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Periodontal Status among Elderly Inhabitants of Northern Manhattan::

The WHICAP Ancillary Study of Oral Health

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Abstract

Aim: We conducted a cross-sectional study of the prevalence, extent and severity of periodontitis in a tri-ethnic cohort of ≥65 year-old participants of the Washington-Heights Inwood Community Aging Project (WHICAP).

Methods: 1,130 individuals (57% of eligible invitees) participated in a full-mouth periodontal examination that included assessments of bleeding on probing, pocket depth and clinical attachment loss (CAL) at six sites/tooth.

Results: Participants had a mean age of 75.4 years (SD 6.7), were predominantly female (66.6%) and Hispanic (44.7%), and of middle/low educational attainment (~82%). The prevalence of edentulism was 14.7%, and an average of 17.1 teeth (SD 8.0) was present among the dentate. The prevalence of moderate/severe periodontitis according to the CDC/AAP definition was 77.5%. Pockets ≥6 mm were found in 50.2% of the sample, affecting an average of 5.7% of teeth/person. Corresponding figures for CAL≥5 mm were 71.4% and 23.6%, respectively. In multivariable models, male gender, being Black or Hispanic, and no dental visit within the prior year were associated with higher proportion of teeth with CAL≥ 5mm.

Conclusions: The prevalence, extent and severity of periodontitis were higher than the US national average in this urban elderly sample, suggesting substantial unmet periodontal treatment needs.

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Conflict of Interest

The authors declare no conflicts of interest.

INTRODUCTION

During the past few decades, life expectancy at 60 years of age has increased significantly worldwide: in 2015, it reached 20.4 years globally, 22 years in Europe, and 22.8 years in the Americas (World Health Organization, 2016). Consequently, the segment of the world population over 60 years continues to expand and is projected to almost double between 2015 and 2050, from 12% to 22% (World Health Organization, 2015). With edentulism decreasing, tooth retention in older dentate persons increasing, and age-associated comorbidities on the rise (Lamster, 2016), the oral health care needs of the elderly continue to grow and become increasingly complex. Periodontitis, an inflammatory, bacterially-driven disease of the tooth-supporting structures (Kinane et al., 2017) is widely prevalent and particularly so in older ages (Kassebaum et al., 2014). Apart from its significant contribution to tooth loss and its effects on oral function, periodontitis negatively affects a person's social and emotional health and overall quality of life (Papapanou and Susin, 2017), and is also a significant source of systemic inflammation (Kebschull et al., 2010). There is a relative paucity of epidemiologic data on the prevalence, extent and severity of periodontitis derived from full-mouth examinations in elderly populations both worldwide and in the United States. In this publication, we present cross-sectional data of periodontal status in a cohort of elderly (≥65 years old) community-dwelling individuals, participants in the Washington-Heights Inwood Community Aging Project.

MATERIAL AND METHODS

Overview of the Washington Heights-Inwood Columbia Aging Project (WHICAP)

WHICAP is a multi-ethnic longitudinal study of aging elderly residing in northern Manhattan. Over the past 20 years, the study has serially assessed more than 5,900 participants with respect to medical, social, and health behavior histories, general medical exams, and neuropsychological testing. The sampling strategies and recruitment outcomes have been described in detail elsewhere (Tang et al., 2001). In brief, individuals ≥65 years old living in northern Manhattan were identified from Medicare records or a commercial marketing company in three waves: 1992, 1999, and 2009. Individuals from this community were sampled across age strata based on broadly defined ethnic categories, resulting in a cohort comprising approximately 42% Caribbean Hispanics, 34% African Americans, and 23% non-Hispanic Whites. The study aims at following all patients from enrollment to death, and later cohorts replenished the sample size reduced due to death or loss to follow-up. The study design and procedures were approved by the Institutional Review Boards (IRB) of the Columbia Presbyterian Medical Center and the New York State Psychiatric Institute.

WHICAP Ancillary Study of Oral Health

The WHICAP ancillary study of oral health is a cross-sectional cohort study conducted between December 2013 and June 2016. Eligible for inclusion were WHICAP participants who were alive, had consented to be approached for ancillary studies, and had attended a parent study visit within a 9-month time window prior to the oral examination. A target sample size of approximately 1,100 individuals over 2.5 years was set. Eligible participants

were contacted by phone or mail by the study coordinator and were invited to an in-person visit at the Medical Center. The study procedures were approved by the CUMC IRB. Written informed consent was obtained from all participants. Table 1 describes the eligible and recruited cohorts by age and gender. Of 1,991 eligible parent-study participants, 1,130 (56.8%) enrolled. There was no conspicuous difference in response rate between femaled and males (55.6% vs. 59.3%), but the response rate decreased with age from 81% among 65–69 year olds to 42% among ≥80 year olds.

