

# 치매 환자의 구강 건강에 영향을 미치는 전신 건강 요인: 종합적 분석

감세훈<sup>1,2</sup>, 박재억<sup>1,3</sup><sup>1</sup>가톨릭대학교 의과대학 치과학교실, <sup>2</sup>가톨릭대학교 은평성모병원 치과, <sup>3</sup>가톨릭대학교 서울성모병원 치과병원 구강악안면외과

## Systemic health factors affecting the dental status of Korean patients with dementia: a comprehensive analysis

Se Hoon Kahm<sup>1,2</sup>, Je-Uk Park<sup>1,3</sup><sup>1</sup>Department of Dentistry, College of Medicine, The Catholic University of Korea,<sup>2</sup>Department of Dentistry, Eunpyeong St. Mary's Dental Hospital, College of Medicine, The Catholic University of Korea,<sup>3</sup>Department of Oral and Maxillofacial Surgery, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea

Received: March 13 2024

Revised: April 1, 2024

Accepted: April 1, 2024

**Corresponding Author:** Je-Uk Park  
Department of Oral and Maxillofacial  
Surgery, Seoul St. Mary's Hospital,  
College of Medicine, The Catholic  
University of Korea, 222 Banpo-daero,  
Seocho-gu, Seoul 06591, Korea  
Tel: +82-2-2030-2898  
Fax: +82-2-2030-2897  
E-mail: jupark@catholic.ac.kr  
https://orcid.org/0000-0002-9704-5402

**Objectives:** Alzheimer's disease, a pervasive neurodegenerative disorder with global implications, links oral health conditions, such as edentulism and periodontitis, to cognitive impairment. This study aimed to objectively assess the oral health of 1,456 patients with dementia using panoramic imaging and explore potential associations between general health and anthropometric measurements.

**Methods:** Patients' panoramic images documented at Seoul St. Mary's Hospital and Eunpyeong St. Mary's Hospital during 2011–2020 were retrospectively scrutinized for oral health parameters. Data on general health, anthropometrics, and body mass index (BMI) were collected. The patients were categorized according to their remaining teeth, dental caries, presence of periodontitis, and BMI.

**Results:** The average age was 74.20 years, and the average teeth number was 20.67. Significant differences in dental caries and periodontitis rates were observed across BMI categories. Younger age and female sex correlated with improved oral health. The underweight BMI group exhibited higher caries rates, whereas the average BMI group showed favorable outcomes for both caries and periodontitis.

**Conclusions:** Comprehensive analysis including panoramic imaging revealed notable associations between oral health and BMI in patients with dementia, emphasizing the importance of regular dental checkups. This study underscores the potential links between oral health and systemic conditions in dementia, necessitating further research to elucidate causal relationships and mechanisms.

**Key Words:** Alzheimer disease, Body mass index, Dementia, Oral health

### Introduction

Alzheimer's disease (AD) is notably prevalent among the global aging population, representing the most common form of dementia<sup>1)</sup>. This condition is typified by a progressive dete-

rioration in memory, cognitive abilities, language, and learning capacity, ultimately culminating in fatality. Globally, over 37 million individuals are afflicted by AD, with the highest incidence observed in the elderly, particularly those aged 65 years and above<sup>2)</sup>. With the anticipated increase in life expectancy

and evolving lifestyles, it is conjectured that the prevalence of AD may rise to one in 85 individuals by 2050<sup>3)</sup>.

AD incurs significant costs, encompassing not only the burden of a terminal illness but also substantial financial and social implications<sup>4)</sup>. Financially, as elderly individuals progressively lose their capacity for gainful employment, they increasingly rely on familial financial support. In advanced stages, the need for caregivers or institutionalization may become imperative. In 2015, the annual socioeconomic cost of AD in China amounted to US \$168 billion. Projections indicate that this figure is expected to rise significantly, reaching US \$507 billion by 2030 and a staggering US \$1,890 billion by 2050<sup>5)</sup>. In essence, the escalating financial burden of AD care is rapidly intensifying. Moreover, providing care for elderly individuals with Alzheimer's can be emotionally and physically taxing. Family members may need to take extended leaves from work, thereby affecting their livelihoods. As the behavioral challenges of these elderly individuals worsen, both family members and caregivers may endure emotional strain.

Edentulism is recognized for its association with an elevated risk of cognitive impairment<sup>6,7)</sup>. Moreover, several oral diseases have been linked to the development of dementia. Given that chronic periodontitis represents a prevalent peripheral immunoinflammatory condition, it has been postulated to exert a notable influence on the progression of AD<sup>8)</sup>. Orofacial pain and its potential causes have been shown to be frequent in people with mild cognitive impairment (MCI) or dementia, so even if orofacial pain is not reported, healthcare providers should perform regular oral exams in people with MCI or dementia<sup>9)</sup>. Study<sup>10)</sup> have also shown a strong link between tooth decay and AD. Contrarily, certain study<sup>11)</sup> has failed to establish an association between periodontitis pocket depth and the occurrence of dementia. The definitive nature of the causal or correlative link between dental conditions and dementia remains a subject of

ongoing inquiry. Ongoing research persists in the investigation of the intricate interrelationship between dementia, cognitive impairment, and oral health, notwithstanding the inherent challenge of establishing causal determinants.

This investigation aimed to employ panoramic imaging to analyze the oral health status of dementia patients seeking hospital treatment, thereby enhancing the objectivity of assessment, and facilitating the exploration of potential interconnections.

## Materials and Methods

### 1. Ethical approval

This study was conducted in accordance with the guidelines of the World Medical Association Helsinki Declaration for biomedical research involving human subjects. This study was approved by the Institutional Review Board (IRB) and Clinical Data Warehouse (CDW) data review board of The Catholic University of Korea, Catholic Medical Center (PC21WISB0077). Needs for informed consent was waived by the IRB. Data were collected and administered by CDW, and the images were exported under supervise of Enterprise Data Platform (EDP) of The Catholic University of Korea Information Convergence Institute.

### 2. Data collection and classification

After IRB and Data review board's approval, of the 1,677 patients diagnosed with dementia at Seoul St. Mary's Hospital and Eunpyeong St. Mary's Hospital during the 10-year period from 1 January 2011 to 31 December 2020, who visited the hospital's dental clinic and had dental panoramic images taken, 221 were excluded, and 1,456 were selected for analysis of their oral health based on the panoramic images obtained using a ProMax (Planmeca, Helsinki, Finland) or Kodak 8000 Digital Panoramic System (Carestream Health Inc., NY, USA) accord-

