TOOTH LOSS, DENTAL PROSTHESES USE AND COGNITIVE PERFORMANCE IN OLDER BRAZILIAN ADULTS: THE SABE COHORT STUDY

Oral health and cognition

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ABSTRACT

Aim: To investigate the within- and between-person longitudinal effects of tooth loss and the use of dentures, clinically assessed by dentists, on cognitive decline in a representative sample of community-dwelling older Brazilian adults. **Methods:** Data came from 1,265, 1,112 and 1,021 individuals aged 60 years or older who participated in the second (2006), third (2010) and fourth (2015) waves, respectively, of the Health, Well-being and Aging study (SABE). Cognitive performance was evaluated with the abbreviated version of the Mini-Mental State Examination (MMSE). The number of natural teeth was classified according to 3 categories: none, 1-19 and 20 or more teeth. The presence of removable full or partial dentures in each dental arch (yes/no) was recorded. Hybrid regression models, adjusted for sociodemographic, behavior and health-related covariates, were used to estimate the between- and within-person effects of the longitudinal association between cognitive performance and oral health. **Results**: Participants with 1-19 and no teeth had, respectively, 1.15 (95% CI: 0.65, 1.66) and 1.54 (95% CI: 0.99, 2.09) units lower MMSE score than those with 20+ teeth. Denture wearers had 1.54 (95% CI: 1.13, 1.95) units greater MMSE score than non-denture wearers and those who started wearing dentures during the follow-up had 0.83 (95%CI: 0.21, 1.45) units greater MMSE score after the transition. **Conclusion**: Our main findings showed that the use of dental prostheses might be a protective factor for cognitive decline.

Keywords: tooth loss, dentures, cognitive impairment, cohort studies

Key points

Oral health is related to cognitive performance

Between-person differences in the number of teeth and use of dental prostheses are associated with cognitive performance

Within-person differences in the use of dental prostheses are associated with cognitive performance

The use of dental prostheses might be a protective factor for cognitive decline

INTRODUCTION

The global increase in the incidence of cognitive impairment and dementia, as a result of population aging, is a major public health concern (1,2). Nearly 9.9 million people develop dementia each year and about 63% of those with this condition are in low- and middle-income countries (2). The associated significant financial and human costs to countries, societies, families, and individuals pave the way to the need for further research aimed at identifying potential modifying risk factors to prevent or minimize cognitive decline and dementia (1).

A growing body of evidence suggests a relationship between cognitive impairment and dementia with tooth loss, as the latter is associated with various general health outcomes such as diabetes (3) and nutrition (4) that are known risk factors affecting cognitive decline (5). However, previous systematic reviews found that this relationship is inconclusive (6–8), highlighting the low-grade level of evidence and the need for further well-designed longitudinal studies. Furthermore, although prosthodontic treatment might increase oral functioning, most of the studies did not evaluate the role of the use of dental prostheses or chewing ability on cognitive decline, rendering the association rather inconclusive.

A previous study found that prosthetic rehabilitation and chewing ability, rather than the number of teeth, were better predictors of mortality and, therefore, could mitigate the effect of tooth loss (9). Regarding cognitive impairment, cross-sectional studies evaluated the association between this condition and chewing ability (10) and the number of teeth with or without the use of dental prostheses (11). Limited findings are available from prospective cohort studies. After adjustment for covariates, two studies suggested no association between cognitive impairment with the use of dental prostheses and number of teeth (12,13) while others reported a significant association (14–16) with a lower risk of dementia among individuals wearing dentures.

The importance of understanding the effect of dental rehabilitation on cognitive impairment should not be underestimated as severe tooth loss is highly prevalent among older adults, especially in low and middle-income countries (17). Therefore, this study aimed to evaluate the within- and between-person longitudinal association among the number of natural teeth, use of dental prostheses, and cognitive performance in a representative sample of community-dwelling older Brazilian adults.