Study procedures: A study coordinator administered a detailed oral health questionnaire in English or Spanish, following which an oral examination by a single, experienced and calibrated dentist (author SB) was conducted. The examination included the soft and hard intraoral tissues and, in dentate participants, a full mouth assessment of periodontal status using a UNC-15 manual probe. Dichotomous assessments of dental plaque and bleeding on probing (BoP), and linear measurements of pocket depth (PD) and clinical attachment level (CAL) were carried out at six sites per tooth (mesiobuccal, midbuccal, distobuccal, distolingual, midlingual and mesiolingual) at all present teeth, excluding third molars.

Examiner calibration: Throughout the course of the study, the examiner was calibrated annually against a “Gold Standard” examiner (PNP). Calibration sessions involved 10 subjects with various levels of periodontitis who were assessed with respect to PD and CAL.

Inter-examiner agreement with the gold standard examiner was set at ≥75% for PD within ±1mm and at ≥60% for CAL within ±1mm. Inter-examiner Cohen’s kappa coefficient was 0.85 and 0.79 and inter-class correlation coefficient 0.81 and 0.75, for PD and CAL, respectively.

Additional variables: As part of the parent WHICAP study, self-reported information was collected on: Race/ethnicity (categorized as White, Black, Hispanic, or Other); educational attainment (low:≤11 years, middle: 12–16 years, high:≥17 years); smoking status (never, former, current); and history of diabetes, heart disease and arthritis.

Cognitive status was assessed in the parent study as reported elsewhere (Noble et al., 2017). In brief, participants underwent an in-person interview of general health and functional ability followed by a structured standardized assessment, including medical history, physical and neurological examination, and a validated comprehensive neuropsychological battery (Stern et al., 1992). The diagnosis of cognitive impairment or dementia was determined by a consensus of physicians, neurologists and neuropsychologists, based on standard research criteria (American Psychiatric Association). All persons with mild cognitive impairment or dementia had evidence of impairment on a neuropsychological test battery with at least mild impairment in social or occupational function (clinical dementia rating ≥0.5).

Data analyses:

Periodontitis prevalence, extent and severity: Continuous measures included mean BoP, PD and CAL and number and proportion of teeth/person and of sites/per person with PD≥4 or ≥6mm, and CAL ≥3 or ≥5mm. We also used the categorical CDC/AAP definitions for population-based surveillance of periodontitis (Eke et al., 2012), according to which PD

and CAL data from all teeth excluding third molars are used to classify participants in one of four categories: (i) “severe periodontitis”: ≥2 interproximal sites with CAL≥6 mm (not on the same tooth) and ≥1 interproximal sites with PD ≥5 mm; (ii) “moderate periodontitis”: ≥2 interproximal sites with CAL ≥4 mm (not on the same tooth), or ≥2 interproximal sites with PD ≥5 mm (not on the same tooth); (iii) “mild” periodontitis: ≥2 interproximal sites with CAL ≥3 mm and ≥2 interproximal sites with PD ≥4 mm (not on the same tooth) or one site with PD ≥5 mm; and (iv) “no” periodontitis: those that did not qualify as mild, moderate, or severe.

Comparisons of frequency distributions across age groups and periodontal status were carried out using analysis of variance (ANOVA) F-test (for continuous variables) or chi-square tests (for categorical variables). The post hoc Kendal’s tau test was used to examine the direction of the distribution, and post hoc Bonferroni adjustment was used for testing differences between specific groups. Multiple linear and logistic regression models examined the effects of independent variables including demographics, health conditions, smoking and periodontal treatment history, on continuous or categorical variables of periodontal status. Beta-repression models examined effects on the proportion of teeth per person with PD≥4mm, CAL≥3mm and CAL≥5mm, adjusting for inflation in zero and one by random perturbation after examining residual plots. A zero-inflated Beta regression model examined effects on the proportion of teeth with PD≥6mm, where serious inflation in zeros occurred. The R statistical software (R Foundation for Statistical Computing, Vienna, Austria) was used to randomly perturb the zero and one observations in the Beta regression and to fit the zero-inflated Beta regression models. All other analyses were performed using the STATA 13.0 statistical software (College Station, TX, USA). A p-value <0.05 was considered statistically significant.

RESULTS

Table 2 describes demographic and other characteristics of the enrolled sample (1,130 participants; mean age 75.4 years, SD 6.7; 66.6% female), stratified by age group. With respect to race/ethnicity, 44.7% of the participants were Hispanic, 30.4% Black and 23.3% White. Approximately 82% of the participants were of low/middle educational attainment, 8.2% were current and 40.7% were former tobacco smokers, and 30% reported having diabetes mellitus. With respect to other comorbidities, 75% suffered from heart disease, 45% from arthritis, and 20% had mild cognitive impairment or dementia (data not shown).

