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Association between tooth loss-related speech and psychosocial impairment with cognitive function: A pilot study in Hong Kong's older population

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Abstract

Background: Tooth loss has been associated with cognitive decline, but the underlying mechanisms involving speech and psychosocial impairment remain unclear.

Objectives: To investigate the impact of tooth loss-related speech and psychosocial impairment on cognitive function in Hong Kong's older population.

Methods: Seventy-six Cantonese-speaking participants between the ages of 51–92 were classified into three groups: patients with complete dentures (CD), partially edentulous patients with less than 10 occluding tooth pairs (OU <10), and at least 10 occluding tooth pairs (OU ≥10). Cognitive function was assessed using the Montreal Cognitive Assessment Hong Kong Version, One-minute Verbal Fluency Task and Hayling Sentence Completion Test. Objective and subjective speech assessments were carried out using artificial intelligence speech recognition algorithm and a self-designed speech questionnaire. The impact of tooth loss on psychosocial condition was evaluated by the Reading the Mind in the Eyes Test and a self-designed questionnaire. Statistical analyses (one-way ANOVA, ANCOVA, Kruskal–Wallis test, Spearman correlation test) were performed.

Results: Tooth loss was significantly associated with lower cognitive function ($p = .008$), speech accuracy ($p = .018$) and verbal fluency ($p = .001$). Correlations were found between cognitive function and speech accuracy ($p < .0001$). No significant difference in tooth loss-related psychosocial impact was found between the three groups.

Conclusion: While warranting larger sample sizes, this pilot study highlights the need for further research on the role of speech in the association between tooth loss and cognitive function. The potential cognitive impact of tooth retention, together with its known biological and proprioceptive benefits, supports the preservation of the natural dentition.

Elaine Yee Lan Kwong and Hui Chen contributed equally to this study.

Co-first authors: Ka Yi Lee and Charlotte Cheuk Kwan Chan contributed equally to this study.

KEYWORDS
cognitive decline, elderly, Hong Kong, psychosocial impairment, speech, tooth loss

1 | INTRODUCTION

Given declining birth rates and increasing life expectancies globally,[1] it has become increasingly imperative to understand the impact of ageing on oral health. Tooth loss affects a substantial percentage of the older population worldwide,[2,3] with almost 1 in 4 individuals above the age of 60 currently suffering from complete edentulism.[4] Despite its wide-ranging prevalence, the consequences of tooth loss extend far beyond the oral cavity, following current research trends highlighting the interrelationship between oral and systemic health.[5] The presence of missing teeth in older adults is associated with poorer levels of physical and mental health[6,7] and reduced quality of life.[8]

Longitudinal studies on older populations have consistently demonstrated a strong association between tooth loss and cognitive decline.[7,9,10] Evidence has suggested that tooth loss increases the risk of cognitive impairment and dementia.[11,12] Several mechanisms have been suggested to underpin this link between tooth loss and cognitive decline. These include the role of nutritional deficiencies arising from difficulties in mastication,[13] decreased mechanoreceptor stimulation and sensory feedback, and elevated systemic inflammation due to oral pathogens,[14] all of which may contribute to cognitive impairment.

To date, the impact of tooth loss on speech and psychosocial wellbeing has not been explored in relation to cognitive function. As speech is a product of the intricate interaction between neural and oral apparatus, impairment in the latter may lead to the inability to articulate certain sounds and a decreased desire to speak.[15] Daily talking is associated with higher oxygenated haemoglobin levels and increased activity in the frontal lobe of the brain.[16] Disruptions in speech patterns and fluency may result in impaired cognitive ability, particularly in working memory,[17] due to reduced stimulation of the prefrontal cortex.

In addition, older adults with missing teeth have reported greater levels of loneliness,[18] lower self-esteem and life satisfaction,[8,19] and reduced participation in regular social activities.[6,20] Social isolation and loneliness are known risk factors for cognitive impairment[21] and Alzheimer's disease,[22] while social engagement, greater sexual satisfaction and positive relationships are protective against cognitive decline.[23–25] Although systematic reviews have explored the relationship between oral health and five of the six neurocognitive domains listed in the Diagnostic and Statistical Manual pertaining to cognitive disorders, the link between social cognition—the remaining neurocognitive domain—and tooth loss has yet to be assessed.[26] Moreover, it is noteworthy that the emotional effects of tooth loss appeared to be less marked in the older population of Hong Kong[27] and neighbouring Asian communities[20] compared to Western societies, despite causing significant restrictions in daily activities.

This pilot study aimed to address the gap in the existing literature by investigating the impact of tooth loss-related speech and psychosocial impairment on cognitive function.

2 | MATERIALS AND METHODS

2.1 | Study population

Participants were recruited from registered patients attending the Prince Philip Dental Hospital, Hong Kong SAR. Eligible participants were divided into three groups based on the number of remaining teeth: (1) the CD group, consisting of edentulous participants wearing complete dentures for over 6 months; (2) the OU <10 group, consisting of partially edentulous participants with less than 10 occluding pairs of teeth; and (3) the OU ≥10 group, consisting of partially edentulous participants with at least 10 occluding pairs of teeth. The rationale for the cut-off for occluding units to be 10 was based on the Shortened Dental Arch Concept as having fewer than 10 occluding units may cause functional impairment.[28]

The study included participants aged 50 years old or above who were medically fit without uncontrolled systemic disease and able to speak and read Chinese (Cantonese), while those with visual or hearing impairment or other significant functional impairments according to the Lawton Instrumental Activities of Daily Living Scale[29] were excluded. Additionally, participants who were heavy smokers (20 or more cigarettes a day), or diagnosed with dementia, neurological, psychiatric disease or obesity (BMI ≥ 30) were excluded. Patients with severe periodontitis, defined as generalized periodontitis stage III or above based on the AAP/EFP 2017 classification,[30] were also excluded, due to the potential confounding effect of periodontal inflammation on cognitive function.[14]

As the main focus of this study was tooth loss, it would have been ideal to have a group of completely edentulous patients without denture replacement. However, as such patients are extremely rare in modern society, complete denture wearers were recruited as a proxy for completely edentulous patients. Participants wearing removable partial dentures were excluded from the study, so that only natural teeth and fixed prostheses were included in the assessment of occluding pairs. This was because of potential discrepancies among participants in their time spent wearing RPDs, resulting in inconsistencies in their true number of occluding units.

