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Interdental Cleaning and Periodontal Pocketing among Finnish Adults

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Abstract

Aim: To investigate the relationship between frequency of interdental cleaning and 11-year change in teeth with periodontal pocketing in Finnish adults.

Methods: Data from 1667 dentate adults, aged 30 to 82 years, who participated in the Health 2000 survey and were re-examined in 2004 and/or 2011 were analysed. Participants reported their frequency of interdental cleaning (either dental floss or interdental brush) at baseline. Teeth with periodontal pocketing (PD) \geq 4mm were counted in every survey and treated as a repeated outcome. The association between the frequency of interdental cleaning and the number of teeth with PD \geq 4mm was evaluated in linear mixed effects models, controlling for demographic factors, socioeconomic position, diabetes, smoking status, toothbrushing frequency, dental attendance and number of teeth.

Results: Twelve percent of adults reported daily interdental cleaning. Significant inverse linear trends in the number of teeth with PD \geq 4mm were found in every survey according to the frequency of interdental cleaning. However, this association was completely attenuated after adjustment for the full set of confounders. Contrarily, toothbrushing frequency was negatively associated with the baseline number of teeth with PD \geq 4mm and its rate of change over time.

Conclusion: Interdental cleaning was not associated with 11-year change in periodontal pocketing after accounting for other established risk factors for periodontal disease.

Clinical Relevance

Scientific rationale for study: The value of interdental cleaning for the prevention of periodontal disease is still unclear.

Principal findings: This population-based prospective study, which only examined pocket depth, shows interdental cleaning was not associated with changes in periodontal pocketing. Toothbrushing was inversely associated with changes in periodontal pocketing.

Practical implications: Interdental cleaning had no additional value to regular toothbrushing for the prevention of periodontal pocketing in the general population.

Introduction

Periodontitis is a chronic inflammatory plaque-related disease characterised by the progressive destruction of the tooth-supporting structure (Papapanou et al., 2018, Caton et al., 2018). Mechanical disruption of the biofilm, via toothbrushing and interdental cleaning, is considered an important strategy for the management of dental caries and gingivitis (Jepsen et al., 2017, Chapple et al., 2015). Interdental cleaning, using either floss or interdental brushes, is advocated to clean interproximal areas between adjacent teeth that a regular toothbrush cannot reach efficiently (Salzer et al., 2015). Flossing at least once daily is the most common recommendation for interdental cleaning (ADA, 2014, PHE/DoH, 2017).

It is now well established that toothbrushing prevents dental caries, especially when used as a means to deliver fluoride toothpaste (Kumar et al., 2016), and periodontal disease (Zimmermann et al., 2015). However, the same cannot be said with regard to interdental cleaning. There is insufficient, mostly weak evidence on the value of flossing and interdental brushing when compared to toothbrushing alone for plaque removal and the maintenance of gingival health (Sambunjak et al., 2011, Poklepovic et al., 2013, Salzer et al., 2015). Rather than not proven effective, some have argued that there is no high-quality evidence from robust prospective studies to evaluate if interdental cleaning prevents periodontal disease (Vernon et al., 2017, Vernon and Seacat, 2017).

Given that a clinical trial with a long follow-up period would be needed to observe changes in standard periodontal measurements (such as pocket depth or clinical attachment loss), longitudinal observational studies may provide useful evidence on this important area. Using data from an ongoing cohort, this study explored the association between frequency of interdental cleaning and the 11-year change in teeth with periodontal pocketing in adults.

Materials and Methods

This report follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The study was not specifically designed to address the research question but rather it was based on secondary analysis of existing data.

Data source

We pooled together data from three surveys in Finland (Figure 1). The Health 2000 Survey (BRIF8901) was a nationally-representative survey of 8028 adults, aged 30 years or more, selected using stratified two-stage cluster sampling (Aromaa and Koskinen, 2004). Of them, 6335 were dentally examined and 5255 were found to have one or more teeth. In 2004-05, 2000 adults were randomly selected from those who were dentally examined in 2000. After excluding participants who died or were edentate, and those living in health centre districts where <15 participants were recruited in 2000, the final sampling frame included 1248 adults who were invited to a new dental examination and 1049 participated. For the Health 2011 Survey, all participants of the Health 2000 Survey alive and in Finland were invited. Only participants living in Southern or Northern Finland (2 of the 5 examination areas, n=3713) were invited to participate in a new dental examination and 1496 agreed (Lundqvist and Mäki-Opas, 2016). The surveys were approved by the Ethics Committee at the Hospital District of Helsinki and Uusimaa. All participants signed a written informed consent before participation.

Overall, 1788 dentate adults had periodontal data for a minimum of two of the three surveys. Of them, 121 (7%) had missing data on relevant variables (education=8, smoking status=8, diabetes=42, toothbrushing=76, interdental cleaning=85, dental attendance=74) and were thus excluded. Periodontal data were available for 1667 adults in 2000, 840 in 2004 and 1031 in 2011. In addition, 1463 (88%) adults had periodontal data for two surveys and 204 (12%) for all three surveys. The follow-up time was 10.8 years, ranging from 10.2 to 11.2 years.