The prevalence of edentulism was 14.7% (166 participants) and was lowest in the 65–69 year old group (6.1%) and highest in the ≥80 year old group (26.5%). Hispanic origin, low educational attainment and diabetes were statistically significantly more frequent among edentulous than dentate enrollees (data not shown). The mean number of teeth was 15.7 (SD 10.1) in the entire sample and decreased with age from 19.4 among 65–69 year olds to 11.4 among participants ≥ 80 years of age. The mean number of teeth among the dentate participants (n=964), was 17.7 (SD 8.0). Dental implants were present in 10.5% of the participants (12.2% of the dentate but only 0.6% of the edentulous), at an average of 0.3 implants/person (SD 1.2). Approximately 65.5% of the sample had visited a dentist within the year preceding their examination date, and this proportion was higher in younger than

older participants (71.3% among 65–69 year olds, 54.8% among ≥80 year oldd). Over 60% of the participants reported brushing ≥2 times/daily, and 55% reported using an inter-dental care device (dental floss or interproximal brush). The frequency of use of inter-dental care devices decreased from 67.3% in the youngest age group to 34.4% in the oldest (data not shown).

Of the 964 dentate participants, 907 (94.1%) underwent full-mouth probing assessments; 47 participants (4.9%) were not probed because they required prophylactic antibiotics according to the current guidelines of the American Heart Association, while 10 participants (1.0%) discontinued the probing examination because of pain or discomfort. Table 3 offers a description of the periodontal status. Dental plaque occurred at an average of 36.4% of tooth surfaces (SE 1.9) in the youngest age group and at 50.6% (SE 2.3) in the oldest. Likewise, BoP increased from 39.8% (SE 1.6) in ages 65–69 years to 48.4% (SE 2.1) in ages ≥80 years. The mean PD was fairly constant across age groups (2.2–2.3 mm), as was the prevalence of PD≥4mm and ≥6mm (96.4% and 50.2%, respectively). Using a ≥4mm threshold of PD, an average of 23.4% of teeth/person and 31.2% of tooth sites/person were affected, with no conspicuous variation by age. Using a ≥6mm threshold of PD resulted in an average of 5.7% of teeth/person and 4.0% of sites/person being affected, again with no consistent pattern emerging with age.

A mean CAL of 2.5mm (SE 0.1) was observed in the entire sample, and was slightly higher (2.8mm, SE 0.1) in the oldest age group. Using cutoff thresholds of ≥3 mm and ≥5 mm of CAL resulted in prevalence estimates of 96.1% and 71.4% respectively, with limited variation across age groups. An average of 71.6% of teeth/person and 40.9% of sites/person displayed CAL ≥3mm, and these proportions were reduced to 23.6% and 10.8% when a ≥5 mm threshold was adopted.

Table 4 describes the distribution of the four-level CDC/AAP classification in the dentate cohort. Since these case definitions require valid clinical attachment level measurements, data from 860 enrollees were included. Overall, 19.7% of the participants were found to be periodontally healthy, while 2.8% had mild, 54.5% had moderate, and 23% had severe periodontitis. The percentage of individuals with moderate/severe periodontitis raged between 73.5% to 79.9% in the four age groups.

Table 5 describes selected continuous measures of periodontal status (mean PD, CAL, number of teeth with PD≥6mm or CAL≥5mm) by CDC/AAP class. Comparisons carried out between consecutive classes showed statistically significant differences in all measures of periodontal status between moderate and severe periodontitis. In addition, mean CAL was statistically significantly different between mild and moderate periodontitis. No differences in any of the continuous measures were observed between the no and mild periodontitis categories.

Lastly, Table 6 presents multiple regression models describing the effects of specific exposures on dental and periodontitis-related outcomes. Higher age, being Black or Hispanic, low educational attainment, tobacco smoking, arthritis and no dental visits within the 12 months preceding the oral examination were significantly associated with lower tooth

retention. Male gender was the only variable that was positively and significantly associated with the proportion of teeth/person with PD≥4 mm, and male gender, being Black or Hispanic, and no dental visits within the preceding 12 months were positively and significantly associated with the proportion of teeth/person with CAL≥5mm. Zero-inflated Beta regression analysis of the proportion of teeth/person with PD≥6mm (Supplemental Table 1) indicated that females and Whites were more likely to have no tooth with PD≥6mm (P<0.001, 0.014, 0.004, respectively), and subjects with dementia were marginally more likely to have higher proportion of teeth with PD≥6 mm (p=0.059). When using the CDC/AAP definition in logistic regression (no/mild periodontitis vs. moderate/severe), only female gender was statistically associated with lower disease severity.

DISCUSSION

In this study, we report on the periodontal status of a multi-ethnic cohort of elderly (≥ 65 years old) community-dwelling residents of northern Manhattan. To facilitate a comparison with existing and future literature, our data presentation largely conforms with the guidelines for reporting periodontitis prevalence and severity in epidemiologic studies proposed by the Joint EU/USA Periodontal Epidemiology Working Group (Holtfreter et al., 2015). Our findings demonstrate a higher extent and severity of periodontitis than that reported in the literature for cohorts of corresponding age although the observed prevalence of edentulism was lower.