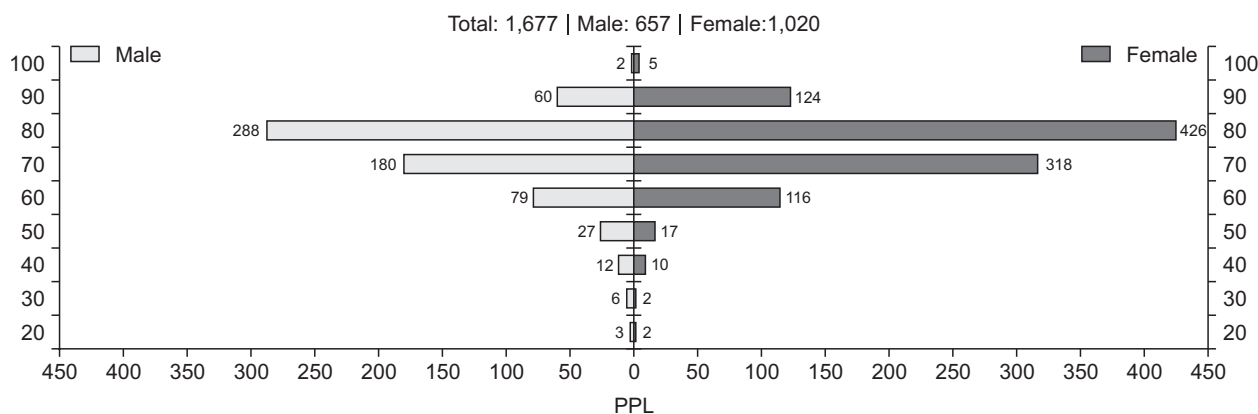
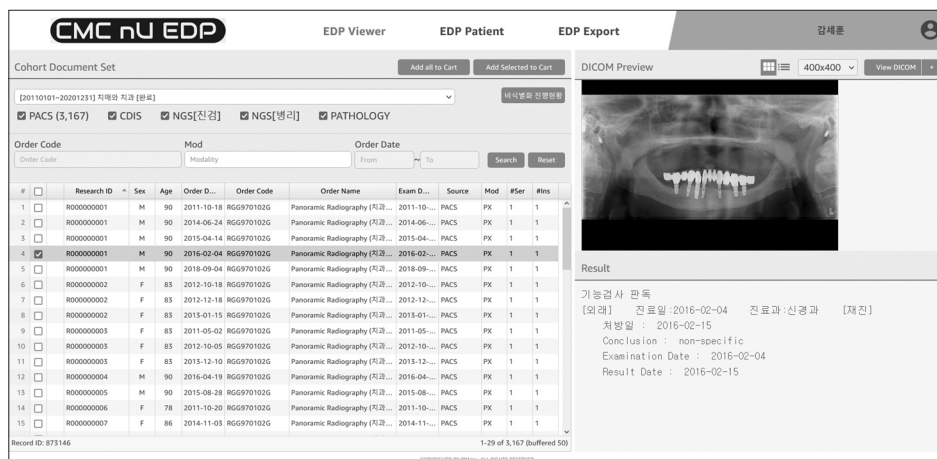


Fig. 1. Gender and age distribution of initially formed Clinical Data Warehouse (CDW).



**Fig. 2.** Basic analysis screen in Enter-prise Data Platform (EDP). The analysis screen in EDP is accessible only in secure, de-identified, and anonymized clinics, allowing direct viewing and analysis of videos on the web.

ing to the user manual. The patient data list was subjected to an automatic de-identification process under the CDW system (Fig. 1). We can merely access the EDP system to receive panoramic images of listed patients after information have been de-identified and secured to protect their privacy. From the collected list, qualified 1,677 patients' images were analyzed directly through web-based the EDP system in JPEG format (Fig. 2). The panorama radiographs with image errors, low-resolution, or pathologic lesion such as cyst and tumors were excluded. And we excluded individuals with fewer than two dementia diagnoses and included patients consistently attending the hospital for both dementia and dental check-up and treatment. Of these patient radiographs, 1,456 patient panoramic images were analyzed by two experienced dentists. Every image was checked twice and recorded numbers, caries, periodontal-level, position of remaining teeth and implant prosthesis.

### 2.1. Inclusion criteria

(1) Patients diagnosed with dementia between 1 Jan 2011 and 31 Dec 2020, at Seoul St. Mary's Hospital and Eunpyeong St. Mary's Hospital in the Republic of Korea.

(2) Patients who visited the hospital's dental clinic and underwent dental panoramic imaging.

### 2.2. Exclusion criteria

(1) Subjects with only a single dementia diagnosis (those with fewer than three visits with diagnosis and treatment). Only patients receiving ongoing treatment for dementia were considered.

(2) Cases where the panoramic dental images were unreadable due to errors or shaking.

**Table 1.** Baseline characteristic of subjects

		Total (%)
Age	N	1,456
	Mean (SD)	74.20 (10.42)
	Median (IQR)	76.00 (11.00)
	Min, max	20.00, 98.00
Gender	N	1,456
	Male	565 (38.80)
	Female	891 (61.20)
Deceased	N	1,456
	Yes	207 (14.22)
	No	1,249 (85.78)
Weight (kg)	N	1,338
	Mean (SD)	58.45 (10.81)
	Median (IQR)	58.00 (14.00)
	Min, max	30.20, 119.00
Height (cm)	N	1,320
	Mean (SD)	158.09 (8.80)
	Median (IQR)	158.00 (13.00)
	Min, max	111.00, 190.00
BMI (kg/m <sup>2</sup> )	N	1,320
	Mean (SD)	23.37 (3.73)
	Median (IQR)	23.25 (4.43)
	Min, max	13.34, 55.19
BMI group	N	1,320
	<18.5	106 (8.03)
	≤18.5, >25	827 (62.65)
	≤25, >30	326 (24.70)
	≤30, >35	56 (4.24)
	≤35, >40	3 (0.23)
	≤40	2 (0.15)

## 3. Statistical analysis

Statistical analyses were performed using SAS ver 9.4 (SAS Institute Inc., Cary, NC, USA). Analyses between two variables were performed using between-treatment *P*-value: ANOVA (A) or Kruskal-wallis test (K), and analyses of multivariate factors were performed using between-treatment *P*-value: Chi-square

test (C) or Fishers exact test (F). Post-hoc *P*-value: testing for Post-hoc method by Bonferroni was performed for validation. Nonparametric testing was applied alongside parametric methods due to inadequate sample sizes in certain subgroups and the potential for non-normal distribution in these segments. This dual approach was adopted to maintain statistical rigor.

Results

Based on panoramic imaging of 1,456 dementia patients, an objective assessment of oral health was performed. They were 74.20 (10.42) years old with an average of 20.67 (8.61) teeth, 565 men and 891 women. Using anthropometric data, BMI was calculated and was 23.37 (3.73). Comorbidities of chronic diseases such as tuberculosis, malignancy, anemia, thyroid disease, diabetes, hypertension, liver disease, and osteoporosis were also assessed. Various blood test indicators were considered in the study. Among these, the levels of C-reactive protein (CRP) and glucose were found to be higher than normal values, while vitamin B12 also showed elevated levels. In contrast, calcium, C-telopeptide, vitamin D, ammonia, Apo E genotype, homocysteine, osteocalcin, troponin-I, and total procollagen type 1 N-terminal propeptide (P1NP) were all within normal ranges (Table 1-3).

