log)[b]	Functional dentition (ref. not functional)	0.07	0.09	0.78	.435	−0.11 to 0.25
	MMSE score	0.05	0.02	3.14	**.002**	0.02-0.09
	Oral health-related Quality of Life (lowest value indicates best oral health-related quality of life)	−0.04	0.02	−2.26	**.025**	−0.08 to −0.01

[a] $\sigma^2 = 17.19$, SE = 2.28, 95% CI 13.23-22.33.

[b] $\sigma^2 = 0.11$, SE = 0.01, 95% CI 0.08-0.14.

Bold values indicate $p < .05$.

level, and location. The association between functional dentition and better quality of life is explained through the intrinsic higher oral health-related quality of life and MMSE score.

This nationally representative study is the first to show the benefits of a functional dentition in individuals aged ≥80 years, in line with a healthy and successful aging. Even though the cross-sectional data study were a limitation for the analysis of complex variables, the study employed GSEM, a model capable of simultaneously evaluating several predictors and outcomes, and their intricate and complex relations, and that has the potential to provide meaning and coherence to the associations that would typically be abstract and ethereal using conventional regression models. These findings are

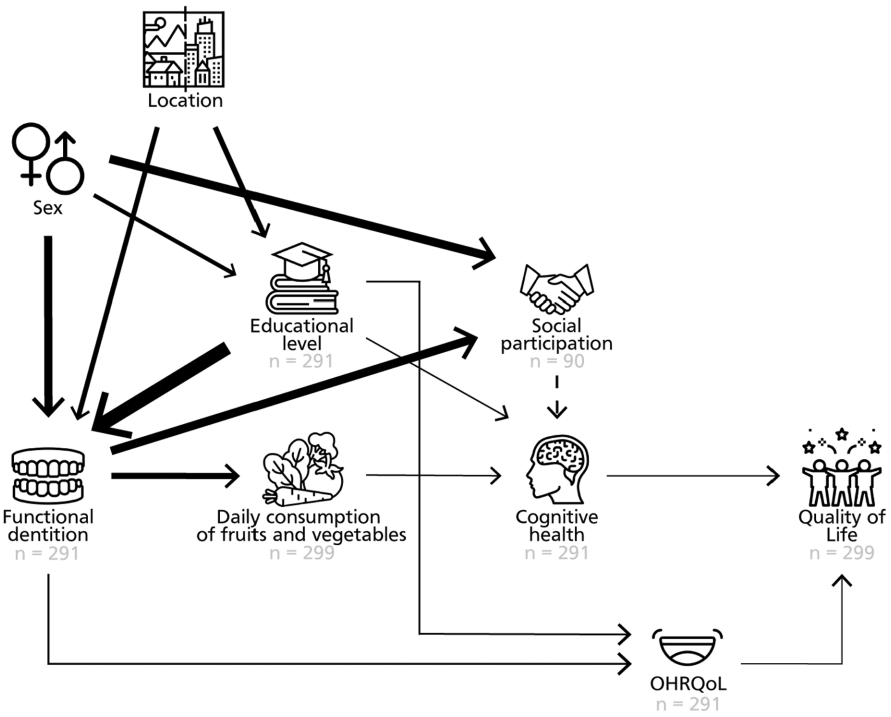

FIGURE 2 Directed acyclic graph for path analysis for the impact of functional dentition on health and well-being outcomes. Continuous line represents a statistically significant path. Discontinuous line represents a path that only has been reported significant in literature. The thickness of the line corresponds to the magnitude of the direct effect.

particularly relevant for quality improvement in healthcare, given that a multi-attribute utility instrument (EQ-5D-3L) was used to quantify the social value of HSs derived from a functional dentition, providing a standardised and preference-oriented approach for decision making. Although the sampling procedure provided high representativeness, the sample was still relatively small and the data lack the follow-up required to demonstrate causality in the proposed model. Additionally, the functional dentition was defined with a cut point of 20 teeth, but the location and opposing contacts between the remaining teeth is unknown. The examination was performed by calibrated nurses who demonstrated a high degree of agreement with a dentist, but it was not possible to record the number of functional occlusal units.[31] Incorporating a complete oral examination would allow a more comprehensive diagnosis of oral health status (such as periodontal health status) and functioning. In parallel, it has been shown that the MMSE has a sensitivity of 30.8% (95% CI 9-61.4) and a specificity of 90.2% (95% CI 76.9-97.3), means that it is an ineffective instrument in the screening for dementia in older persons.[45] In addition, precise measures for oral health-related quality of life are required in the future. Despite these limitations, exploratory path analyses give a clear direction for future research aimed at comprehensively characterising this population.