After screening, participants who met the inclusion criteria were given an information sheet and written consent was obtained before they were included in the study. Sociodemographic information, including highest education level attained, working status, diet, smoking habit, alcohol habit, and the frequency of exercise, social cognitive activities ('playing mahjong, chess or bridge') and

intellectual activities ('reading a newspaper, magazine or book'), was collected from all participants.

2.2 | Clinical assessment

Full mouth examination and intra-oral periodontal charting were conducted by two trained operators (CCKC and KYL) in the Clinical Research Centre of the Prince Philip Dental Hospital, Hong Kong SAR, PR China. The location and number of missing teeth, the number of occluding units, six-point periodontal pocket depth and bleeding on probing were recorded for each participant. For participants in the CD group, an assessment of the quality of the complete dentures was conducted by one experienced dentist (CFH). The factors examined were (1) satisfactory stability, retention and support of the complete dentures determined by CFH, (2) the patient's subjective satisfaction of their complete denture with regard to denture function, including speech and mastication.

2.3 | Cognitive assessment

Four cognitive assessment batteries were used to correlate the association of tooth loss-related speech and psychosocial impairment with cognitive function. *Montreal Cognitive Assessment Hong Kong Version* (*HK-MoCA*) is a valid and widely used screening tool for cognitive impairment adapted to the HK population.[31] An additional mark was added to the total score for participants whose education level was less than or equal to primary school level. This scoring approach was validated within a dementia population.[32] *One-minute Verbal Fluency* (*OMVF*) *Task* (modified Chinese version) was designed to assess the ability of participants in association, and organization of their thinking and memory. Participants were given a single Chinese character and asked to give as many homophones of the character as possible in 1 min.[33] They were also asked to name as many animal names as possible in 1 min, and the number of correct answers was recorded. *Hayling Sentence Completion Test*[34] is a measure of response inhibition, sentence comprehension and creative cognition, requiring participants to complete a sentence read aloud first with a correct word and secondly with a nonsense word. Scores were calculated by measuring the response speed in both parts, and an additional score was given according to the degree of relevance of the response.

2.4 | Speech assessment

Objective speech assessment was carried out by asking the participants to read a passage in Cantonese, which was recorded and later analysed by an artificial intelligence (AI) speech recognition algorithm (Sonix, AI-speech recognition system). The use of such computer-based speech recognition systems to measure speech accuracy has been demonstrated in previous studies.[35–37] The *accuracy percentage* was defined by the percentage of the correctly transcribed words derived from the AI algorithm in contrast to the original transcription. In addition, specific words containing /k/ (e.g., 近 / kɒn6/), /t/ (e.g., 動 /toŋ6/), /h/ (e.g., 學 /hɔk6/), /j/ (e.g., 由 / jɒu4/), /tʃ/(e.g., 自/tʃi6/) and /s/ (e.g., 生 /ʃaŋ1/) syllables which focused on articulation in the alveolar, palatal and velar areas were selected by a speech therapist (SSYP) for manual detection of correct pronunciation of the specific syllables. Subjective impact of tooth loss on speech was examined by a self-designed questionnaire asking participants to what degree their missing teeth affected their pronunciation of different syllables.

2.5 | Psychosocial assessment

The traditional Chinese version of the '*Reading the Mind in the Eyes Test*' (*RMET*),[38] which has been validated[39] and used in previous population studies of older adults,[40] was chosen to assess social cognition. This test required the correct identification of a single emotion (out of a multiple choice of four options) and gender of the person displayed in a photograph of the eye region. In addition, a self-designed questionnaire containing 19 items was given to the participants to rate the impact of tooth loss on interference to daily activities, social relationships and intimacy, as well as individual acceptance of tooth loss.

2.6 | Statistical analysis

The Kolmogorov–Smirnov test was used to check the normality of the numerical data. One-way ANOVA test was adopted to compare the mean among the three groups followed by Bonferroni post hoc pairwise comparisons when the data followed normality distribution. Otherwise, Kruskal–Wallis H test followed by Dunn–Bonferroni post hoc pairwise comparisons was adopted to compare the mean rank among the three groups when the data were not parametric. For categorical data, that is, Hayling Sentence Completion Test result, Goodman and Kruskal's gamma correlation tests were utilized to show if there was a correlation between tooth number and test result. The chi-squared test with Cramér's V correlation was used to detect associations between sociodemographic factors and groups of participants based on the number of remaining teeth. Analysis of covariance (ANCOVA) test with stepwise backward analysis was adopted to investigate if the difference in HK-MoCA scores among three groups was still significant after taking sociodemographic factors, including age and sex, into account. Regression analysis was then adopted to find out the variance inflation factor (VIF) of the two significant variables to HK-MoCA score, education background and the degree of tooth loss. Correlation analysis was performed through the Spearman correlation test to assess the relationship between cognitive

performance, the speech function and social participation, respectively. SPSS 24.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for data analysis. The statistical significance was set at .05.

3 | RESULTS

3.1 | Participant recruitment

A total of 432 potential participants were screened for eligibility. Two participants had complete dentures that were deemed unsatisfactory by both the dentist and the participant, and were therefore excluded from the study. The first participant had not worn the denture for over 1 year due to looseness, while the second was excluded due to a 2 mm open bite extending between the two upper first premolars bilaterally, resulting in severe functional limitations during mastication and speech. After assessing the other inclusion criteria, 76 participants who met the requirements were included, of which 17 were in the CD group, 24 were in the OU <10 group and 35 were in the OU ≥10 group. Figure 1 illustrates a flowchart of the participant recruitment.

3.2 | Sociodemographic characteristics

The included participants' ages ranged from 51 to 92 years old. The mean age of the CD, OU <10 and OU ≥10 groups was 74.41 ± 9.81, 69. 58 ± 4.47 and 68.51 ± 6.03 years, respectively. One-way ANOVA test revealed a significant difference in age among the three groups (F (2, 73) = 12.107, p = .001). Bonferroni post hoc test found that the mean age was significantly different between CD and OU ≥10 (p < .001), OU <10 and OU ≥10 group (p = .03). No significant differences in the rest of the parameters were found among the three groups. The sociodemographic data of the three groups are listed in Table 1.