Table 2. Underlying medical conditions

		Total (%)
Tuberculosis	N	1,456
	Yes	6 (0.41)
	No	1,450 (99.59)
Cancers	N	1,456
	Yes	132 (9.07)
	No	1,324 (90.93)
Anaemia	N	1,456
	Yes	110 (7.55)
	No	1,346 (92.45)
Thyroid	N	1,456
	Yes	158 (10.85)
	No	1,298 (89.15)
Diabetes	N	1,456
	Yes	432 (29.67)
	No	1,024 (70.33)
Hypertension	N	1,456
	Yes	561 (38.53)
	No	895 (61.47)
Liver disease	N	1,456
	Yes	107 (7.35)
	No	1,349 (92.65)
Osteoporosis	N	1,456
	Yes	265 (18.20)
	No	1,191 (81.80)

In this study, a cohort of 1,398 patients retaining residual teeth underwent examination and subsequent analysis to identify dental caries and periodontitis lesions amenable to

Table 3. Diagnostic medical information

		Total (%)
25 (OH) vitamin D total	N	359
	Mean (SD)	27.49 (13.17)
	Median (IQR)	27.06 (17.99)
	Min, max	4.50, 112.16
Ammonia	N	390
	Mean (SD)	56.93 (42.64)
	Median (IQR)	49.33 (28.00)
	Min, max	17.00, 701.00
Apo E genotyping	N	303
	E2/E3	22 (7.26)
	E2/E4	5 (1.65)
	E3/E3	205 (67.66)
	E3/E4	68 (22.44)
	E4/E4	3 (0.99)
Calcium	N	1,125
	Mean (SD)	8.81 (0.55)
	Median (IQR)	8.80 (0.71)
	Min, max	6.79, 10.84
CRP (C-reactive protein), quan.	N	1,089
	Mean (SD)	2.13 (2.98)
	Median (IQR)	0.78 (2.97)
	Min, max	0.01, 26.77
C-telopeptide	N	163
	Mean (SD)	0.33 (0.22)
	Median (IQR)	0.28 (0.27)
	Min, max	0.03, 1.84
Glucose	N	1,280
	Mean (SD)	124.27 (37.31)
	Median (IQR)	113.62 (36.98)
	Min, max	65.67, 443.00
Homocysteine	N	209
	Mean (SD)	13.58 (8.90)
	Median (IQR)	11.60 (5.60)
	Min, max	4.60, 100.00
Osteocalcin	N	129
	Mean (SD)	14.97 (8.81)
	Median (IQR)	13.19 (7.54)
	Min, max	2.25, 73.90
Troponin-I	N	343
	Mean (SD)	4.32 (24.84)
	Median (IQR)	0.02 (0.11)
	Min, max	0.00, 359.95
Vitamin B12 (cyanocobalamin)	N	148
	Mean (SD)	1,009.43 (1,062.25)
	Median (IQR)	707.50 (658.75)
	Min, max	126.00, 6,000.00
P1NP	N	66
	Mean (SD)	36.94 (22.81)
	Median (IQR)	32.95 (27.53)
	Min, max	8.52, 121.00

radiographic assessment. The cohort comprised 600 patients exhibiting fair caries morbidity (0-4 teeth), 297 with poor caries morbidity (5-14 teeth), and 501 with worse caries morbidity (15 or more teeth). Our findings indicated that in the female subgroup, younger age was associated with improved outcomes,

with notable distinctions observed with respect to body mass index (BMI) stratification. Particularly, among the BMI subgroups, individuals falling into the very low (BMI<18.5) and low (BMI 18.5-25) categories displayed higher rates of suboptimal caries outcomes, whereas the average (BMI 25-30) and slightly

**Table 4.** Oral health panoramic image analysis via dental caries existence

		Total (%)	Fair (0-4) (%)	Poor (5-14) (%)	Worse (15≥) (%)
Age	N	1,398	600	297	501
	Mean (SD)	73.95 (10.46)	70.93 (11.53)	73.88 (10.17)	77.60 (7.81)
	Median (IQR)	75.00 (12.00)	73.00 (14.00)	75.00 (10.00)	78.00 (11.00)
	Min, max	20.00, 98.00	20.00, 97.00	28.00, 96.00	48.00, 98.00
	Between <i>P</i> -value		<0.0001* (K)		
	Post-hoc <i>P</i> -value		0.0002* (W) <sup>12)</sup>	<0.0001* (W) <sup>23)</sup>	<0.0001* (W) <sup>13)</sup>
Gender	N	1,398	600	297	501
	Male	541 (38.70)	202 (33.67)	121 (40.74)	218 (43.51)
	Female	857 (61.30)	398 (66.33)	176 (59.26)	283 (56.49)
	Between <i>P</i> -value		0.0027* (C)		
	Post-hoc <i>P</i> -value		0.1134 (C) <sup>12)</sup>	1.0000 (C) <sup>23)</sup>	0.0024* (C) <sup>13)</sup>
Death status	N	1,398	600	297	501
	Yes	194 (13.88)	62 (10.33)	42 (14.14)	90 (17.96)
	No	1,204 (86.12)	538 (89.67)	255 (85.86)	411 (82.04)
	Between <i>P</i> -value		0.0013* (C)		
	Post-hoc <i>P</i> -value		0.2809 (C) <sup>12)</sup>	0.4802 (C) <sup>23)</sup>	0.0008* (C) <sup>13)</sup>
Weight (kg)	N	1,290	568	278	444
	Mean (SD)	58.54 (10.73)	59.39 (10.79)	58.89 (10.63)	57.23 (10.62)
	Median (IQR)	58.00 (13.60)	58.15 (13.10)	58.90 (14.50)	57.00 (14.00)
	Min, max	30.20, 119.00	34.00, 119.00	36.00, 113.00	30.20, 90.40
	Between <i>P</i> -value		0.0185* (K)		
	Post-hoc <i>P</i> -value		1.0000 (W) <sup>12)</sup>	0.1752 (W) <sup>23)</sup>	0.0185* (W) <sup>13)</sup>
Height (cm)	N	1,272	564	272	436
	Mean (SD)	158.12 (8.72)	158.27 (8.57)	158.77 (8.37)	157.53 (9.09)
	Median (IQR)	158.00 (12.75)	158.00 (12.25)	159.00 (12.80)	157.00 (13.90)
	Min, max	111.00, 190.00	136.10, 190.00	135.00, 182.00	111.00, 179.00
	Between <i>P</i> -value		0.2188 (K)		
	Post-hoc <i>P</i> -value		0.9276 (W) <sup>12)</sup>	0.2092 (W) <sup>23)</sup>	0.0033* (W) <sup>13)</sup>
BMI (kg/m <sup>2</sup> )	N	1,272	564	272	436
	Mean (SD)	23.40 (3.73)	23.67 (3.53)	23.39 (3.50)	23.05 (4.08)
	Median (IQR)	23.31 (4.41)	23.52 (4.55)	23.44 (4.03)	22.89 (4.53)
	Min, max	13.34, 55.19	13.34, 37.42	13.41, 41.01	13.84, 55.19
	Between <i>P</i> -value		0.0043* (K)		
	Post-hoc <i>P</i> -value		0.9276 (W) <sup>12)</sup>	0.2092 (W) <sup>23)</sup>	0.0033* (W) <sup>13)</sup>
BMI group	N	1,272	564	272	436
	<18.5	102 (8.02)	33 (5.85)	21 (7.72)	48 (11.01)
	≤18.5, >25	794 (62.42)	346 (61.35)	170 (62.50)	278 (63.76)
	≤25, >30	317 (24.92)	154 (27.30)	72 (26.47)	91 (20.87)
	≤30, >35	54 (4.25)	30 (5.32)	8 (2.94)	16 (3.67)
	≤35, >40	3 (0.24)	1 (0.18)	0 (0.00)	2 (0.46)
	≤40	2 (0.16)	0 (0.00)	1 (0.37)	1 (0.23)
	Between <i>P</i> -value		0.0092 (C)		
	Post-hoc <i>P</i> -value		0.8880 (F) <sup>12)</sup>	0.9378 (F) <sup>23)</sup>	0.0103* (F) <sup>13)</sup>

Between-treatment *P*-value: ANOVA (A) or Kruskal-wallis test (K).