The recent publication by (Eke et al., 2016) arguably presents the most relevant data against which our current findings may be compared and contrasted. These authors analyzed the latest USA national data pertaining to the periodontal status of 1,511 individuals ≥65 years old which were derived from the combined NHANES 2009–2010 and 2011–2012 cycles. Importantly, their findings are based on full-mouth, six-site per tooth probing assessments, i.e., on a very similar examination methodology. However, a notable advantage of our examination protocol is that it also included assessments of prevalent gingival inflammation, expressed through BoP.

The prevalence of edentulism in NHANES 2009–2012 was 19% versus 14.7% in WHICAP, and ranged from 13.5% in ages 65–74 years (vs. 8.4%) to 24.1% in ages ≥75 years (vs. 23.5%). This lower prevalence of edentulism in WHICAP occurred despite the fact that the mean age of the elderly cohort in NHANES 2009–2012 was 72.5 years vs. 75.4 years in WHICAP. However, it must be noted that approximately 57% of the eligible participants of the parent WHICAP participated in the ancillary study of oral health. It is conceivable that the rate of edentulism could be higher in the portion of the eligible sample that did not respond to the invitation for an oral examination. On the other hand, the mean number of teeth/person among dentate participants was lower in WHICAP than in NHANES. Hence, NHANES participants in ages 65–74 years had an average of 21.8 teeth present versus 19.1 teeth in WHICAP; the corresponding comparison for participants in ages over 75 years was 19.4 versus 15.4 (Paul Eke, personal communication, October 17, 2017).

With respect to clinical periodontal status, substantially higher mean PD (2.3 mm vs. 1.63 mm) and mean CAL (2.5 mm vs. 1.71 mm) were observed in WHICAP than in NHANES

2009–2012. Likewise, 96.4% of WHICAP participants had at least one site with PD≥4mm and 50.2% of the cohort had at least one site with PD≥6 mm. Corresponding figures in NHANES were 48.3% and 11.9%, respectively. The average WHICAP participant had 5.7% of teeth and 4.0% of sites with PD≥6mm, as compared to 1.62% and 0.45% of the average dentate NHANES participant. The higher severity of periodontal disease in WHICAP versus NHANES was further corroborated by the more detailed analysis of clinical attachment level measures: while a similar prevalence of CAL≥3mm was observed in WHICAP and NHANES (96.1% vs. 96.4%), the prevalence of CAL≥5mm was 71.4% in WHICAP and 62.3% in NHANES. On average, 23.6% of teeth and 10.8% of sites had a CAL≥5 mm in WHICAP, as compared to 18.0% and 8.8% in NHANES.

The apparent higher extent and severity of periodontitis in WHICAP than NHANES reflected by the continuous measures described above was also corroborated by analyses based on the CDC/AAP classification system. Thus, 23% of the WHICAP cohort fell into the “severe periodontitis” and 80.3% in the “total periodontitis” category (mild+moderate +severe). Corresponding figures in NHANES were 11% and 68%, respectively. In other words, the prevalence of CDC/AAP severe periodontitis was twice as high in WHICAP than in individuals of corresponding age nationwide, while only 19.7% of WHICAP participants as compared to 32% nationwide were considered periodontitis-free. Interestingly, the Eke et al. 2016 publication also provided model-derived estimates of prevalence of severe periodontitis among individuals of comparable age in the entire state of New York, which amounted to 12.4%, while the estimated proportion of periodontitis-free individuals was 32.6%. It appears therefore that the prevalence, extent, and severity of periodontitis in WHICAP exceeds both the nationwide and the state level estimates. This occurred despite a conceivable selection bias that would likely predispose the generally healthier portion of the elderly participants of the parent study, or those more aware of their oral health status, to attend the ancillary study of oral health. However, it should also be noted that the race/ethnicity breakdown of the elderly NHANES cohort (80.1% White, 7.6% Black and 3.2% Mexican American; Paul Eke, personal communication, March 27, 2018) was substantially different from that in WHICAP ancillary study (23.3% White, 30.4% Black, and 44.7% Hispanic). Likely, this has also affected the observed differences in periodontitis prevalence and severity between the two samples.

Notably, a very limited proportion of the sample fell into the mild periodontitis category. In addition, the virtual absence of any clinically meaningful differences in clinical periodontal status between individuals in the no and mild periodontitis categories in any age group (Table 5), questions the utility of this particular subcategory. Arguably, a description of periodontal status based on continuous measures of extent and severity of pocketing and attachment loss (Table 3) provides a more granular and clinically relevant information than the categorical CDC/AAP system (Table 4).