3.3 | Cognitive function

According to the HK-MoCA classification,[31] the cut-off score for cognitive impairment is 21/22 over the total score of 30. In the CD group, 10 participants (58.8%) had normal cognitive function and 7 of them (41.2%) may suffer from cognitive impairment. In the OU <10 group, 19 participants (79.2%) had normal cognition, while 5 of them (20.8%) may have cognitive impairment. In OU ≥10 group, most of the participants had normal cognition (n = 33, 94.3%), only 2 (5.7%) may have cognitive impairment. The result of the chi-square test revealed a significant association between cognition and tooth number (p = .008). The mean scores of HK-MoCA in CD group, OU <10 group and OU ≥10 group were 21.00 ± 4.66, 23.92 ± 4.33 and 25.60 ± 2.67, respectively. The Kruskal–Wallis H test revealed a significant difference in terms of HK-MoCA scores among the three groups (H(2) = 13.93, p < .000). In addition, post hoc test revealed that the CD group had a significantly lower median score than the OU ≥10 group (p = .001). Although there were significant differences in age between the three groups, two-way analysis of covariance (ANCOVA test) demonstrated that the association between degree of tooth loss and cognitive function (acting as outcome)

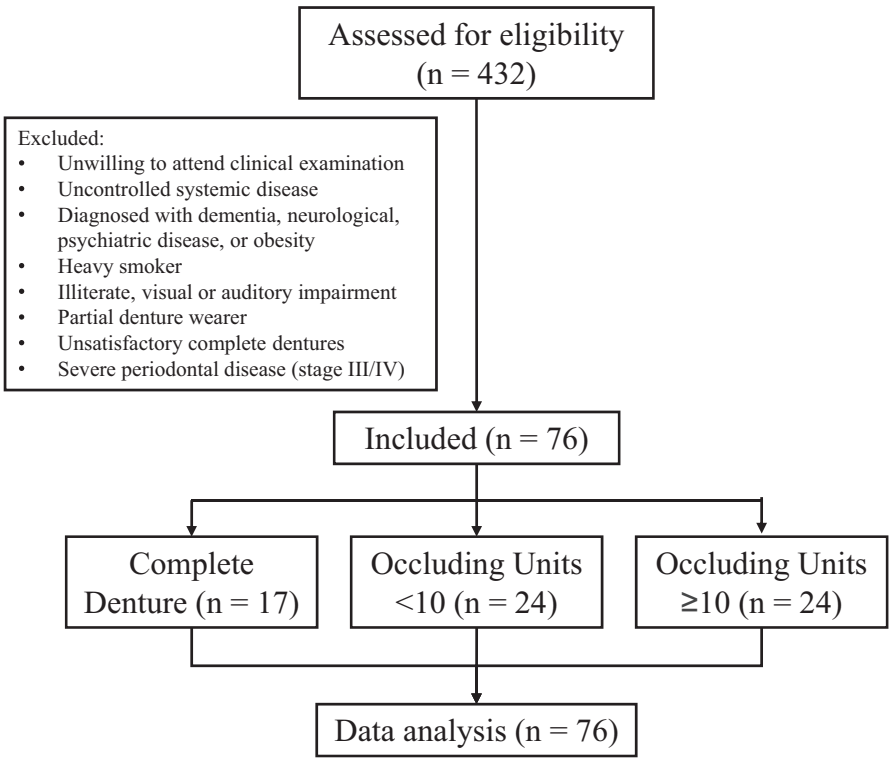

FIGURE 1 Flowchart for participant recruitment.

TABLE 1 Sociodemographic characteristics of the participants.

Characteristic	CD ($n=17$) Mean ± SD	OU <10 ($n=24$) Mean ± SD	OU ≥10 ($n=35$) Mean ± SD	Total ($n=76$) Mean ± SD	p[a]
Age	74.41 ± 9.81	69.58 ± 4.47	64.91 ± 6.03	68.51 ± 7.58	**<.000**
Weight (kg)	58.87 ± 8.27	59.86 ± 12.28	65.74 ± 12.04	62.35 ± 11.69	.061
Height (m)	1.59 ± 0.095	1.60 ± 0.098	1.62 ± 0.091	1.61 ± 0.093	.582
Body mass index (BMI)	23.29 ± 3.13	23.22 ± 3.11	24.96 ± 3.03	24.04 ± 3.15	.060
	n (%)	*n* (%)	*n* (%)	*n* (%)	χ^2	p[b]	Cramér's *V*
Gender							
Female	10 (58.8)	13 (54.2)	14 (40.0)	37 (48.7)	2.045	.360	0.164
Male	7 (41.2)	11 (45.8)	21 (60.0)	39 (51.3)			
Highest education level attained							
Primary School or below	5 (29.4)	6 (25.0)	4 (11.4)	15 (19.7)	8.045	.235	0.230
Junior secondary	5 (29.4)	9 (37.5)	9 (25.7)	23 (30.3)			
Upper secondary	5 (29.4)	9 (37.5)	20 (57.1)	34 (44.7)			
College or above	2 (11.8)	0 (0.0)	2 (5.7)	4 (5.3)			
Working status							
Currently employed	3 (17.6)	10 (41.7)	10 (28.6)	23 (30.3)	3.179	.528	0.145
Retired	13 (76.5)	13 (54.2)	22 (62.9)	48 (63.2)			
Unemployed	1 (5.9)	1 (4.2)	3 (8.6)	5 (6.6)			
Smoking habit							
Non-smoker	14 (82.4)	20 (83.3)	32 (91.4)	66 (86.8)	7.181	.127	0.217
Former	0 (0.0)	2 (8.3)	3 (8.6)	5 (6.6)			
Smoker (<20 cigarettes/day)	3 (17.6)	2 (8.3)	0 (0.0)	5 (6.6)			
Diet							
Non-vegetarian	16 (94.1)	23 (95.8)	34 (97.1)	73 (96.1)	.281	.869	0.061
Vegetarian	1 (5.9)	1 (4.2)	1 (2.9)	3 (3.9)			
Alcohol habit							
Non drinker	14 (82.4)	16 (66.7)	23 (65.7)	53 (69.7)	1.658	.437	0.148
Social drinker	3 (17.6)	8 (33.3)	12 (34.3)	23 (30.3)			
>30-min physical exercise							
Daily	12 (70.6)	16 (66.7)	16 (45.7)	44 (57.9)	15.885	.103	0.323
A few times a week	2 (11.8)	2 (8.3)	12 (34.3)	16 (21.1)			
A few times a month	0 (0.0)	2 (8.3)	3 (8.6)	5 (6.6)			
Monthly	0 (0.0)	0 (0.0)	2 (5.7)	2 (2.6)			
Once in a few months	2 (11.8)	1 (4.2)	0 (0.0)	3 (3.9)			
Never	1 (5.9)	3 (12.5)	2 (5.7)	6 (7.9)			
Social cognitive activities (*Playing Mahjong, chess or bridge*)							
Daily	0 (0.0)	1 (4.2)	3 (8.6)	4 (5.3)	8.403	.590	0.235
A few times a week	0 (0.0)	2 (8.3)	2 (5.7)	4 (5.3)			
A few times a month	0 (0.0)	2 (8.3)	1 (2.9)	3 (3.9)			
Monthly	1 (5.9)	2 (8.3)	2 (5.7)	5 (6.6)			
Once in a few months	0 (0.0)	2 (8.3)	1 (2.9)	3 (3.9)			
Never	16 (94.1)	15 (62.5)	26 (74.3)	57 (75.0)			