METHODS

Data source

This was a prospective study with a representative sample of individuals aged 60 years or older who participated in the Health, Well-being and Aging study (SABE). SABE started in 2000 as a multicenter study conducted in seven main urban centers in Latin America. In Brazil, the study was carried out in the city of São Paulo and, in 2006, became a cohort study performed in 5-year intervals. At each new wave, a new sample of 60-64-years-old individuals was included to keep the representativeness of this age group. The original and new samples were recruited using two-stage stratified random sampling i.e. census track and household.

In 2006, 1,115 individuals who participated in the baseline (2000) were reinterviewed and 298 new participants aged 60–64 were added. In 2010, during the third wave, 978 older adults were located and interviewed again, and 356 older adults (aged 60 to 64 years) became part of the investigation. In 2015, 838 older adults were located and interviewed and 386 new respondents age 60–64 became part of the investigation. A detailed description of the study design and sampling can be found elsewhere (18).

Since clinical oral health measures were not available at baseline, in this study we used data from the second (2006), third (2010) and fourth (2015) waves. Of the 1,413, 1,333 and 1,224 participants in each wave, 1,265, 1,112 and 1,021 respectively were included in this study as they had information on all relevant variables. Overall, 384 participants had three waves of data, 649 had two waves of data and 947 had one wave of data (either 2006, 2010 or 2015).

SABE study was approved by the Ethics in Research Committee of the School of Public Health of the University of São Paulo. Written informed consent from the volunteer participants was obtained at the time of each interview.

Measures

Cognitive performance was the dependent variable, evaluated with the abbreviated version of the Mini-Mental State Examination (MMSE), which has been used for cognitive screening in the study since the first wave. This version has 13 items, with a maximum score of 19 points where lower scores indicate poorer cognitive capacity (19). In this study, the total score was used to evaluate the cognitive decline from 2006 to 2015 (three repeated assessments).

The number of natural teeth and the use of dental prostheses were the independent variables of interest. Both measures were obtained through clinical oral examinations, performed by trained dentists using standardized criteria. Only the number of natural teeth was included in the tooth count and was classified according to 3 categories: none, 1-19 and 20 or more teeth (reference group, representing having a functional dentition). A functional dentition was defined according to the World Health Organization (20) as the presence of 20 or more natural teeth, reflecting the minimum threshold for adequate oral functionality. The presence of complete dentures or partial removable dentures in any dental arch was also recorded (yes, no). The presence of these prostheses was evaluated during the clinical examination. Both variables were measured in every wave (2006, 2010 and 2015).

Several variables were included in the analysis as confounders of the association between the number of teeth and cognitive ability. Sociodemographic factors were sex, age, whether living alone and education level (0-3 years [low], 4-7 years [median], 8+ years [high]). Behavioral factors were smoking status (never, former and current), physical activity (no, yes [at least 150 minutes of moderate or vigorous activities per week or 75 minutes of vigorous activity per week]) and alcohol intake (no, yes, no risk; yes, with risk).(21) Information on whether participants had ever been diagnosed by a medical doctor with hypertension, diabetes, cardiovascular disease and stroke was also included in the analysis. Finally, body mass index (BMI) was determined based on body measurements carried out by trained dietitians (<25, 25-29, 30+).

Statistical analysis

All analyses were conducted in Stata 16 (StataCorp LP, College Station, TX). We first compared the exposure groups, namely number of teeth and use of dentures, according to sociodemographic, behavioral and health-related covariates at every wave, using the Chi-squared test. Thereafter, MMSE scores at every wave were compared by exposure groups and covariates. Student's t-test was used when comparing 2 groups and Royston's test for linear trends was used when comparing ordered groups (age, education, smoking, alcohol intake and BMI).