Data reported by (Hirotomi et al., 2014) facilitate a comparison of periodontal status with elderly populations outside the US, including 70-year old participants in the Niigata Study in Japan (Hirotomi et al., 2002), 65–74 year old participants in the Study of Health in Pomerania, Germany (SHIP) (Hensel et al., 2003) and the Third German Oral Health Study (DMS III) (Micheelis and Reich, 1999). The prevalence of edentulism was 7.5% in the

Niigata study, 33.5% in SHIP and 22.9% in DMS III. The corresponding age-specific prevalence estimates in WHICAP were 3.6% for individuals 70 years of age, and between 6.1% to 10.2% in ages 65–74 years. The mean number of teeth among dentate participants was 19.0 in the Niigata study, 12.3 in SHIP and 15.3 in DMS III. Similarly, the corresponding age-specific means in WHICAP were 21.1 teeth for 70 year olds, and between 19.9 and 18.3 teeth in ages 65–74 years. On the other hand, the prevalence of PD≥6mm was 10.2%, 23.8% and 20.8%, in each of the three cohorts respectively, as compared to approximately 50% in WHICAP participants. Likewise, the prevalence of CAL≥5 mm was 12.9% in Japan, 37.3% in Pomerania and 30.8% in West Germany, as compared to 70–72% in WHICAP. Severe periodontitis according to CDC/AAP affected only 2% of the cohort in Japan, 25.5% in Pomerania, 21.7% in West Germany and between 20.7–22.2%, depending on age, in WHICAP. The observed discrepancies between several measures of periodontitis between WHICAP and the afore-mentioned studies may be attributed to a combination of methodological and sociodemographic determinants (including socioeconomic status and access to dental insurance and quality dental care), cohort effects, as well as differences in biological exposures. With respect to the latter, although the prevalence of smoking was quite similar in WHICAP (51.8%) and NHANES (48%), the prevalence of self-reported diabetes was much higher in WHICAP (30%) than in NHANES (19.3%). Both the literature and the findings from the presented multivariable models (Table 6) point to the detrimental effects of these two risk factors on periodontal status. Interestingly, arthritis emerged as significantly and negatively associated with tooth retention. Although our analyses did not precisely differentiate between different forms of arthritic disease, and arthritis was not significantly associated with periodontal status in any model, recent literature suggests a reciprocal association between rheumatoid arthritis and periodontitis (Fuggle et al., 2016, Potempa et al., 2017).

In conclusion, the comprehensive description of periodontal status in this elderly cohort revealed high prevalence extent and severity of periodontitis, suggesting a substantial unmet need for periodontal care. Given that the WHICAP oral health study participants have fully developed periodontal phenotypes due to their age, the data offer a unique opportunity to study the determinants of periodontitis over the life time, including the role of genetic predispositions and the periodontal microbiome. These analyses are currently underway.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Clinical Relevance

Scientific rationale: To gain further knowledge on the level and determinants of oral health in the elderly, we examined the periodontal status of a tri-ethnic cohort of individuals ≥ 65 years old in Northern Manhattan.

Principal findings: The prevalence, extent and severity of periodontitis in the cohort were higher than the US national average, although the rates of edentulism were lower. Male gender, being Black or Hispanic, and no dental visits within the last year were associated with higher proportion of teeth with advanced clinical attachment loss while, in addition, older age, low educational attainment, smoking and arthritis were associated with lower tooth retention.

Practical Implications: We documented a substantial unmet periodontal treatment needs in a sample of community-dwelling elderly individuals in an urban metropolitan area.

Table 1.

Description of the study sample

Age, years	Eligible Sample[1]		Enrolled Sample[2]		Response Rate	
	Female	Male	Female	Male	Female	Male
	n	n	n (%)	n (%)	%	%
65–69	240	123	192 (65.3)	102 (34.7)	80.0	82.9
70–74	414	198	243 (66.8)	121 (33.2)	58.7	61.1
75–79	252	103	137 (71.0)	56 (29.0)	54.4	54.4
80+	448	213	180 (64.5)	99 (35.5)	40.2	46.5
All ages	1,354	637	752 (66.6)	378 (33.4)	55.6	59.3
Total	1,991		1,130		56.8	

[1] WHICAP participants who attended a parent study visit within 9 months prior to the oral health study visit

[2] WHICAP oral health study participants

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Table 2.