(Continues)

TABLE 1 (Continued)

	n (%)	n (%)	n (%)	n (%)	χ^2	p[b]	Cramér's V
Intellectual activities (*Reading newspaper, magazine or book*)							
Daily	11 (64.7)	13 (54.2)	25 (71.4)	49 (64.5)	14.060	.170	0.304
A few times a week	3 (17.6)	2 (8.3)	3 (8.6)	8 (10.5)			
A few times a month	2 (11.8)	0 (0.0)	2 (5.7)	4 (5.3)			
Monthly	1 (5.9)	2 (8.3)	0 (0.0)	3 (3.9)			
Once in a few months	0 (0.0)	2 (8.3)	3 (8.6)	5 (6.6)			
Never	0 (0.0)	5 (20.8)	2 (5.7)	7 (9.2)			

Note: Statistical significant differences ($p < .05$) are presented in bold.

Abbreviations: CD, patients wearing complete dentures; *n*, number; OU <10, patients with fewer than ten occluding units; OU ≥10, patients with more than ten occluding units; SD, standard deviation; χ^2, chi-squared test.

[a]One-way ANOVA test.

[b]Chi-square test.

TABLE 2 Stepwise backward regression analysis showing the predictors of HK-MoCA score.

Parameter	Estimate	Standard error	95% CI lower	95% CI upper	p-Value	VIF	Pairwise comparison
Intercept	28.018	1.794	24.440	31.596	<.000		
Highest education level attained					.002		
(1) Primary school or below	−5.923	1.962	−9.837	−2.010	.004	1.036	(1) < (2), (3), (4)
(2) Junior secondary	−2.125	1.896	−5.907	1.657	.266		
(3) Senior secondary school	−2.090	1.849	−5.778	1.597	.262		
(4) College or above	0[a]						
Degree of tooth loss					.001		
(1) 0 (i.e., CD group)	−4.036	1.047	−6.125	−1.947	.000	1.036	(1) < (2), (3)
(2) 1–10 (i.e., OU <10 group)	−1.040	0.935	−2.904	0.825	.270		
(3) ≥10 (i.e., OU ≥10 group)	0[a]						

[a]This parameter is set to zero because it is redundant.

Abbreviations: CD, patients wearing complete dentures; CI, confidence interval; OU <10, patients with fewer than ten occluding units; OU ≥10, patients with more than ten occluding units; VIF, variance inflation factor.

prevailed ($p = .037$) even after adjusting for age. A multiple ANCOVA model having cognitive function as outcome with backward selection of tooth loss and all sociodemographic factors (including age gender, education, dietary habits, exercise habits and engagement in social and intellectual activities) was also executed as shown in Table 2. In the final model, tooth loss was still a significant factor on HK-MOCA scores ($p = .001$) even after adjusting for education level. Bonferroni adjusted pairwise comparisons showed that participants with CD had significantly lowered HK-MoCA scores than those with natural teeth.

Goodman and Kruskal's gamma correlation test revealed a moderate positive correlation between the number of teeth and the Hayling Sentence Completion Test, but statistical significance was not achieved ($G = 0.230$, $p = .116$). One-way ANOVA revealed a significant difference in mean score of the One-minute Verbal Fluency Test among the three groups (F (2, 73) = 8.013, $p = .001$). Bonferroni post hoc analysis revealed a significant difference between group CD and group OU ≥10 ($p = .001$), with group CD showing a lower mean score (Table 3).

3.4 | Speech assessment

Significant differences in speech accuracy identified by the AI algorithm were found among the three groups (H(2) = 7.999, $p = .018$), with group CD having a significantly lower accuracy rate than group OU ≥10 ($p = .022$). In addition, significant differences in the accuracy of /k/ (H(2) = 7.289, $p = .026$) and /h/ (H(2) = 9.672, $p = .008$) sounds were found among the three groups, respectively. Post hoc test showed that there was a significant difference between the CD and OU ≥10 groups, with CD having a lower median accuracy in /k/ ($p = .035$) and /h/sound ($p = .006$). There was no significant difference detected among the three groups in terms of self-perceived speech difficulty after tooth loss ($p = .845$) (Table 3).

TABLE 3 The result of the cognitive, speech and psychosocial assessment in three groups.