These findings reinforce several individual statements within a common conceptual and empirical framework that integrates functional, biological, and psychosocial aspects,[10] after adjusting for the main determinants demonstrated for functional dentition and oral health,[46] nutrition,[32] and MMSE.[33] Consequently, the effects of functional dentition on the intake of multiple nutrients and food groups are well known.[34] The preservation of a natural dentition[47] has an important influence on food selection and intake of essential nutrients,[48] generating a virtuous biopsychosocial circle. Furthermore, consumption of fruits and vegetables is linked to cognitive health of older people,[33] an aspect that is confirmed in the present study, and is in agreement with the findings obtained in a 6-year longitudinal study in Japan that showed an association between the number of teeth and onset of dementia, partially mediated by nutritional and social factors.[35]

On the other hand, oral health status is also associated with social isolation.[36] Consequently, older adults without a functional dentition may prefer not to attend social events.[10] In Chile, the social participation of the aged increases until the age of 80, when it begins to decrease. Although this study did not show an association between social participation frequency and MMSE score or quality of life, other national studies have shown that social participation and social networks are important factors in the well-being of aged individuals,[37] and revealed that differences in cognitive health due to disparities in social participation are determined by location.[38,39] Therefore, having a functional dentition could also have a role in cognitive health and well-being through higher social participation frequency. Recently, an association was demonstrated between oral health-related quality of life (assessed using the OHIP-14) and EQ-5D-3L HSs in a Paraguayan population.[41]

While functionality has a role in maintaining cognitive function and slowing cognitive decline, some studies have suggest that (high-performance) mastication could be a protective factor or attenuator of cognitive decline, even after adjusting for confounders.[49-53] The physiological mechanisms that could support this association have not yet been clearly determined in terms of their existence, magnitude and direction and given the natural history of cognitive decline the causal claims about this association must be done cautiously.[54] However, as mentioned above, even in the absence of a physiological mechanism to explain these findings, in view of the evidence,

oral health is an important aspect of health and well-being itself, and should not be neglected at any point in the life course, given all its implications in the biopsychosocial sphere. In this sense, as hypothesized by Thomson & Barak,[54] childhood cognitive function is linked to better oral health and access to dental care throughout life. Those with greater cognitive function likely to have fewer missing teeth, and consequently, greater cognitive reserve, and later onset of cognitive decline in old age. By contrast, their less privileged counterparts tend to have higher experience of caries and periodontitis, the main causes of tooth loss, possibly due to poor access to routine dental care.

Regarding gender inequalities, there were differences between the sexes in relation to educational level, occupation, and in and metabolic syndrome, favouring males. Interestingly, this phenomenon is not different from the global reality.[55] However, it should be noted that the male population included in the present study represents socially advantaged individuals. At the OECD level, men with a higher educational level live approximately 7 years longer than those with less education.[56] For the same reason, older men are more likely to have a better quality of life than women.[57] Therefore, public policies for the aged should focus on gender, especially for females and low-income males.

Unquestionably, longitudinal studies are required to provide a causal inference approach to scrutinise these hypotheses and the underlying mechanisms that support their interpretation. Nevertheless, in light of these findings, which highlight the importance of a functional dentition within the biopsychosocial sphere, it is necessary to move towards the inclusion of oral health in all policies. Currently, the National Oral Health Plan 2021-2030 proposes increasing the prevalence of adults and older people with functional dentition. However, the different oral health programs and health plans in Chile, such as the Explicit Health Guarantee "Comprehensive Oral Health for Adults 60 years of age" or the future Oral Health Program "Ríe mayor" stipulated in the National Comprehensive Health Plan for Older Persons and its Action Plan 2020-2030, do not set any clear and measurable goal, and neither do them mention the strategies the country is taking to achieve this objective. Oral health must not be neglected, and policies must consider the strengthening and enhancement of programs that contribute to maintaining a functional dentition throughout the life-course, with an interdisciplinary focus, given all the positive implications that oral health has for multiple outcomes in people as they age.

5 | CONCLUSION

The implications of having a functional dentition encompass a broad range of features, feasibly including social, functional and nutritional benefits, which collectively enhance the quality of life and well-being of people aged ≥80 years. It is necessary to promote preventive public policies throughout the entire life-course in Chile that contribute to achieving the benefits of a functional dentition in the "fourth age".

AUTHOR CONTRIBUTIONS

Gustavo Sáenz-Ravello: Conceptualization, Methodology, Formal Analysis, Data Curation, Writing—Original Draft, Writing—Review and Editing, Visualisation; Johanna Contreras: Conceptualization, Writing — Original Draft, Writing—Review and Editing; Mauricio Baeza: Conceptualization, Validation, Writing—Original Draft, Writing—Review and Editing; Ana Beatriz Silva: Resources, Writing—Original Draft, Writing—Review and Editing; Karen Danke: Writing—Original Draft, Writing—Review and Editing; Sebastián Gonzalez: Writing—Original Draft, Writing—Review and Editing; Gisela Jara: Resources, Writing—Original Draft, Writing—Review and Editing; Jorge Gamonal: Conceptualization, Writing—Original Draft, Writing—Review and Editing, Supervision, Project Administration, Funding acquisition.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

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