Between-treatment *P*-value: Chi-square test (C) or Fishers exact test (F).

Post-hoc *P*-value: testing for Post-hoc method by Bonferroni.

<sup>12)</sup>Dental caries fair (0-4) vs. poor (5-14).

<sup>23)</sup>Dental caries poor (5-14) vs. worse (15~).

<sup>13)</sup>Dental caries fair (0-4) vs. worse (15~).

elevated (BMI 30+) categories exhibited favorable caries morbidity (Table 4).

Parallel trends were observed in periodontitis morbidity, with 312 patients in the fair (0-4) group, 270 in the poor (5-14)

group, and 815 in the worse (15 or more) group. Consistent with the caries analysis, younger age and female gender were linked to improved periodontal outcomes, and BMI-based distinctions remained noteworthy. Specifically, individuals in the low BMI

**Table 5.** Oral health panoramic image analysis via periodontal health

		Total (%)	Fair (0-4) (%)	Poor (5-14) (%)	Worse (15≥) (%)
Age	N	1,397	312	270	815
	Mean (SD)	73.94 (10.46)	68.87 (13.74)	73.21 (9.50)	76.12 (8.43)
	Median (IQR)	75.00 (12.00)	72.00 (15.00)	74.00 (12.00)	77.00 (10.00)
	Min, max	20.00, 98.00	20.00, 97.00	29.00, 92.00	41.00, 98.00
	95% C.I.	69.00, 81.00	63.00, 78.00	68.00, 80.00	72.00, 82.00
	Between <i>P</i> -value		<0.0001* (K)		
	Post-hoc <i>P</i> -value		0.0012* (W) <sup>12)</sup>	<0.0001* (W) <sup>23)</sup>	<0.0001* (W) <sup>13)</sup>
Gender	N	1,397	312	270	815
	Male	541 (38.73)	90 (28.85)	101 (37.41)	350 (42.94)
	Female	856 (61.27)	222 (71.15)	169 (62.59)	465 (57.06)
	Between <i>P</i> -value		<0.0001* (C)		
	Post-hoc <i>P</i> -value		0.0848 (C) <sup>12)</sup>	0.3287 (C) <sup>23)</sup>	<0.0001* (C) <sup>13)</sup>
Death status	N	1,397	312	270	815
	Yes	194 (13.89)	38 (12.18)	40 (14.81)	116 (14.23)
	No	1,203 (86.11)	274 (87.82)	230 (85.19)	699 (85.77)
	Between <i>P</i> -value		0.5955 (C)		
Weight (kg)	N	1,289	291	251	747
	Mean (SD)	58.54 (10.74)	59.54 (11.52)	59.44 (10.01)	57.85 (10.62)
	Median (IQR)	58.00 (13.60)	58.00 (14.00)	59.50 (13.00)	58.00 (14.30)
	Min, max	30.20, 119.00	35.00, 119.00	36.00, 92.00	30.20, 93.00
	95% C.I.	51.40, 65.00	52.00, 66.00	52.00, 65.00	50.70, 65.00
	Between <i>P</i> -value		0.1150 (K)		
Height (cm)	N	1,271	288	250	733
	Mean (SD)	158.13 (8.72)	158.63 (8.64)	157.76 (8.55)	158.06 (8.81)
	Median (IQR)	158.00 (12.80)	158.00 (11.55)	158.00 (12.30)	158.00 (13.00)
	Min, max	111.00, 190.00	136.10, 190.00	111.00, 178.00	135.00, 182.00
	95% C.I.	152.00, 164.80	152.45, 164.00	151.70, 164.00	152.00, 165.00
	Between <i>P</i> -value		0.7774 (K)		
BMI (kg/m <sup>2</sup> )	N	1,271	288	250	733
	Mean (SD)	23.40 (3.73)	23.65 (3.75)	23.89 (3.86)	23.13 (3.65)
	Median (IQR)	23.31 (4.42)	23.48 (4.72)	23.57 (4.08)	23.07 (4.50)
	Min, max	13.34, 55.19	13.34, 41.01	13.84, 55.19	13.41, 36.25
	95% C.I.	21.08, 25.50	21.17, 25.89	21.48, 25.56	20.80, 25.29
	Between <i>P</i> -value		0.0165* (K)		
BMI group	Post-hoc <i>P</i> -value		1.0000 (W) <sup>12)</sup>	0.0363* (W) <sup>23)</sup>	0.1339 (W) <sup>13)</sup>
	N	1,271	288	250	733
	<18.5	102 (8.03)	23 (7.99)	9 (3.60)	70 (9.55)
	≤18.5, >25	793 (62.39)	167 (57.99)	161 (64.40)	465 (63.44)
	≤25, >30	317 (24.94)	84 (29.17)	69 (27.60)	164 (22.37)
	≤30, >35	54 (4.25)	12 (4.17)	10 (4.00)	32 (4.37)
	≤35, >40	3 (0.24)	1 (0.35)	0 (0.00)	2 (0.27)
	≤40	2 (0.16)	1 (0.35)	1 (0.40)	0 (0.00)
	Between <i>P</i> -value		0.0407 (C)		
	Post-hoc <i>P</i> -value		0.6443 (F) <sup>12)</sup>	0.0240* (F) <sup>23)</sup>	0.3813 (F) <sup>13)</sup>

Between-treatment *P*-value: ANOVA (A) or Kruskal-wallis test (K).

Between-treatment *P*-value: Chi-square test (C) or Fishers exact test (F).

Post-hoc *P*-value: testing for Post-hoc method by Bonferroni.

<sup>12)</sup>Periodontitis fair (0-4) vs. poor (5-14).

<sup>23)</sup>Periodontitis poor (5-14) vs. worse (15~).

<sup>13)</sup>Periodontitis fair (0-4) vs. worse (15~).