	CD ($n=17$)	OU <10 ($n=24$)	OU ≥10 ($n=35$)		
	$M \pm SD$	$M \pm SD$	$M \pm SD$	*p*-Value	Pairwise comparisons
Cognitive assessment					
HK-MoCA	21.00 ± 4.66	23.92 ± 4.33	25.60 ± 2.67	**.001**[a]	**3 > 1 = 2**
OMVFT-T	20.59 ± 6.54	23.62 ± 5.48	27.49 ± 6.18	**.001**[b]	**3 > 1 = 2**
Animal. *N*	14.82 ± 4.38	16.33 ± 4.30	19.03 ± 5.26	**.009**[b]	**3 > 1 = 2**
Speech assessment					
/k/	21.18 ± 2.16	21.54 ± 2.72	22.54 ± 0.61	**.026**[a]	**3 > 1 = 2**
/t/	16.53 ± 1.46	16.88 ± 1.75	17.43 ± 0.78	.087[a]	1 = 2 = 3
/h/	11.59 ± 1.87	12.50 ± 1.10	12.77 ± 0.43	**.008**[a]	**3 > 1 = 2**
/j/	14.29 ± 2.54	14.46 ± 2.38	15.46 ± 1.01	.075[a]	1 = 2 = 3
/tʃ/	13.41 ± 4.05	13.58 ± 4.57	14.89 ± 2.71	.494[a]	1 = 2 = 3
/s/	11.47 ± 3.50	12.33 ± 3.19	13.49 ± 1.76	.191[a]	1 = 2 = 3
AI accuracy	67.00 ± 34.01	84.58 ± 21.63	90.28 ± 7.36	**.018**[a]	**3 > 1 = 2**
Speech difficulty after tooth loss	26.41 ± 16.71	24.29 ± 17.90	25.66 ± 19.81	.845[a]	1 = 2 = 3
Social participation					
RMET: emotion	18.50 ± 6.35	19.21 ± 3.53	21.23 ± 4.95	.122[b]	1 = 2 = 3
RMET: gender	29.81 ± 6.66	34.25 ± 1.39	34.11 ± 2.74	**.002**[a]	**3 > 1 = 2**
'tooth loss is an inevitable part of ageing'	3.35 ± 1.00	3.33 ± 0.96	3.20 ± 1.13	.859[a]	1 = 2 = 3
'individual acceptance of tooth loss'	2.98 ± 0.81	3.07 ± 0.78	2.92 ± 0.84	.846[a]	1 = 2 = 3
'interference to daily activities'	2.80 ± 1.20	2.60 ± 0.71	2.29 ± 0.94	.172[a]	1 = 2 = 3
'social relationship and intimacy'	2.66 ± 1.18	2.39 ± 0.82	2.21 ± 1.03	.416[a]	1 = 2 = 3

Note: Statistical significant differences ($p < .05$) are presented in bold.

Abbreviations: Animal. *N*, One-Minute Verbal Fluency Test Animal number score; CD, patients wearing complete dentures; HK-MoCA, Montreal Cognitive Assessment Hong Kong Version; M, mean in one-way ANOVA test or median in Kruskal–Wallis H test; *n*, number; OMVFT-T, One-Minute Verbal Fluency Test total score; OU <10, patients with fewer than ten occluding units; OU ≥10, patients with more than ten occluding units; SD, standard deviation.

[a]Kruskal–Wallis H test.

[b]One-way ANOVA test.

3.5 | Psychosocial function

In the gender recognition component of the RMET, significant differences were found among the three groups ($H(2) = 12.373$, $p = .02$), with the CD group having a significantly lower mean rank than the OU <10 ($p = .014$) and OU ≥10 ($p = .002$) groups. No significant differences were found between the three groups with regard to different components of the psychosocial questionnaire, which were categorized under individual acceptance of tooth loss, self-reported interference to daily activities and self-perceived impact on social relationships and intimacy.

3.6 | Correlation between tooth loss-related speech and psychosocial impairment and cognitive function

Spearman's correlation test revealed a positive monotonic correlation between the /ts/ sound and HK-MoCA ($r_s = 0.497$, $n = 76$, $p < .001$) and Hayling Sentence Completion test ($r_s = 0.375$, $n = 76$, $p < .001$), respectively. The /j/ sound ($r_s = 0.351$, $n = 76$, $p < .01$) and AI accuracy were found to be correlated with HK-MoCA scores ($r_s = .470$, $n = 76$, $p < .001$).

Regarding the relationship between social participation and cognitive function, Spearman's correlation revealed a positive monotonic correlation between the emotion component of the RMET with the results of HK-MoCA ($r_s = 0.471$, $n = 76$, $p < .001$), One-minute Verbal Fluency test ($r_s = 0.398$, $n = 76$, $p < .001$) and Animal Number in One Minute Verbal Fluency Test ($r_s = 0.379$, $n = 76$, $p < .01$). Similarly, in the gender component of the RMET, a positive monotonic correlation was found with the overall results of the One-minute Verbal Fluency Test ($r_s = 0.398$, $n = 76$, $p < .001$), HK-MoCA ($r_s = 0.315$, $n = 76$, $p < .01$) and the Animal Number in One-minute Verbal Fluency Test ($r_s = 0.336$, $n = 76$, $p < .01$) (Table 4).

4 | DISCUSSION

This pilot study suggests a potential correlation between cognitive impairment and tooth loss-related speech impairment in Hong

TABLE 4 Correlation between tooth loss-related speech and psychosocial impairment and cognitive function.

	Cognitive function			
	HK-MoCA	Animal. *N*	OMVFT-T	HSCT
Speech assessment				
/k/	**0.335****	0.159	0.223	0.143
/t/	**0.329****	0.160	0.174	0.140
/h/	**0.322****	0.036	0.113	0.234
/j/	**0.351****	**0.253***	**0.266***	**0.313***
/tʃ/	**0.497*****	0.216	**0.260***	**0.375*****
/s/	**0.415*****	0.153	0.158	**0.259***
AI clarity	**0.470*****	0.206	**0.301****	**0.238***
'speech difficulty after tooth loss'	−0.225	−0.044	−0.075	−0.166
Psychosocial assessment				
RMET: emotion	**0.471*****	**0.379****	**0.398*****	**0.261***
RMET: gender	**0.315****	**0.336****	**0.389*****	0.112
'tooth loss is an inevitable part of ageing'	−0.107	−0.103	−0.171	**−0.304***
'individual acceptance of tooth loss'	−0.122	−0.023	−0.034	−0.171
'interference to daily activities'	**−0.266***	−0.190	**−0.235***	−0.171
'social relationship and intimacy'	0.175	**0.275***	**0.228***	0.168

Note: Correlations significantly different from zero are presented in bold.

Abbreviations: AI, artificial intelligence speech recognition algorithm; Animal. *N*, One-Minute Verbal Fluency Test Animal number score; HK-MoCA, Montreal Cognitive Assessment Hong Kong Version; HSCT, Hayling Sentence Completion Test; OMVFT-T, One-Minute Verbal Fluency Test total score; RMET, Reading the Mind in the Eyes Test.

*$p < .05$; **$p < .01$; ***$p < .001$.

Kong's older adults. Greater occluding units correlated with better performance in the HK-MoCA, measuring cognitive function, and the Hayling Sentence Completion Test, which examines the executive and inhibition components in speech production and cognition.[33] With greater remaining teeth, participants demonstrated a higher degree of accuracy in the AI-speech recognition algorithm and pronunciation of the selected syllables. Speech accuracy and the production of /j/ and /ts/ were found to correlate with HK-MoCA scores, indicating that deterioration of speech following tooth loss may impact the language and speech aspect of cognition.