The associations of the number of teeth and denture use with BMI and MMSE scores were modeled in hybrid (linear) models fitted to the 10-year panel data and adjusting for time-invariant (sex and education) and time-varying covariates (age, living alone, smoking status, physical activity, alcohol intake, high blood pressure, diabetes, cardiovascular disease, stroke). The use of time-varying oral health measures and other covariates allowed a better understanding of the impact of their transitions on the outcome over time. BMI was an additional time-varying confounder when modeling MMSE scores. Hybrid models allow partitioning time-variant predictors into between- and within-person effects, thus combining the advantages of fixed-effects and random-effects models (22). This is accomplished by including two indicators for each time-varying covariate: one is the mean MMSE score across all waves for each individual, which captures between-person effects, and the other is the deviation from that mean MMSE score, which captures within-person effects (22). The hybrid model was estimated using the *xthybrid* command in Stata. A random intercept for the outcome (BMI or MMSE score) was included to account for the dependency of the repeated measurements within participants. Participants' age was modeled as a random effect to allow for individual differences in the rate of change in BMI and MMSE scores over time.

RESULTS

We analyzed 3,396 data points in 1,980 adults (1,265, 1,112 and 1,021 in waves 2, 3 and 4, respectively), with a mean of 1.7 data points per participant (range: 1 to 3). The characteristics of participants in each wave are shown in Table 1. In all, 52.0%, 42.8% and 35.6% of participants were edentulous whereas 78.9%, 73.7% and 72.4% wore removable dentures in waves 2, 3 and 4, respectively. In every wave, monotonic trends in MMSE scores were observed according to the number of teeth and BMI groups (Table 2). Participants with more teeth and greater BMI had higher MMSE scores. No differences in the MMSE score were found between denture and non-denture wearers in any of the three waves.

The mean BMI score was 26.4 (SD: 5.0, range: 15.2-51.1), 28.1 (SD: 5.3, range: 15.1-53.6) and 28.5 (SD: 5.4, range: 14.3-55.3) in waves 2, 3 and 4, respectively. Participants with no teeth had lower BMI (-0.03; 95%CI: -0.88, 0.81) and participants with 1-19 teeth had greater BMI (0.62; 95% CI: -0.15, 1.38) than those with 20+ teeth, but this association was not statistically significant (Table 3). In addition, although not statistically significant, participants who transitioned from having 20+ teeth to 1-19 teeth and no teeth had, respectively, 0.25 (95% CI: -0.43, 0.93) and 0.27 (95% CI: -0.65, 1.18) kg/m^2 greater BMI than those who always had 20+ teeth. As for denture use, denture wearers had lower BMI (-0.48; 95% CI: -1.12, 0.16) than non-denture wearers and there was a decrease in BMI (-0.22; 95% CI: -0.70, 0.25) among participants who transitioned from not wearing dentures to wearing dentures.

The mean MMSE score was 15.5 (SD: 3.9, range: 0 to 19), 15.9 (SD: 3.5, range: 0 to 19) and 15.9 (SD: 3.2, range: 0 to 19) in waves 2, 3 and 4, respectively. Participants with 1-19 and no teeth had, respectively, 1.15 (95% CI: 0.65, 1.66) and 1.54 (95% CI: 0.99, 2.09) units lower MMSE score than those with 20+ teeth whereas participants transitioning from 20+ teeth to 1-19 teeth and no teeth had, respectively, 0.28 (95%CI: -0.62, 1.18) units greater and 0.27 (95%CI: 0.65, -1.18) units lower MMSE score than those who remained in the group with 20+ teeth (Table 4). Denture wearers had 1.54 (95% CI: 1.13, 1.95) units greater MMSE score than non-denture wearers and those who started wearing dentures during the follow-up had 0.83 (95%CI: 0.21, 1.45) units greater MMSE score after the transition. The between-person effects for number of teeth and denture use were attenuated but remained significant after further adjustment for BMI groups. However, the within-person effect of denture use was fully attenuated after that adjustment. The MMSE score increased by 0.43 (95% CI: -0.18, 1.05) units among those who transitioned from not wearing dentures to wearing dentures.