**Table 6.** Oral health panoramic image analysis via BMI comparison

		Total (%)	Underweight (%)	Normal (%)	Obesity (including pre-obesity) (%)
Imaging	N	1,320	106	827	387
	Yes	1,310 (99.24)	103 (97.17)	822 (99.40)	385 (99.48)
	No	10 (0.76)	3 (2.83)	5 (0.60)	2 (0.52)
	Between <i>P</i> -value		0.0367 (C)		
	Post-hoc <i>P</i> -value		0.1565 (F) <sup>(12)</sup>	1.0000 (F) <sup>(23)</sup>	0.2073 (F) <sup>(13)</sup>
Maxillary anterior teeth	N	1,310	103	822	385
	Mean (SD)	3.10 (1.52)	2.90 (1.60)	3.09 (1.53)	3.18 (1.48)
	Median (IQR)	4.00 (1.00)	4.00 (2.00)	4.00 (1.00)	4.00 (1.00)
	Min, max	0.00, 5.00	0.00, 4.00	0.00, 5.00	0.00, 4.00
	Between <i>P</i> -value		0.1255 (K)		
Maxillary canine	N	1,310	103	822	385
	Mean (SD)	1.62 (0.72)	1.48 (0.81)	1.62 (0.72)	1.66 (0.68)
	Median (IQR)	2.00 (0.00)	2.00 (1.00)	2.00 (0.00)	2.00 (0.00)
	Min, max	0.00, 2.00	0.00, 2.00	0.00, 2.00	0.00, 2.00
	Between <i>P</i> -value		0.0825 (K)		
Maxillary molars	N	1,310	103	822	385
	Mean (SD)	5.24 (3.06)	4.45 (3.23)	5.21 (3.09)	5.53 (2.93)
	Median (IQR)	6.00 (5.00)	5.00 (7.00)	6.00 (6.00)	7.00 (5.00)
	Min, max	0.00, 10.00	0.00, 10.00	0.00, 10.00	0.00, 10.00
	Between <i>P</i> -value		0.0113* (K)		
Maxillary mastication	Post-hoc <i>P</i> -value		0.0590 (W) <sup>(12)</sup>	0.5024 (W) <sup>(23)</sup>	0.0079* (W) <sup>(13)</sup>
	N	1,310	103	822	385
	Low (0-2)	320 (24.43)	36 (34.95)	209 (25.43)	75 (19.48)
	Medium (3-5)	227 (17.33)	17 (16.50)	141 (17.15)	69 (17.92)
	High (6>)	763 (58.24)	50 (48.54)	472 (57.42)	241 (62.60)
Maxillary teeth	Between <i>P</i> -value		0.0173* (C)		
	Post-hoc <i>P</i> -value		0.3264 (C) <sup>(12)</sup>	0.2209 (C) <sup>(23)</sup>	0.0104* (C) <sup>(13)</sup>
	N	1,310	103	822	385
	Mean (SD)	9.97 (4.87)	8.83 (5.26)	9.92 (4.93)	10.37 (4.61)
	Median (IQR)	12.00 (7.00)	11.00 (9.00)	12.00 (7.00)	12.00 (6.00)
Mandibular incisors	Min, max	0.00, 16.00	0.00, 16.00	0.00, 16.00	0.00, 16.00
	Between <i>P</i> -value		0.0327* (K)		
	Post-hoc <i>P</i> -value		0.1021 (W) <sup>(12)</sup>	0.8560 (W) <sup>(23)</sup>	0.0243* (W) <sup>(13)</sup>
	N	1,310	103	822	385
	Mean (SD)	3.34 (1.31)	2.97 (1.54)	3.34 (1.31)	3.44 (1.22)
Mandibular canine	Median (IQR)	4.00 (0.00)	4.00 (2.00)	4.00 (0.00)	4.00 (0.00)
	Min, max	0.00, 4.00	0.00, 4.00	0.00, 4.00	0.00, 4.00
	Between <i>P</i> -value		0.0032* (K)		
	Post-hoc <i>P</i> -value		0.0114* (W) <sup>(12)</sup>	0.8360 (W) <sup>(23)</sup>	0.0022* (W) <sup>(13)</sup>
	N	1,310	103	822	385
Mandibular molars	Mean (SD)	1.80 (0.59)	1.70 (0.67)	1.80 (0.61)	1.84 (0.50)
	Median (IQR)	2.00 (0.00)	2.00 (0.00)	2.00 (0.00)	2.00 (0.00)
	Min, max	0.00, 7.00	0.00, 2.00	0.00, 7.00	0.00, 2.00
	Between <i>P</i> -value		0.0597 (K)		
	N	1,310	103	822	385
Mandibular teeth	Mean (SD)	5.78 (2.90)	5.07 (2.96)	5.70 (2.94)	6.14 (2.76)
	Median (IQR)	7.00 (4.00)	6.00 (6.00)	7.00 (5.00)	7.00 (3.00)
	Min, max	0.00, 10.00	0.00, 10.00	0.00, 10.00	0.00, 10.00
	Between <i>P</i> -value		0.0015* (K)		
	Post-hoc <i>P</i> -value		0.0615 (W) <sup>(12)</sup>	0.0767 (W) <sup>(23)</sup>	0.0012* (W) <sup>(13)</sup>
Mandibular teeth	N	1,310	103	822	385
	Mean (SD)	10.91 (4.31)	9.74 (4.59)	10.82 (4.38)	11.42 (4.03)
	Median (IQR)	13.00 (5.00)	12.00 (6.00)	13.00 (5.00)	13.00 (4.00)
	Min, max	0.00, 17.00	0.00, 16.00	0.00, 17.00	0.00, 16.00
	Between <i>P</i> -value		0.0005* (K)		
Mandibular teeth	Post-hoc <i>P</i> -value		0.0191* (W) <sup>(12)</sup>	0.0790 (W) <sup>(23)</sup>	0.0003* (W) <sup>(13)</sup>

Table 6. Continued 1

		Total (%)	Underweight (%)	Normal (%)	Obesity (including pre-obesity) (%)
Total teeth	N	1,310	103	822	385
	Mean (SD)	20.88 (8.49)	18.56 (8.70)	20.74 (8.62)	21.78 (8.04)
	Median (IQR)	24.00 (12.00)	21.00 (15.00)	24.00 (13.00)	25.00 (10.00)
	Min, max	0.00, 32.00	0.00, 32.00	0.00, 32.00	0.00, 32.00
	Between <i>P</i> -value		0.0017* (K)		
	Post-hoc <i>P</i> -value		0.0229* (W) <sup>12)</sup>	0.2107 (W) <sup>23)</sup>	0.0011* (W) <sup>13)</sup>
Number of teeth in group (mastication)	N	1,310	103	822	385
	Low (0-9)	186 (14.20)	21 (20.39)	121 (14.72)	44 (11.43)
	Med (10-19)	247 (18.85)	27 (26.21)	155 (18.86)	65 (16.88)
	High (20>)	877 (66.95)	55 (53.40)	546 (66.42)	276 (71.69)
	Between <i>P</i> -value		0.0117* (C)		
	Post-hoc <i>P</i> -value		0.0989 (C) <sup>12)</sup>	0.4704 (C) <sup>23)</sup>	0.0054* (C) <sup>13)</sup>
Dentures	N	1,310	103	822	385
	Yes	320 (24.43)	31 (30.10)	208 (25.30)	81 (21.04)
	No	990 (75.57)	72 (69.90)	614 (74.70)	304 (78.96)
	Between <i>P</i> -value		0.1038 (C)		
Group implants	N	1,310	103	822	385
	Yes	346 (26.41)	20 (19.42)	223 (27.13)	103 (26.75)
	No	964 (73.59)	83 (80.58)	599 (72.87)	282 (73.25)
	Between <i>P</i> -value		0.2425 (C)		
Number of implants	N	1,310	103	822	385
	Mean (SD)	1.12 (2.50)	0.74 (2.07)	1.14 (2.51)	1.19 (2.58)
	Median (IQR)	0.00 (1.00)	0.00 (0.00)	0.00 (1.00)	0.00 (1.00)
	Min, max	0.00, 17.00	0.00, 14.00	0.00, 17.00	0.00, 16.00
	Between <i>P</i> -value		0.1751 (K)		
Tooth decay	N	1,310	103	822	385
	Mean (SD)	2.35 (2.84)	3.07 (3.22)	2.33 (2.83)	2.21 (2.71)
	Median (IQR)	2.00 (4.00)	2.00 (5.00)	2.00 (4.00)	1.00 (3.00)
	Min, max	0.00, 22.00	0.00, 19.00	0.00, 22.00	0.00, 14.00
	Between <i>P</i> -value		0.0150* (K)		
	Post-hoc <i>P</i> -value		0.0272* (W) <sup>12)</sup>	1.0000 (W) <sup>23)</sup>	0.0127* (W) <sup>13)</sup>
Tooth decay group	N	1,272	102	794	376
	Fair	564 (44.34)	33 (32.35)	346 (43.58)	185 (49.20)
	Normal	272 (21.38)	21 (20.59)	170 (21.41)	81 (21.54)
	Poor	213 (16.75)	21 (20.59)	141 (17.76)	51 (13.56)
	Poorer	107 (8.41)	11 (10.78)	62 (7.81)	34 (9.04)
	Worst	116 (9.12)	16 (15.69)	75 (9.45)	25 (6.65)
	Between <i>P</i> -value		0.0232* (C)		
	Post-hoc <i>P</i> -value		0.3261 (C) <sup>12)</sup>	0.3589 (C) <sup>23)</sup>	0.0110* (C) <sup>13)</sup>
Caries prevalence	N	1,273	102	795	376
	Mean (SD)	15.87 (22.33)	23.01 (28.00)	16.07 (22.58)	13.52 (19.53)
	Median (IQR)	7.69 (21.43)	14.55 (33.33)	7.69 (21.74)	6.90 (17.86)
	Min, max	0.00, 133.33	0.00, 100.00	0.00, 133.33	0.00, 100.00
	Between <i>P</i> -value		0.0025* (K)		
Periodontitis	Post-hoc <i>P</i> -value		0.0199* (W) <sup>12)</sup>	0.3389 (W) <sup>23)</sup>	0.0018* (W) <sup>13)</sup>
	N	1,308	103	822	383
	Mean (SD)	3.96 (3.19)	4.63 (3.73)	3.99 (3.14)	3.71 (3.12)
	Median (IQR)	4.00 (5.00)	5.00 (6.00)	4.00 (5.00)	3.00 (5.00)
	Min, max	0.00, 21.00	0.00, 18.00	0.00, 15.00	0.00, 21.00
	Between <i>P</i> -value		0.0570 (K)		