Recent evidence has emerged indicating that tooth loss is a risk factor for cognitive impairment.[11,12] The results of this study align with previous research, as the CD group demonstrated significantly lower HK-MoCA scores than those in the partially edentulous groups, while those with OU <10 also had significantly lower HK-MoCA scores than those with OU ≥10. Periodontal pathogens in the oral cavity introduce elevated inflammatory mediators into the systemic circulation,[14] which may contribute to chronic neuroinflammation and cognitive decline.[9] Additionally, decreased masticatory activity from reduced occluding units may lower blood flow to the somatosensory cortex region responsible for working memory.[17] Furthermore, tooth loss may contribute to a decrease in nutritional quality,[13] and deficiencies in specific nutrient groups have been linked to cognitive decline.[41]

The act of speech production is a highly intricate and exact process involving the coordinated movement of various oral structures, including the tongue, lips, jaw and masticatory muscles.[42,43] Throughout the various stages of speech production, several brain regions, including the primary motor cortex, the prefrontal cortex, the supplementary motor area and the cerebellum, are activated, which are essential in the execution of speech-related movements.[44,45] Thus, reduced occluding units may not only impair proprioception from the oral cavity, but also disrupt the coordination among various oral structures, further compounding the negative impact on cognitive function. Interestingly, the treatment of edentulism with complete dentures did not lead to improved speech accuracy and cognitive outcomes in our study. The CD group exhibited significantly lower scores in the verbal fluency tests and significantly less accurate speech compared to the partially edentulous groups, even while wearing complete dentures that were deemed to be of satisfactory quality in terms of retention, stability and support during clinical examination. This may be due to palatal denture coverage reducing the tongue-back movement during the production of /k/ and /h/ sounds, resulting in lower accuracy of these syllables.

The association between tooth loss-related speech deterioration and cognitive function may potentially be explained by the impact of regular speech production on prefrontal cortex activity[17] and cerebral blood oxygen levels.[16] It is reasonable to

hypothesize that improved speech accuracy and clarity could enhance self-confidence and promote engagement in conversations with others. Conversely, difficulties with speech may result in reduced social participation which has been linked to cognitive decline[21,22] and decreased life satisfaction.[46] However, no significant differences in self-reported speech difficulties were found among the three groups in this study, which contradicts findings from other evidence.[15] This discrepancy may be attributed to the Cantonese language's greater utilization of vowel allophones and fewer tongue tip consonants compared to English, suggesting that Cantonese speech involves less dental articulation than English.[47] Hence, it is plausible that individuals with fewer teeth may not perceive speech difficulties subjectively, despite exhibiting objective difficulties in accurately producing certain words. Also, individuals may adapt to speech impairment and develop compensatory strategies,[48] leading to a lack of awareness of their own speech difficulties.

In terms of the self-perceived impact of tooth loss, no significant differences were found between the three groups with regard to individual acceptance of tooth loss, and self-reported interference to daily activities, social relationships and intimacy. This finding aligns with a prior investigation of community-dwelling elderly in Hong Kong,[27] which determined that tooth loss had little impact on daily activities, such as attending social gatherings and eating in public. On the other hand, research conducted in Western populations[8] revealed that many older adults struggled to accept tooth loss, which had a detrimental impact on their confidence, social relationships and participation in social activities. As cultural norms and expectations influence psychological beliefs and individual lifestyles, such high degree of acceptance in the current study may reflect a deeply rooted societal misconception in Hong Kong that tooth loss is a natural part of ageing, which was held by 63% of non-institutionalized elderly according to the city's latest community oral health survey.[3] Moreover, the traditional values intertwined in collectivist Chinese society, such as filial piety, may mitigate the impact of tooth loss on social isolation.[49] Meanwhile, the current study was conducted during COVID-19 pandemic, a period marked by substantial restrictions on social activity and the implementation of stringent mask-wearing policies. In Hong Kong, individuals frequently wear masks even when experiencing a common cold. This cultural norm of mask-wearing may alleviate some of the embarrassment associated with tooth loss during social interactions. Nevertheless, it is crucial not to underestimate the psychosocial impact of tooth loss, given that greater social relationships may reduce the risk of cognitive decline over time.[21,23–25]

Despite a positive correlation between participants' HK-MoCA scores and their ability to accurately identify emotions in the RMET, no significant difference was found when considering the extent of tooth loss. While gender recognition was significantly poorer in edentulous patients, the insignificant differences in emotion recognition may be attributed to the limitation of RMET to measure social cognition, as it involves recognizing emotion from the faces of Caucasian individuals, whereas the study population solely comprised Chinese participants.

This research is subject to several limitations that must be taken into account. First, the small sample size of this pilot study limits the reliability and generalizability of the results. Although great effort was put into recruiting participants, the COVID-19 restrictions that were in place during the entirety of the study period limited the intake of elderly participants into the hospital patient pool, as well as participants' willingness to join clinical studies that required removal of their face masks. While the current study has included only completely edentulous patients and partially dentate patients without removable prostheses, future research may consider expanding the partially dentate patient group to include a control group with only natural teeth and a partially edentulous group with removable dentures, to assess whether the prosthetic replacement of teeth has an effect on cognitive function.

Second, the cross-sectional design inherently restricts its ability to establish causality between the variables under investigation. As such, it remains unclear whether cognitive impairment was a result of tooth loss, speech impairment and psychosocial dissatisfaction, or vice versa. Further research is required to ascertain the temporal relationship between tooth loss and cognitive impairment, specifically concerning speech and psychosocial changes. Despite accounting for known variables that could affect the HK-MoCA result, residual confounders remain a possibility due to cognition's multifactorial nature. Given the large age difference between the completely and partially edentulous groups, future research may consider the recruitment of age-matched controls. Nevertheless, age, gender, diet and exercise habits were not found to affect the association between tooth loss and cognitive function in this study, which is in line with a previous study of cognition in older adults in Hong Kong.[31] Although primary school education level predicted lower HK-MoCA scores (Table 2), there was no significant difference in education level between the three groups (Table 1).