Characteristics of the enrolled sample (N=1,130) by age groups

		Age groups								Overall p-value	Post-hoc test		All ages	
		65–69y		70–74y		75–79y		80+y			Kendall's Tau-B (Chi^2 test)	Bonferroni (ANOVA)		
Number of subjects [n; (row %)]		294	(26.0)	364	(32.2)	193	(17.1)	279	(24.7)	-	-	-	1,130	(100)
Number of edentulous subjects [n; (column %)]	Edentulous	18	(6.1)	37	(10.2)	37	(19.2)	74	(26.5)	**<0.001**	0.202	-	166	(14.7)
Age [Mean; SD]		68.0;	1.7	73.0;	1.4	77.8;	1.5	84.9;	3.5	**<0.001**	-	*a,b,c,d,e,f*	75.4;	6.7
Gender [n; (column %)]	Male	102	(34.7)	121	(33.2)	56	(29.0)	99	(35.5)	0.487	-	-	378	(33.4)
	Female	192	(65.3)	243	(66.8)	137	(71.1)	180	(64.5)				752	(66.6)
Race / Ethnicity [n; (column %)]	White	95	(32.3)	102	(28.0)	25	(13.0)	41	(14.7)	**<0.001**	−0.162	-	263	(23.3)
	Black	115	(39.1)	102	(28.0)	62	(32.1)	65	(23.3)	**<0.001**	−0.099	-	344	(30.4)
	Hispanic	77	(26.2)	151	(41.5)	105	(54.4)	172	(61.6)	**<0.001**	0.246	-	505	(44.7)
	Other	7	(2.4)	9	(2.5)	1	(0.5)	1	(0.4)	0.069	-	-	18	(1.6)
Educational attainment [n; (column %)]	Low	57	(19.4)	124	(34.1)	97	(50.3)	155	(55.6)	**<0.001**	0.259	-	433	(38.3)
	Middle	158	(53.7)	158	(43.3)	73	(37.8)	100	(35.8)	**<0.001**	−0.129	-	489	(43.3)
	High	74	(25.2)	80	(22.0)	22	(11.4)	24	(8.6)	**<0.001**	−0.163	-	200	(17.7)
Smoking status [n; (column %)]	Never	132	(44.9)	175	(48.1)	93	(48.2)	145	(52.0)	0.667	-	-	545	(48.2)
	Former	114	(38.8)	141	(38.7)	87	(45.1)	118	(42.2)	0.502	-	-	460	(40.7)
	Current	28	(9.5)	43	(11.8)	10	(5.2)	11	(4.0)	**0.001**	−0.092	-	92	(8.2)
Diabetes mellitus [n; (column %)]		73	(24.8)	106	(29.1)	74	(38.3)	86	(30.8)	**0.016**	0.059	-	339	(30.0)
Number of teeth present* [Mean; SD]		19.4;	9.2	17.1;	9.8	13.4;	9.5	11.4;	10.0	**<0.001**	-	*a,b,c,d,e*	15.7;	10.1
Number of dental implants present [Mean; SD]		0.3;	1.2	0.3;	1.2	0.3;	1.3	0.3;	1.0	0.839	-	-	0.3;	1.2
Participants with ≥1 dental implants [n; (column %)]		34	(11.6)	37	(10.2)	23	(11.9)	25	(9.0)	0.680	-	-	119	(10.5)
Dental visit within the last 12 months [n; (column %)]		209	(71.3)	252	(69.2)	126	(65.3)	153	(54.8)	**<0.001**	−0.115	-	740	(65.5)
Tooth brushing ≥ 2 times/day [n; (column %)]		204	(74.2)	233	(71.9)	128	(82.6)	150	(74.3)	0.090	-	-	715	(63.3)

*Based on a 32-tooth dentition

Kendall’s Tau-B test (−1 to +1): ‘>0’ signifies increase in percentage distributions with increasing age, ‘<0’ signifies decrease in percentage distributions with increasing age

Bonferroni ($p<0.05$):

[*‘a’*] describes a significant difference between age groups 65–69 vs 70–74;

[*‘b’*] 65–69 vs 75–79 ;

[*‘c’*] 65–69 vs 80+;

[*‘d’*] 70–74 vs 75–79 ;

[*‘e’*] 70–74 vs 80+ ;

[*‘f”*] 75–79 vs 80+

Table 3.

Periodontal status among dentate participants with available probing depth and clinical attachment level measurements (N = 907)

	Age groups								All ages	
	65–69 (n = 264)		70–74 (n = 305)		75–79 (n = 146)		80+ (n =192)		(N = 907)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Number of teeth*	20.5	0.5	19.1	0.5	16.6	0.6	15.6	0.6	18.4	0.3
Dental Plaque (%)	36.4	1.9	37.9	1.6	40.0	2.4	50.6	2.3	40.5	1.0
Bleeding on Probing (%)	39.8	1.6	37.9	1.4	41.4	2.1	48.4	2.1	41.2	0.9
Probing depth										
Mean PD (mm)	2.3	0.0	2.2	0.0	2.2	0.0	2.3	0.1	2.3	0.0
Prevalence of PD ≥ 4mm (%)	98.1	0.8	96.4	1.1	97.3	1.4	93.2	1.8	96.4	0.6
Prevalence of PD ≥ 6mm (%)	53.8	3.1	48.9	2.9	46.6	4.1	50.0	3.6	50.2	1.7
Number of teeth/person with PD ≥ 4mm	4.2	0.3	4.0	0.2	3.1	0.3	3.7	0.3	3.8	0.1
Proportion of teeth/person with PD ≥ 4mm (%)	24.4	1.6	22.7	1.4	20.4	2.2	25.7	2.2	23.4	0.9
Number of teeth/person with PD ≥ 6mm	0.9	0.1	0.7	0.1	0.5	0.1	1.2	0.2	0.8	0.1
Proportion of teeth/person with PD ≥ 6mm (%)	6.0	1.0	4.8	0.7	3.9	1.5	8.2	1.3	5.7	0.5
Number of sites/person with PD ≥ 4mm	35.4	1.5	27.8	1.3	25.9	1.8	26.7	1.8	32.4	0.8
Proportion of sites/person with PD ≥ 4mm (%)	34.7	1.2	29.9	1.1	28.0	1.5	30.7	1.7	31.2	0.7
Number of sites/person with PD ≥ 6mm	3.9	0.5	3.0	0.3	2.3	0.5	4.7	0.8	3.5	0.3
Proportion of sites/person with PD ≥ 6mm (%)	4.3	0.6	3.3	0.5	2.5	0.5	5.8	1.0	4.0	0.3
Clinical attachment level										
Mean CAL (mm)	2.5	0.1	2.4	0.1	2.4	0.1	2.8	0.1	2.5	0.1
Prevalence of CAL ≥ 3mm (%)	97.3	1.0	97.0	1.0	97.3	1.4	92.2	1.9	96.1	0.6
Prevalence of CAL ≥ 5mm (%)	72.7	2.7	70.5	2.6	73.3	3.7	69.8	3.3	71.4	1.5
Number of teeth/person with CAL ≥ 3mm	14.3	0.5	12.4	0.4	10.0	0.6	9.4	0.5	12.0	0.3
Proportion of teeth/person with CAL ≥ 3mm (%)	75.0	1.8	70.4	1.7	71.2	3.1	68.9	2.6	71.6	1.1
Number of teeth/person with CAL ≥ 5mm	3.2	0.2	3.0	0.2	2.9	0.3	3.3	0.3	3.1	0.1
Proportion of teeth/person with CAL ≥ 5mm (%)	22.2	1.8	20.5	1.5	23.0	2.5	31.1	2.6	23.6	1.0
Number of sites/person with CAL ≥ 3mm	45.8	1.8	39.0	1.6	32.5	2.1	32.2	1.9	38.5	0.9
Proportion of sites/person with CAL ≥ 3mm (%)	42.7	1.6	39.1	1.4	39.6	2.2	42.5	2.2	40.9	0.9