DISCUSSION

Our analyses using data from a representative sample of community-dwelling older Brazilian adults showed a longitudinal association between cognitive performance and clinically assessed oral health i.e. number of natural teeth and use of dental prostheses. The between-person differences in the number of natural teeth and use of dentures were associated with MMSE scores over time. The within-person longitudinal effects of the use of dentures on cognition, rather than the number of natural teeth, after adjusting for sociodemographic, behavior and health-related covariates, was the main finding. The attenuation of the associations after adjusting for body mass index is worth noting.

Our between-person analyses corroborate previous studies which suggested better cognition among individuals with a higher number of teeth and those using dental prostheses (7,14–16). However, differences in cognitive impairment assessment and oral health status make direct comparisons between studies difficult. Besides, contradicting findings between oral health and cognition could be attributed to the fact that most previous studies did not adjust their analyses for either dental rehabilitation or masticatory function (11).

The studies that addressed these oral health conditions evaluated the onset of dementia and used a combination of baseline self-reported number of teeth and use of dentures as the oral health measures (13–16). Yang et al. 2021 (14), reported a significant interaction of tooth loss and denture use with the onset of dementia. Compared to individuals with 20 or more teeth, a lack of association was found among denture users with 1-9 teeth and a protective effect was observed among denture users with 10-19 teeth (HR 0.83, 95% CI: 0.70, 0.99) (14). Similar findings were reported in a 4-year follow-up study with older Japanese adults (16). No significant difference in the risk of dementia was found between participants with few teeth and using dentures and participants having 20 teeth or more. People with few teeth and no dentures had higher risk for dementia (16). In cross-sectional analyses, chewing ability (10) and non-rehabilitated lost teeth (11) rather than tooth loss was associated with cognitive impairment.

Our within-person analysis adds to the literature by suggesting that those who started wearing dentures during the follow-up had higher cognitive performance over time. The findings support the need to consider oral health functioning (*e.g.,* masticatory function, chewing ability, dental rehabilitation), besides the simple teeth count, when investigating the effect of oral health on cognitive impairment. The attenuation of the within-person differences in cognitive decline between individuals with and without dentures after adjusting for BMI could be supported by the above-mentioned nutritional pathway. Tooth loss has been associated with nutrient intake and nutritional status (4) and, although, use of dental prostheses may not fully compensate for the masticatory function it can mitigate its impact on nutrition by favoring food selection and nutrient intake (23).

Besides difficulties in eating, tooth loss without replacement can affect social aspects of daily living such as embarrassment upon smiling, laughing, or showing their teeth and speech problems (24). Therefore, another potential explanation for the observed findings might rely on a moderation role of dental rehabilitation on the previously reported impact of tooth loss on depression (25) and social isolation (26) which have been associated with cognitive decline (27). Finally, it has been suggested that masticatory performance might be associated with brain activity and cerebral blood flow (28). It is worth mentioning, that although periodontal disease has been previously associated with dementia (29), we did not find an association in further analyses (data not shown). However, the low prevalence of periodontal disease in the sample because of the high prevalence of tooth loss limited our analyses. This aspect should be further investigated in future studies.

This study has strengths and limitations that should be acknowledged. To the best of our knowledge, this is the first longitudinal study to analyze both between- and within-person effects of tooth loss and the use of dentures, clinically assessed by dentists, on cognitive decline after adjusting for a wide range of covariates. As potential limitations, we would like to cite the short period of follow-up for individuals entering the cohort in the third wave, the lack of exclusion of individuals with dementia at baseline, and the possible loss to follow-up of individuals with dementia as these might have contributed to a smaller variability in the cognition score. Second, although MMES is one of the most widely used instruments for screening cognitive impairment, it has a ceiling effect that should be taken into account when interpreting the results (30). Third, reverse causality concerning tooth loss and cognitive impairment should not be ruled out. However, this is an unlikely possibility as in this Brazilian older population severe tooth loss is likely to have happened at a younger age (31). Fourth, despite the association between tooth loss and cognition might be generalized to other populations, the lack of evaluation of actual oral functioning status, such as chewing, speaking, the esthetics of the participants with/without the denture, might limit the generalizability of our findings. Finally, as most of the participants did not present changes in their tooth loss category, the fixed effects analyses may underestimate the effect of the number of teeth on cognitive decline (32).