An attempt to reduce the impact of periodontal inflammation on cognitive function was made by excluding participants with stage III or IV periodontitis. The included participants, who were recruited from the patient pool of a teaching hospital, had received periodontal therapy and regular supportive care, and were found to have generally well-maintained dentition upon clinical examination. However, the cause of tooth loss in edentulous patients was not queried and past periodontal disease may have played a role.

The study's findings may not be generalized to other language speakers, given the unique qualities of Cantonese speech. It is worth noting that while all participants were fluent in Cantonese, some individuals may not speak Cantonese as their first language. These individuals may have immigrated to Hong Kong some time ago and may have dialectal accents influencing the speech assessment results.

5 | CONCLUSION

This pilot study paves the way for further research to investigate the potential correlation between cognitive impairment and tooth

loss-related speech impairment in older adults in Hong Kong. The findings indicate that tooth loss may be associated with cognitive impairment, verbal fluency and speech accuracy, but should be interpreted cautiously as a larger sample size is warranted. The clinical significance of these findings highlights the importance of preserving the dentition, especially among the older population where tooth loss is common and may be accepted as a natural consequence of ageing. In the present study, complete denture wearers had worse cognitive performance than partially edentulous patients without prosthetic replacement. Together with the known advantages of preserving the natural dentition, including reduced alveolar bone resorption and maintaining the proprioceptive ability of the periodontium, this finding may provide further support to encourage patients to retain their teeth for their overall health and wellbeing. There was limited psychosocial impact of tooth loss in this population, which may reflect variations in cultural norms and expectations. While the data show that tooth loss can affect certain aspects of speech in the older population, further longitudinal studies are needed to elucidate their role in mediating the association between tooth loss and cognitive function.

AUTHOR CONTRIBUTIONS

KY Lee and CCK Chan have contributed to design of the study, acquisition, analysis and interpretation and drafted the manuscript. C Yip, JTW Li, CF Hau and SSY Poon have contributed to design of the study, acquisition and interpretation and critically revised the manuscript. HM Chen and KY Li have contributed to acquisition, analysis and interpretation and critically revised the manuscript. MF Burrow and GHY Wong have contributed to conception and critically revised the manuscript. EYL Kwong and H Chen have contributed to conception, acquisition and interpretation and critically revised the manuscript. All authors above have given final approval of this version and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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CONFLICT OF INTEREST STATEMENT

We confirm that there were no conflicts of interest pertaining to this study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICAL APPROVAL

Ethical approval was obtained from the Institutional Review Board of The University of Hong Kong/Hospital Authority Hong Kong West Cluster (UW 22–196) prior to the commencement of the study.

REFERENCES

1. Ageing: United Nations; Available from: https://www.un.org/en/global-issues/ageing.
2. Oral Health: World Health Organization; 2023 Available from: https://www.who.int/news-room/fact-sheets/detail/oral-health#:~:text=Edentulism%20(total%20tooth%20loss)&text=The%20estimated%20global%20average%20prevalence,aged%2020%20years%20or%20older.
3. Oral Health Survey. Hong Kong SAR: Department of Health. 2011 Available from: https://www.toothclub.gov.hk/en/en_pdf/Oral_Health_Survey_2011/Oral_Health_Survey_2011_WCAG_20141112_(EN_Full).pdf
4. Global oral health status report: towards universal health coverage for oral health by 2030: World Health Organization. 2022 Available from: https://www.who.int/publications/i/item/9789240061484
5. Tonetti MS, Jepsen S, Jin L, Otomo-Corgel J. Impact of the global burden of periodontal diseases on health, nutrition and wellbeing of mankind: a call for global action. *J Clin Periodontol*. 2017;44(5):456-462.
6. Muhammad T, Srivastava S. Tooth loss and associated self-rated health and psychological and subjective wellbeing among community-dwelling older adults: a cross-sectional study in India. *BMC Public Health*. 2022;22(1):7.
7. Galindo-Moreno P, Lopez-Chaichio L, Padial-Molina M, et al. The impact of tooth loss on cognitive function. *Clin Oral Investig*. 2022;26(4):3493-3500.
8. Rodrigues SM, Oliveira AC, Vargas AM, Moreira AN, E Ferreira EF. Implications of edentulism on quality of life among elderly. *Int J Environ Res Public Health*. 2012;9(1):100-109.
9. Li J, Xu H, Pan W, Wu B. Association between tooth loss and cognitive decline: a 13-year longitudinal study of Chinese older adults. *PLoS One*. 2017;12(2):e0171404.
10. Xu S, Huang X, Gong Y, Sun J. Association between tooth loss rate and risk of mild cognitive impairment in older adults: a population-based longitudinal study. *Aging (Albany NY)*. 2021;13(17):21599-21609.
11. Shen T, Lv J, Wang L, Wang W, Zhang D. Association between tooth loss and dementia among older people: a meta-analysis. *Int J Geriatr Psychiatry*. 2016;31(8):953-955.
12. Qi X, Zhu Z, Plassman BL, Wu B. Dose-response meta-analysis on tooth loss with the risk of cognitive impairment and dementia. *J Am Med Dir Assoc*. 2021;22(10):2039-2045.
13. Saito S, Ohi T, Murakami T, et al. Association between tooth loss and cognitive impairment in community-dwelling older Japanese adults: a 4-year prospective cohort study from the Ohasama study. *BMC Oral Health*. 2018;18(1):142.
14. Said-Sadier N, Sayegh B, Farah R, et al. Association between periodontal disease and cognitive impairment in adults. *Int J Environ Res Public Health*. 2023;20(6):4707.
15. Artjomenko V, Vidzis A, Broka K. The assessment of speech quality and Intellibility after replacement of lost teeth with removable dentures: review of literature. *Acta Chirurgica Latviensis*. 2012;12(1):72-77.
16. Fukaya Y, Kawaguchi M, Kitamura T. Does everyday conversation contribute to cognitive functioning? A comparison of brain activity during task-oriented and life-worldly communication using near-infrared spectroscopy. *Gerontol Geriatr Med*. 2020;6:2333721420980309.
17. Frith C, Dolan R. The role of the prefrontal cortex in higher cognitive functions. *Brain Res Cogn Brain Res*. 1996;5(1–2):175-181.
18. Qi X, Pei Y, Wang K, Han S, Wu B. Social isolation, loneliness and accelerated tooth loss among Chinese older adults: a longitudinal study. *Community Dent Oral Epidemiol*. 2023;51(2):201-210.
19. Rouxel P, Tsakos G, Chandola T, Watt RG. Oral health-a neglected aspect of subjective well-being in later life. *J Gerontol B Psychol Sci Soc Sci*. 2018;73(3):382-386.
20. Naik AV, Pai RC. Study of emotional effects of tooth loss in an aging north Indian community. *ISRN Dent*. 2011;2011:395498.