Table 6. Continued 2

		Total (%)	Underweight (%)	Normal (%)	Obesity (including pre-obesity) (%)
Periodontitis group	N	1,271	102	793	376
	Fair	288 (22.66)	23 (22.55)	167 (21.06)	98 (26.06)
	Normal	250 (19.67)	9 (8.82)	161 (20.30)	80 (21.28)
	Poor	331 (26.04)	24 (23.53)	198 (24.97)	109 (28.99)
	Poorer	208 (16.37)	20 (19.61)	142 (17.91)	46 (12.23)
	Worst	194 (15.26)	26 (25.49)	125 (15.76)	43 (11.44)
	Between <i>P</i> -value		0.0005* (C)		
	Post-hoc <i>P</i> -value		0.0604 (C) <sup>12)</sup>	0.0348* (C) <sup>23)</sup>	0.0006* (C) <sup>13)</sup>
Periodontitis morbidity	N	1,273	102	795	376
	Mean (SD)	25.28 (25.22)	30.79 (26.80)	26.20 (25.61)	21.85 (23.52)
	Median (IQR)	18.75 (27.64)	25.83 (42.00)	20.00 (28.31)	16.67 (24.80)
	Min, max	0.00, 133.33	0.00, 100.00	0.00, 133.33	0.00, 100.00
	Between <i>P</i> -value		0.0008* (K)		
	Post-hoc <i>P</i> -value		0.1955 (W) <sup>12)</sup>	0.0100* (W) <sup>23)</sup>	0.0034* (W) <sup>13)</sup>

Between-treatment *P*-value: ANOVA (A) or Kruskal-wallis test (K).

Between-treatment *P*-value: Chi-square test (C) or Fishers exact test (F).

Post-hoc *P*-value: testing for Post-hoc method by Bonferroni.

<sup>12)</sup>Underweight vs. Normal.

<sup>23)</sup>Normal vs. obese.

<sup>13)</sup>Underweight vs. obese.

group (BMI 18.5–25) were more likely to exhibit suboptimal periodontal outcomes, while those in the average BMI group (BMI 25–30) showed favorable caries morbidity (Table 5).

Following the general classification, further analyses were performed to compare the condition of the teeth in groupings based on BMI. There were 1,320 individuals with anthropometric records, categorized into three groups: underweight, normal, and obese (including pre-obese), with 106, 827, and 387 individuals in each group. The presence or absence of teeth showed a significant difference in the maxillary incisors ( $P=0.0113$ ), anterior mandibular incisors ( $P=0.0032$ ), and mandibular incisors ( $P=0.0015$ ), and the mean number of total teeth was 18.56, 20.74, and 21.78. The caries morbidity rate was also different in the underweight group with 3.07 teeth, the normal group with 2.33 teeth, and the obese (including pre-obese) group with 2.21 teeth, and the caries morbidity rate was 23.01%, 16.07%, and 13.52%. The number of teeth with periodontitis did not show a statistically significant difference, but showed a trend of 4.63, 3.99, and 3.71, and the periodontitis morbidity rate was 30.79%, 26.20%, and 21.85%. Following the primary BMI categorization, we conducted additional analyses to assess tooth conditions within specific BMI groupings. This sub analysis involved 1,320 individuals with recorded anthropometric data, who were stratified into three BMI categories: underweight, normal, and obese (including pre-obese), comprising 106, 827, and 387 individuals, respectively. Notably, a statistically significant difference

was observed in the presence or absence of teeth in relation to maxillary incisors ( $P=0.0113$ ), anterior mandibular incisors ( $P=0.0032$ ), and mandibular incisors ( $P=0.0015$ ). Furthermore, the mean total number of teeth varied across these groups, measuring 18.56, 20.74, and 21.78, respectively (Table 6).

Additionally, disparities in caries morbidity rates were evident, with the underweight group displaying a rate of 3.07 teeth, the normal group 2.33 teeth, and the obese (including pre-obese) group 2.21 teeth, accompanied by caries morbidity rates of 23.01%, 16.07%, and 13.52%, respectively. Conversely, while the number of teeth affected by periodontitis did not exhibit statistical significance, there was a discernible trend with values of 4.63, 3.99, and 3.71 in the underweight, normal, and obese (including pre-obese) groups, respectively. The corresponding periodontitis morbidity rates were 30.79%, 26.20%, and 21.85%.

## Discussion

In this study of 1,456 dementia patients, researchers conducted a thorough panoramic image analysis of oral health. Parallel trends were observed in periodontitis, with younger age and female gender associated with better outcomes. Distinctions based on BMI were also evident, with individuals in the low BMI group more likely to experience suboptimal periodontal outcomes, while the average and slightly elevated BMI groups displayed favorable caries morbidity. Further analyses assessed

tooth conditions within specific BMI categories (underweight, normal, obese), revealing significant differences in the presence or absence of teeth, notably in specific tooth types. Caries morbidity rates varied among these BMI groups, and while the number of teeth affected by periodontitis did not show statistical significance, a clear trend emerged across the BMI categories. Specifically, the study found that the 1,456 dementia patients were 74.20 (10.42) years old and had an average of 20.67 (8.61) teeth. This is very interesting, as a previous report by Korean researchers<sup>12)</sup> found that people aged 65-69 had 21.24 (7.95) teeth, 70-74 had 18.87 (8.71) teeth, and 75-79 had 16.33 (9.57) teeth. The mean value in this study was 74.2 years (10.42), with 20.67 (8.61) teeth, indicating very good tooth preservation. This analysis is based on imaging data of patients with dementia, but with regular visits to the hospital, dental check-ups, and panoramic imaging, which may explain the better results. In the field, it is possible that there are many more patients with poorer oral hygiene or uncooperative patients who are unable to undergo such examinations and treatments. The potential role of socioeconomic factors, particularly in larger urban settings, in driving improvements in oral health should not be discounted as a contributing factor<sup>13)</sup>.