	Age groups								All ages	
	65–69 (n = 264)		70–74 (n = 305)		75–79 (n = 146)		80+ (n =192)		(N = 907)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Number of sites/person with CAL ≥ 5mm	7.5	0.7	6.9	0.6	6.7	0.9	8.5	0.9	7.4	0.4
Proportion of sites/person with CAL ≥ 5mm (%)	10.5	1.2	9.2	1.0	9.2	1.3	14.9	1.6	10.8	0.6

* Based on a 32-tooth dentition

PD: Probing depth; CAL: Clinical attachment level; SE: Standard error

Table 4.

Distribution of participants according to the CDC/AAP case definition by age (N = 860)

CDC/AAP classes	Age groups				All ages
	65–69y	70–74y	75–79y	80+y	
	n (%)	n (%)	n (%)	n (%)	n (%)
No	50 (19.8)	57 (19.1)	31 (22.8)	31 (18.3)	169 (19.7)
Mild	6 (2.3)	10 (3.3)	5 (3.7)	3 (1.8)	24 (2.8)
Moderate	143 (55.7)	170 (56.9)	71 (52.2)	85 (50.3)	469 (54.5)
Severe	57 (22.2)	62 (20.7)	29 (21.3)	50 (29.6)	198 (23.0)

Table 5.

Selected continuous measures of periodontal status by CDC/AAP class (N = 860)

CDC/AAP classes	Mean PD (SD)	Mean CAL (SD)	# teeth with PD≥ 6 mm (SD)	# teeth with CAL≥ 5 mm (SD)
No	1.9 (0.2)	1.4 (0.9)	0.0 (0.1)	0.2 (0.6)
Mild	2.1 (1.9)	1.4 (0.7)	0.0 (0.1)	0.2 (0.4)
Moderate	2.1 (0.3)	2.4 (0.9)	0.1 (0.3)	2.0 (3.6)
Severe	2.8 (0.8)	3.7 (1.5)	1.7 (2.9)	7.9 (6.8)
post-hoc Bonferroni (p-value <0.05)	*c*	*b, c*	*c*	*c*

PD: Probing Depth; CAL: Clinical Attachment Level; SD: Standard Deviation

Statistical comparisons carried out between consecutive groups

Significant difference between No vs. Mild = ‘a’; Mild vs. Moderate = ‘b’; Moderate vs. Severe = ‘c’

Table 6.

Multivariable regression models examining the effects of specific exposures on selected dental and periodontitis-related outcomes