21. Gardener H, Levin B, DeRosa J, et al. Social connectivity is related to mild cognitive impairment and dementia. *J Alzheimers Dis*. 2021;84(4):1811-1820.
22. Ren Y, Savadlou A, Park S, Siska P, Epp JR, Sargin D. The impact of loneliness and social isolation on the development of cognitive decline and Alzheimer's disease. *Front Neuroendocrinol*. 2023;69:101061.
23. Kuiper JS, Zuidersma M, Zuidema SU, et al. Social relationships and cognitive decline: a systematic review and meta-analysis of longitudinal cohort studies. *Int J Epidemiol*. 2016;45(4):1169-1206.
24. Oh SS, Cho E, Kang B. Social engagement and cognitive function among middle-aged and older adults: gender-specific findings from the Korean longitudinal study of aging (2008–2018). *Sci Rep*. 2021;11(1):15876.
25. Smith AG, Bardach SH, Barber JM, et al. Associations of future cognitive decline with sexual satisfaction among married older adults. *Clin Gerontol*. 2021;44(3):345-353.
26. Nangle MR, Riches J, Grainger SA, Manchery N, Sachdev PS, Henry JD. Oral health and cognitive function in older adults: a systematic review. *Gerontology*. 2019;65(6):659-672.
27. McMillan AS, Wong MC. Emotional effects of tooth loss in community-dwelling elderly people in Hong Kong. *Int J Prosthodont*. 2004;17(2):172-176.
28. Käyser AF. Shortened dental arches and oral function. *J Oral Rehabil*. 1981;8(5):457-462.
29. Gillen G. Chapter 1 – overview of cognitive and perceptual rehabilitation. In: Gillen G, ed. *Cognitive and Perceptual Rehabilitation*. Mosby; 2009:1-31.
30. Papapanou PN, Sanz M, Buduneli N, et al. Periodontitis: consensus report of workgroup 2 of the 2017 world workshop on the classification of periodontal and peri-implant diseases and conditions. *J Periodontol*. 2018;89(Suppl 1):S173-S182.
31. Yeung PY, Wong LL, Chan CC, Leung JL, Yung CY. A validation study of the Hong Kong version of Montreal cognitive assessment (HK-MoCA) in Chinese older adults in Hong Kong. *Hong Kong Med J*. 2014;20(6):504-510.
32. Wong A, Law LS, Liu W, et al. Montreal cognitive assessment: one cutoff never fits all. *Stroke*. 2015;46(12):3547-3550.
33. Chan R, Chen E, Raymond D, Chan C. Development of a Chinese verbal fluency test for the Hong Kong psychiatric setting. *Hong Kong J Psychiatry*. 2004;14:8-11.
34. Burgess PW, Shallice T, Thames Valley Test C. *The Hayling and Brixton tests*. Thames Valley Test Company Bury St Edmunds; 1997.
35. Stelzle F, Ugrinovic B, Knipfer C, et al. Automatic, computer-based speech assessment on edentulous patients with and without complete dentures – preliminary results. *J Oral Rehabil*. 2010;37(3):209-216.
36. Knipfer C, Bocklet T, Noeth E, et al. Speech intelligibility enhancement through maxillary dental rehabilitation with telescopic prostheses and complete dentures: a prospective study using automatic, computer-based speech analysis. *Int J Prosthodont*. 2012;25(1):24-32.
37. Knipfer C, Riemann M, Bocklet T, et al. Speech intelligibility enhancement after maxillary denture treatment and its impact on quality of life. *Int J Prosthodont*. 2014;27(1):61-69.
38. Baron-Cohen S, Wheelwright S, Hill J, Raste Y, Plumb I. The "Reading the mind in the eyes" Test revised version: a study with Normal adults, and adults with Asperger syndrome or high-functioning autism. *J Child Psychol Psychiatry*. 2001;42(2):241-251.
39. Vellante M, Baron-Cohen S, Melis M, et al. The "Reading the mind in the eyes" test: systematic review of psychometric properties and a validation study in Italy. *Cogn Neuropsychiatry*. 2013;18(4):326-354.
40. Lee S, Jacobsen EP, Jia Y, Snitz BE, Chang CH, Ganguli M. Reading the mind in the eyes: a population-based study of social cognition in older adults. *Am J Geriatr Psychiatry*. 2021;29(7):634-642.
41. Kim JM, Stewart R, Prince M, et al. Dental health, nutritional status and recent-onset dementia in a Korean community population. *Int J Geriatr Psychiatry*. 2007;22(9):850-855.
42. Gracco VL, Löfqvist A. Speech motor coordination and control: evidence from lip, jaw, and laryngeal movements. *J Neurosci*. 1994;14(11 Pt 1):6585-6597.
43. Murray GM, Carignan C, Whittle T, Gal JA, Best C. Pterygoid muscle activity in speech: a preliminary investigation. *J Oral Rehabil*. 2022;49(12):1135-1143.
44. Ranasinghe KG, Kothare H, Kort N, et al. Neural correlates of abnormal auditory feedback processing during speech production in Alzheimer's disease. *Sci Rep*. 2019;9(1):5686.
45. Paquier P, Mariën P. A synthesis of the role of the cerebellum in cognition. *Aphasiology*. 2005;19:3-19.
46. Chen Y, Yang C, Feng S. The effect of social communication on life satisfaction among the rural elderly: a moderated mediation model. *Int J Environ Res Public Health*. 2019;16(20):3791.
47. Chan AYW, Li DCS. English and cantonese phonology in contrast: explaining cantonese ESL learners' english pronunciation problems. *Lang Cult Curric*. 2000;13(1):67-85.
48. Buckner RL, Corbetta M, Schatz J, Raichle ME, Petersen SE. Preserved speech abilities and compensation following prefrontal damage. *Proc Natl Acad Sci USA*. 1996;93(3):1249-1253.
49. Takahashi S, Naganuma T, Kurita N, et al. Social isolation/loneliness and tooth loss in community-dwelling older adults: the Sukagawa study. Innovation. *Aging*. 2023;7(6):igad065.

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