Periodontitis can be characterized as a 'low-grade systemic disease' due to the release of proinflammatory cytokines into the systemic circulation and the elevation of CRP<sup>14)</sup>. Inflammation is recognized as a central factor in both the pathogenesis, serving as a bridging mechanism between periodontitis and AD. The observed positive correlation between CRP and periodontal disease could potentially serve as a plausible underlying mechanism in explaining the association between periodontal disease and the heightened risk of cardiovascular disease (CVD) among afflicted individuals<sup>15,16)</sup>. Elevated CRP levels among individuals with advanced periodontal disease remained significant in multivariate analyses ( $P < 0.01$ ), even after accounting for established risk factors associated with heightened CRP levels such as diabetes, arthritis, emphysema, smoking, and anti-inflammatory medications, while also considering sociodemographic factors<sup>17)</sup>. Elevated CRP has also been observed in edentulous individuals, suggesting a possible role for this increased inflammation in dementia.

Beyond the established connection between CRP and inflammation, a plethora of investigations have delved into the relationship between periodontitis and dementia. Periodontitis is common in the elderly and can become more prevalent in AD due to reduced oral hygiene abilities as the disease progresses. In a six-month observational study of 60 participants with mild to moderate Alzheimer's, periodontitis was not initially related

to cognitive state but was later linked to a six-fold increase in cognitive decline rates, possibly through systemic inflammation effects<sup>18)</sup>. According to prior research, periodontitis is recognized for its capacity to release pro-inflammatory cytokines into the systemic circulation, thereby inducing a state of "low-grade systemic inflammation." Remarkably, periodontitis shares two pivotal attributes with AD: the presence of oxidative damage and inflammation, both of which are prominently observed in the brain pathology associated with AD<sup>19)</sup>.

In a comprehensive multivariate analysis conducted in the United States, cognitive function demonstrated a discernible association with oral health<sup>20)</sup>. Notably, individuals with lower cognitive scores exhibited a higher prevalence of dental decay, tooth loss, and a greater extent of periodontal disease sites. Additionally, various individual sociodemographic attributes, health behaviors, and adherence to regular dental visits displayed statistically significant correlations with oral health status. Beyond the role of periodontitis-related inflammation, it is imperative to acknowledge the potential impact of tooth decay progression and tooth loss on cognitive function. In a cross-sectional study<sup>21-23)</sup> of 137 subjects from the Oral Health, Bite Force and Dementia (OrBiD) study, dementia severity was linked to reduced dental care utilization and worsening oral health. Decay increased with cognitive decline, but other dental health aspects showed no significant differences. Oral hygiene deteriorated, and periodontal treatment was needed for all subjects. Several oral health conditions appear to exhibit associations with, or coincide with, the progression or exacerbation of dementia.

Nutritional status was assessed using BMI and the Mini Nutritional Assessment (MNA). Normal BMI subjects had more functional teeth units (FTUs) than underweight ones. Normal MNA subjects had more natural, non-replaced FTUs than those at risk of under-nutrition<sup>24)</sup>. Maintaining posterior occlusion is crucial for good nutrition in older individuals. Studies, including this one, suggest that dentition loss may impact functional abilities, potentially interacting with factors like BMI to affect patient outcomes. Emerging evidence underscores the association between BMI and adverse health outcomes, yet investigations pertaining to the link between BMI and dementia have yielded inconsistent findings. Notably, findings from the Framingham Offspring cohort study, which tracked participants until 2017, revealed 190 cases of dementia. It was observed that each unit increase in BMI during the age range of 40-49 was associated with an elevated dementia risk, although this risk appeared to diminish after the age of 70. Furthermore, individuals categorized as obese in the 40-49 age group exhibited a heightened

risk of dementia<sup>25)</sup>. Previous study<sup>15)</sup> of CRP have also adjusted CRP levels for factors known to be associated with elevated CRP levels, including age, smoking, BMI, triglycerides, and cholesterol. Age and BMI have been found to be significant covariates.

The study<sup>26)</sup> identified that decreasing BMI trends were linked to an elevated risk of developing dementia in late life. Specifically, individuals who exhibited a pattern of BMI decline, characterized by initial midlife increase followed by subsequent midlife decline, faced a significantly higher risk of dementia compared to those whose BMI remained stable (hazard ratio: 3.84, 95% confidence interval: 1.39-10.60). This suggests that the declining BMI dementia association was particularly influenced by a subgroup displaying a specific mid-life BMI trajectory involving both increase and decline. This study additionally revealed improved oral health among individuals in the increased BMI group. It is postulated that favorable oral health in later life may contribute to more effective dietary intake and the adoption of a healthier lifestyle. Conversely, suboptimal oral health may give rise to dietary challenges, potentially resulting in diminished systemic health, encompassing cognitive impairment and the onset of dementia.

In the context of tooth loss, the study revealed an observed association between the absence of maxillary and mandibular molars and the advancement of dementia. The underlying concept underscores the importance of recognizing the role of molars in establishing a functional occlusion. Consequently, both dental practitioners and patients should prioritize the preservation of healthy molars as part of their oral health endeavors. In a Japanese cross-sectional study<sup>27)</sup> investigating the nexus between posterior teeth occlusion and cognitive function among nursing home elderly residents, the analysis encompassed 200 participants. After adjusting for demographic factors and teeth count, a statistically significant association was established between higher total FTUs and elevated Mini-Mental State Examination (MMSE) scores. These findings underscore the independent link between the loss of posterior teeth occlusion and cognitive decline in study<sup>24)</sup>. It is plausible that a contributory factor underlying these findings revolves around facilitating adequate nutritional intake, thereby supporting overall bodily health and optimal functioning.

The study acknowledges limitations including potential bias from regional healthcare advantages in a South Korean urban setting, where patients likely received enhanced care and monitoring. Additionally, inconsistencies in the timing of panoramic imaging post-dementia diagnosis impede standardization for analysis. The necessity for longitudinal studies to explore the progression of dementia and corresponding oral health changes

is evident. Our data, while indicating fewer teeth in dementia patients compared to the elderly population, suggest oral health maintenance is achievable with careful monitoring and timely interventions, potentially benefiting overall systemic health and dementia management. As a study, this research establishes a basis for future comparative analyses between groups with and without dementia, paving the way for a diverse range of investigative endeavors. Based on the findings in this study, the oral health of people with dementia can be improved to maintain quality of life with proper education and ongoing oral care, and it is important that healthcare providers and caregivers pay attention to this aspect.