Variables		Periodontal outcome measures: Continuous: Number of teeth (N = 1,130) Linear regression coef.	(95% CI)	p-value	Proportion of teeth/person with: PD ≥ 4mm (N = 868) β regression coef.	(95% CI)	p-value	PD ≥ 6mm Zero - inflation	CAL ≥ 3mm (N = 868) β regression coef.	(95% CI)	p-value	CAL ≥ 5mm (N = 868) β regression coef.	(95% CI)	p-value	Categorical: Moderate/severe vs. mild/no (CDC/AAP) (N = 860) Logistic regression aOR	(95% CI)	p-value	
Age	65–69y	ref					ref					ref				ref		ref
	70–74y	−1.1	(−2.4 to −0.2)	0.095	−0.08	(−0.27 to 0.11)	0.398	−0.26	(−0.46 to −0.06)		**0.011**	−0.10	(−0.30 to 0.10)	0.338	0.9	(0.6 to 1.3)	0.526	
	75–79y	−3.2	(−4.8 to −1.6)	**<0.001**	−0.19	(−0.43 to 0.06)	0.131	−0.33	(−0.58 to −0.08)		**0.010**	−0.07	(−0.32 to 0.18)	0.570	0.7	(0.4 to 1.1)	0.143	
	>80y	−4.4	(−5.9 to −2.9)	**<0.001**	0.01	(−0.23 to 0.24)	0.960	−0.40	(−0.64 to −0.15)		**0.001**	0.16	(−0.08 to 0.40)	0.196	1.0	(0.6 to 1.7)	0.975	
Gender	Male	ref			ref			ref				ref			ref			
	Female	0.6	(−0.5 to 1.7)	0.260	−0.29	(−0.46 to −0.13)	**<0.001**	−0.29	(−0.46 to −0.12)		**0.001**	−0.40	(−0.57 to −0.23)	**<0.001**	0.4	(0.3 to 0.6)	**<0.001**	
Race / Ethnicity	White	ref			ref			ref				ref			ref			
	Black	−5.4	(−6.9 to −3.9)	**<0.001**	0.20	(−0.02 to 0.42)	0.076	0.07	(−0.16 to 0.29)		0.563	0.28	(0.06 to 0.51)	**0.013**	0.9	(0.6 to 1.5)	0.677	
	Hispanic	−6.0	(−7.6 to −4.3)	**<0.001**	0.18	(−0.07 to 0.43)	0.159	0.14	(−0.11 to 0.40)		0.274	0.32	(0.06 to 0.57)	**0.014**	1.5	(0.8 to 2.6)	0.195	
	Other	−2.5	(−6.6 to 1.6)	0.240	0.13	(−0.15 to 0.41)	0.666	0.38	(−0.25 to 1.00)		0.239	0.04	(−0.58 to 0.66)	0.901	0.7	(0.2 to 2.6)	0.638	
Educational attainment	Low	ref			ref			ref		Not reported (mentioned under results section)		ref			ref			
	Middle	1.5	(0.1 to 2.9)	**0.034**	0.01	(−0.20 to 0.21)	0.947	−0.12	(−0.34 to 0.09)		0.254	−0.11	(−0.33 to 0.10)	0.310	1.0	(0.6 to 1.6)	0.870	
	High	3.4	(1.6 to 5.3)	**<0.001**	0.13	(−0.15 to 0.41)	0.362	−0.20	(−0.48 to 0.09)		0.170	−0.08	(−0.36 to 0.20)	0.587	0.9	(0.5 to 1.7)	0.703	
Smoking status	Never	ref			ref			ref				ref			ref			
	Fomer	−1.4	(−2.4 to −0.3)	**0.011**	−0.01	(−0.16 to 0.16)	0.987	−0.07	(−0.23 to 0.09)		0.395	0.01	(−0.15 to 0.17)	0.908	1.2	(0.8 to 1.7)	0.439	
	Current	−5.4	(−7.3 to −3.5)	**<0.001**	−0.03	(−0.33 to 0.26)	0.829	0.11	(−0.19 to 0.42)		0.471	0.28	(−0.02 to 0.59)	0.071	1.8	(0.9 to 3.8)	0.109	
Diabetes mellitus (vs. no diabetes)		−1.0	(−2.2 to 0.1)	0.074	0.14	(−0.03 to 0.32)	0.112	0.14	(−0.04 to 0.32)		0.131	0.18	(0.00 to 0.36)	0.053	1.1	(0.7 to 1.7)	0.574	
Cognitive decline (vs. none)		−1.0	(−2.4 to −0.3)	0.123	0.08	(−0.13 to 0.29)	0.455	0.13	(−0.08 to 0.35)		0.229	0.14	(−0.07 to 0.36)	0.199	0.8	(0.5 to 1.4)	0.468	
Heart disease (any vs. none)		−1.0	(−2.2 to 2.7)	0.124	−0.14	(−0.33 to 0.05)	0.157	−0.20	(−0.40 to 0.00)		0.050	−0.11	(−0.31 to 0.09)	0.282	1.0	(0.7 to 1.6)	0.875	
Arthritis (vs. none)		−1.5	(−2.6 to −0.4)	**0.008**	−0.08	(−0.25 to 0.08)	0.315	0.02	(−0.15 to 0.19)		0.791	−0.08	(−0.25 to 0.09)	0.342	0.9	(0.7 to 1.4)	0.782	
Last dental visit within 12months (vs. > 12 months prior)		5.1	(4.0 to 6.1)	**<0.001**	−0.04	(−0.21 to 0.13)	0.651	−0.12	(−0.30 to 0.05)		0.173	−0.22	(−0.40 to −0.05)	**0.013**	1.1	(0.8 to 1.7)	0.457	

aOR = Adjusted Odds Ratio