In summary, this study showed that the use of dental prostheses might be a protective factor for cognitive decline. This finding has important public health implications. First, it highlights the importance of preventing tooth loss throughout the life course. Second, this finding reinforces the need for a more comprehensive universal health care coverage, especially in low- and middle-income countries, where the largest proportion of the world's older adult population lives and severe tooth loss is highly prevalent. This could potentially be a way to reduce inequalities in dental rehabilitation access and avoid or minimize the negative effects of tooth loss on general health.

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Table 1. Characteristics of participants in every wave

	Wave 2 (2006)		Wave 3 (2010)		Wave 4 (2015)	
	n	**%**	**n**	**%**	**n**	**%**
Sex						
Men	477	37.7	398	35.8	357	35.0
Women	788	62.3	714	64.2	664	65.0
Age						
60-69 years	493	39.0	525	47.2	599	58.7
70-79 years	405	32.0	314	28.2	258	25.3
80+ years	367	29.0	273	24.6	164	16.1
Living alone						
No	1054	83.3	938	84.4	838	82.1
Yes	209	16.5	174	15.6	183	17.9
Education						
Low	622	49.2	454	40.8	320	31.3
Middle	440	34.8	413	37.1	375	36.7
High	203	16.0	245	22.0	326	31.9
Smoking						
Never	696	55.0	579	52.1	507	49.7
Former	436	34.5	411	37.0	383	37.5
Current	133	10.5	122	11.0	131	12.8
Physical activity						
No	562	44.4	678	61.0	612	59.9
Yes	703	55.6	434	39.0	409	40.1
Alcohol intake						
No	934	73.8	794	71.4	713	69.8
Yes, no risk	270	21.3	285	25.6	289	28.3
Yes, with risk	61	4.8	33	3.0	19	1.9
High blood pressure						
No	454	35.9	330	29.7	303	29.7
Yes	811	64.1	782	70.3	718	70.3
Diabetes						
No	1012	80.0	809	72.8	717	70.2
Yes	253	20.0	303	27.2	304	29.8
Cardiovascular disease						
No	954	75.4	817	73.5	752	73.7
Yes	311	24.6	295	26.5	269	26.3
Stroke						
No	1163	91.9	1020	91.7	947	92.8
Yes	102	8.1	92	8.3	74	7.2
BMI (kg/m^2)						
<25	536	42.4	318	28.6	267	26.2
25-29.9	465	36.8	442	39.7	405	39.7
30+	264	20.9	352	31.7	349	34.2
Number of teeth						
20+	161	12.7	197	17.7	213	20.9
1-19	446	35.3	439	39.5	445	43.6
None	658	52.0	476	42.8	363	35.6
Denture use						
No	267	21.1	293	26.4	282	27.6
Yes	998	78.9	819	73.7	739	72.4

Table 2. Cross-sectional variations in the Mini-Mental State Examination (MMSE) scores by covariates