## Conclusions

In this comprehensive study involving 1,456 dementia patients, panoramic imaging and blood tests were employed to evaluate oral health and its correlation with various health indicators. The results indicated a significant association between the number of remaining teeth, especially maxillary and mandibular incisors, and BMI categories, as well as certain blood test markers like CRP. Factors such as younger age, female gender, and specific BMI ranges correlated with improved oral and periodontal outcomes. Overall, the study underscores the significance of preserving good oral health in dementia patients, suggesting that it can be attained through regular check-ups and timely implant or prosthodontic interventions. In dementia care, it is crucial to recognize that efforts toward oral health promotion may influence dementia progression, enhance quality of life, and support overall health maintenance.

## Ethical Approval

The study was conducted according to the guidelines of the Declaration of Helsinki. And this study was approved by the Institutional Review Board (IRB) and Clinical Data Warehouse (CDW) data review board of the Catholic University of Korea, Catholic Medical Center (Approval No. PC21WISB0077, 15 September 2022). The authors are on consent to participate and consent to publish. The IRB waived the written documentation of informed consent.

## Consent for Publication

Not applicable.

## Availability of Data and Materials

The datasets generated and/or analyzed during the present study are not publicly available as ethics approval was granted on the basis that only the researchers involved in the study could access the identified data but are available and accessible from the corresponding author on reasonable request.

## Conflict of Interest

The authors declare no conflict of interest.

## Acknowledgements

None.

## ORCID

Se Hoon Kahm, <https://orcid.org/0000-0001-6945-8480>

## References

- Rafii MS, Aisen PS. Recent developments in Alzheimer's disease therapeutics. *BMC Med* 2009;7:7.
- Galimberti D, Scarpini E. Progress in Alzheimer's disease research in the last year. *J Neurol* 2013;260(7):1936–1941.
- Brookmeyer R, Johnson E, Ziegler-Graham K, Arrighi HM. Forecasting the global burden of Alzheimer's disease. *Alzheimers Dement* 2007;3(3):186–191.
- Crous-Bou M, Minguillon C, Gramunt N, Molinuevo JL. Alzheimer's disease prevention: from risk factors to early intervention. *Alzheimers Res Ther* 2017;9(1):71.
- Jia J, Wei C, Chen S, Li F, Tang Y, Qin W, et al. The cost of Alzheimer's disease in China and re-estimation of costs worldwide. *Alzheimers Dement* 2018;14(4):483–491.
- Galindo-Moreno P, Lopez-Chaichio L, Padial-Molina M, Avila-Ortiz G, O'Valle F, Ravidá A, et al. The impact of tooth loss on cognitive function. *Clin Oral Investig* 2022;26(4):3493–500.
- Yoo JJ, Yoon JH, Kang MJ, Kim M, Oh N. The effect of missing teeth on dementia in older people: a nationwide population-based cohort study in South Korea. *BMC Oral Health* 2019;19(1):61.
- Gaur S, Agnihotri R. Alzheimer's disease and chronic periodontitis: is there an association? *Geriatr Gerontol Int* 2015;15(4):391–404.
- Delwel S, Scherder EJA, de Baat C, Binnekade TT, van der Wouden JC, Hertogh C, et al. Orofacial pain and its potential oral causes in older people with mild cognitive impairment or dementia. *J Oral Rehabil* 2019;46(1):23–32.
- Tiisanoja A, Syrjala AM, Tertsonen M, Komulainen K, Pesonen P, Knuuttila M, et al. Oral diseases and inflammatory burden and Alzheimer's disease among subjects aged 75 years or older. *Spec Care Dentist* 2019;39(2):158–165.
- Holmer J, Eriksdotter M, Habel H, Hed Myrberg I, Jonsson A, Pussinen PJ, et al. Periodontal conditions and incident dementia: A nationwide Swedish cohort study. *J Periodontol* 2022;93(9):1378–1386.
- Lee JH, Yi SK, Kim SY, Kim JS, Kim HN, Jeong SH, et al. Factors Related to the Number of Existing Teeth among Korean Adults Aged 55–79 Years. *Int J Environ Res Public Health* 2019;16(20).
- Henshaw MM, Karpas S. Oral Health Disparities and Inequities in Older Adults. *Dent Clin North Am* 2021;65(2):257–273.
- Abbaya K, Puthanagar NY, Naduwinmani S, Chidambar YS. Association between Periodontitis and Alzheimer's Disease. *N Am J Med Sci* 2015;7(6):241–246.
- Noack B, Genco RJ, Trevisan M, Grossi S, Zambon JJ, De Nardin E. Periodontal infections contribute to elevated systemic C-reactive protein level. *J Periodontol* 2001;72(9):1221–1227.
- Kamer AR, Craig RG, Dasanayake AP, Brys M, Glodzik-Sobanska L, de Leon MJ. Inflammation and Alzheimer's disease: possible role of periodontal diseases. *Alzheimers Dement* 2008;4(4):242–250.
- Slade GD, Offenbacher S, Beck JD, Heiss G, Pankow JS. Acute-phase inflammatory response to periodontal disease in the US population. *J Dent Res* 2000;79(1):49–57.
- Ide M, Harris M, Stevens A, Sussams R, Hopkins V, Culliford D, et al. Periodontitis and Cognitive Decline in Alzheimer's Disease. *PLoS One* 2016;11(3):e0151081.
- Gurav AN. Alzheimer's disease and periodontitis--an elusive link. *Rev Assoc Med Bras (1992)* 2014;60(2):173–180.
- Wu B, Plassman BL, Crout RJ, Liang J. Cognitive function and oral health among community-dwelling older adults. *J Gerontol A Biol Sci Med Sci* 2008;63(5):495–500.
- Jockusch J, Hopfenmuller W, Nitschke I. Influence of cognitive impairment and dementia on oral health and the utilization of dental services: Findings of the Oral Health, Bite force and Dementia Study (OrBiD). *BMC Oral Health* 2021;21(1):399.
- Jockusch J, Hahnel S, Nitschke I. Use of handgrip strength measurement as an alternative for assessing chewing function in people with dementia. *BMC Geriatr* 2022;22(1):769.
- Jockusch J, Wiedemeier D, Nitschke I. The OrBiD (Oral Health, Bite Force and Dementia) Pilot Study: A Study Protocol for New Approaches to Masticatory Muscle Training and Efficient Recruitment for Longitudinal Studies in People with Dementia. *Int J Environ Res Public Health* 2022;19(6):3700.
- Adiatman M, Ueno M, Ohnuki M, Hakuta C, Shinada K, Kawaguchi Y. Functional tooth units and nutritional status of older people in care homes in Indonesia. *Gerodontology* 2013;30(4):262–269.
- Li J, Joshi P, Ang TFA, Liu C, Auerbach S, Devine S, et al. Mid- to Late-Life Body Mass Index and Dementia Risk: 38 Years of Follow-up of the Framingham Study. *Am J Epidemiol* 2021;190(12):2503–2510.
- Li J, Liu C, Ang TFA, Au R. BMI decline patterns and relation to dementia risk across four decades of follow-up in the Framingham Study. *Alzheimers Dement* 2022;19(6):2520–2527.
- Takeuchi K, Izumi M, Furuta M, Takeshita T, Shibata Y, Kageyama S, et al. Posterior Teeth Occlusion Associated with Cognitive Function in Nursing Home Older Residents: A Cross-Sectional Observational Study. *PLoS One* 2015;10(10):e0141737.