	Wave 2 (2006)			Wave 3 (2010)			Wave 4 (2015)		
	n	**Mean**	**(SD)**	**n**	**Mean**	**(SD)**	**n**	**Mean**	**(SD)**
BMI (kg/m^2)									
<25	536	14.9	(4.6)	318	15.2	(4.4)	267	15.6	(3.7)
25-29.9	465	15.8	(3.3)	442	16.1	(3.2)	405	15.7	(3.1)
30+	264	16.2	(3.3)	352	16.4	(2.9)	349	16.3	(2.9)
P value for trend[†]		*<0.001*			*<0.001*			*0.003*	
Number of teeth									
20+	161	17.3	(2.2)	197	17.1	(2.3)	213	16.6	(2.9)
1-19	446	16.1	(3.3)	439	16.3	(3.4)	445	16.1	(2.9)
None	658	14.7	(4.4)	476	15.2	(3.9)	363	15.2	(3.6)
P value for trend[†]		*<0.001*			*<0.001*			*<0.001*	
Denture use									
No	267	15.3	(4.7)	293	16.0	(3.9)	282	16.1	(3.3)
Yes	998	15.6	(3.7)	819	15.9	(3.4)	739	15.8	(3.1)
P value[a]		*0.350*			*0.732*			*0.141*	

[†]Student's t-test was used to compare two groups and Royston test was used to test for linear trends with ordered categories

Table 3. Hybrid regression model for the associations of number of teeth and denture use with BMI score (n=3,396 repeated assessments in 1,980 adults)

	Coef.†	**[95% CI]**	**p value**
Between-person fixed effects			
Number of teeth			
1-19	0.62	[-0.15, 1.38]	0.113
None	-0.03	[-0.88, 0.81]	0.939
Denture use (reference: No)			
Yes	-0.48	[-1.12, 0.16]	0.139
Constant	37.59	[35.43, 39.75]	<0.001
Within-person fixed effects			
Number of teeth			
1-19	0.25	[-0.43, 0.93]	0.472
None	0.27	[-0.65, 1.18]	0.570
Denture use (reference: No)			
Yes	-0.22	[-0.70, 0.25]	0.354
Random effects			
Variance (age slope)	0.03	[0.02, 0.05]	
Variance (age intercept)	20.65	[19.29, 22.11]	
Variance (BMI)	2.49	[2.23, 2.77]	

†Model adjusted for age, sex, education, living alone, smoking, physical activity, alcohol intake, hypertension, diabetes, cardiovascular disease, stroke.

Table 4. Hybrid regression model for the associations of number of teeth and denture use with MMSE scores (n=3,396 repeated assessments in 1,980 adults)

	Confounder-adjusted			Confounder + BMI adjusted		
	Coef.†	**[95% CI]**	**p value**	**Coef.**[a]	**[95% CI]**	**p value**
Between-person fixed effects						
Number of teeth						
1-19	-1.15	[-1.66, -0.65]	<0.001	-0.82	[-1.28, -0.36]	<0.001
None	-1.54	[-2.09, -0.99]	<0.001	-1.18	[-1.69, -0.68]	<0.001
Denture use (reference: No)						
Yes	1.54	[1.13, 1.95]	<0.001	1.11	[0.72, 1.49]	<0.001
BMI in kg/m²				0.06	[0.03, 0.09]	<0.001
Intercept	23.06	[21.66, 4.45]	<0.001	19.36	[17.73, 20.99]	<0.001
Within-person fixed effects						
Number of teeth						
1-19	0.28	[-0.62, 1.18]	0.544	0.19	[-0.69, 1.06]	0.673
None	-0.27	[-1.48, 0.94]	0.661	-0.27	[-1.45, 0.91]	0.654
Denture use (reference: No)						
Yes	0.83	[0.21, 1.45]	0.008	0.43	[-0.18, 1.05]	0.166
BMI in kg/m²				0.13	[0.06, 0.20]	<0.001
Random effects						
Variance (age slope)	0.04	[0.03, 0.08]		0.02	[0.01, 0.06]	
Variance (age intercept)	6.61	[5.88, 7.43]		4.82	[4.19, 5.53]	
Variance (cognition)	5.08	[4.53, 5.70]		4.74	[4.21, 5.34]	

†Model adjusted for age, sex, education, living alone, smoking, physical activity, alcohol intake, hypertension, diabetes, cardiovascular disease, stroke.