Variables selection

Interdental cleaning at baseline was the main exposure of interest. A single question asked participants about their frequency of interdental cleaning (use of dental floss or interdental brush) with four response options (daily, weekly, less frequently and not at all). Demographic characteristics (sex and age), socioeconomic position (education), health status (diabetes) and behaviours (toothbrushing frequency, smoking status and dental attendance pattern), all measured at baseline, were included in the analysis as confounders. Education was indicated by the highest qualification and participants classified as having completed basic, secondary or higher education. Diabetes was derived from multiple sources, either a positive response to the question ‘has a doctor ever diagnosed you with diabetes?’ or a fasting plasma glucose test ≥ 7.0 mmol/l. Toothbrushing frequency was collected using five options (more than twice daily, twice daily, once daily, less often than daily and never). As no participants in the study sample reported never brushing, analysis was based on the four remaining groups. Smoking status was defined according to four questions taken from the WHO (1998) questionnaire. Current smokers were those who reported that they smoked at least 100 times in their lifetime, they smoked regularly (daily for at least one year), and they last smoked today or the day before. Former smokers were those who reported that they smoked at least 100 times in their lifetime but did not smoke during the last year. Dental attendance pattern was reported using three options (regularly for check-ups, only when in trouble or never). Due to the small number of participants reporting never visiting the dentist (n=17), they were merged with those reporting only when in trouble. Self-reports on interdental cleaning and toothbrushing were validated against dental plaque levels at baseline. Dental plaque was assessed at three tooth surfaces (buccal surface of the most posterior tooth in the first sextant, lingual surface of the most posterior tooth in the fourth sextant, and the buccal surface of the lower left canine), with the highest of three categories (no visible plaque, visible plaque in gingival margin, visible plaque also elsewhere) being recorded. Significant positive trends in plaque levels were found by interdental cleaning and toothbrushing frequency (Table 1).

Dental examinations were conducted at every survey following the same protocol. They were carried out by 5 dentists in 2000, 1 in 2004/05 and 4 in 2011. Dentists examined participants while they were reclined on a portable dental chair, and using mouth mirror, WHO periodontal probe, headlamp and fibre optic light. The periodontal examination was based on the measurement of pocket depth (PD) at four sites per tooth (distobuccal, mid-buccal, mesiolingual and mid-lingual). Only the deepest site per tooth was recorded according to

three bands (0-3, 4-5, 6+mm). Third molars and root remnants were excluded. All dentists were trained and calibrated before the surveys. Under field conditions in 2000, Kappa statistics for inter- and intra-examiner reliability were 0.41 and 0.83 at tooth level, respectively (Suominen-Taipale et al., 2004, Suominen-Taipale et al., 2008). The number of teeth with $PD \geq 4$ mm for each participant was calculated in every survey and used as a repeated outcome measure (Joshi et al., 2018). The 4mm cut-off point reflects shallow pocketing and is the lower of two thresholds recommended for reporting PD data in epidemiological studies (Holtfreter et al., 2015, WHO, 2013).

Statistical analysis

Analyses were carried out using Stata SE version 15 (StataCorp LP, College Station, TX). The associations of interdental cleaning and toothbrushing with the number of teeth with $PD \geq 4$ mm in every survey were first examined. Student's t-test was used to compare the number of teeth with $PD \geq 4$ mm by sex, diabetes and dental attendance pattern whereas the analysis of variance (ANOVA) was used to compare the number of teeth with $PD \geq 4$ mm by age groups, education, smoking status, toothbrushing, interdental cleaning and number of teeth. Age and number of teeth were treated as categorical for these bivariable presentations only.

A linear mixed effects (LME) model was fitted to model the 11-year change in teeth with $PD \geq 4$ mm using the three periodontal assessments. LME models can model correlated (repeated) outcome measures with missing data and unevenly spaced measurement occasions (Singer and Willett, 2003, Twisk, 2013). Upon preliminary inspection of the data, two time indicators were chosen to model the non-linear nature of the average growth trajectory (i.e. a peak noted in the second survey). The first indicator was continuous age (centred at 46.9 years, the average age at baseline). The intercept and slope were fitted as random effects to model individual variation in baseline value and rate of change in teeth with $PD \geq 4$ mm, respectively. The second indicator was a fixed-effect variable with two categories (coded 1 for the second survey and 0 otherwise) called survey, to capture the increase in number of teeth with $PD \geq 4$ mm that was seen in the second survey. For sensitivity analysis, we used data from 2000 and 2011 only (n=1078) to assess the impact of removing the peak observed in 2004/05. The covariance matrix was estimated without imposing any constraints (unstructured).

A null model with both time indicators was first fitted to estimate the rate of change in teeth with $PD \geq 4$ mm. Then, the association of interdental cleaning with the 11-year change in teeth with $PD \geq 4$ mm was tested in sequential models. The main effects model included terms for all baseline predictors (sex, education, diabetes, smoking status, toothbrushing, interdental cleaning, dental attendance pattern and continuous number of teeth). All predictors were treated as time-invariant for analysis. In this model, the parameter associated with each predictor estimates its effect on the baseline number of teeth with $PD \geq 4$ mm. Then, the association of each predictor with the change in teeth with $PD \geq 4$ mm over time was tested by including their interaction (product term) with each time indicator to the main effects model. These interactions estimate the effect of the predictor on the change in teeth with $PD \geq 4$ mm over 11 years. The likelihood ratio test (LRT) was used to evaluate whether the addition of the interaction terms to the main effects model improved the goodness-of-fit of the model. The null hypothesis for the LRT assumes that the interaction terms are equal to zero and that the model containing only the main effects of predictors should be preferred. The final LME model consisted of all main effects and any significant interactions with time. To aid interpretation of the significant interactions, predicted mean number of teeth with $PD \geq 4$ mm at every survey (i.e. trajectories over time) were computed from the final LME model stratified according to the categories of the predictor.

Results

The study sample consisted of 54% women and middle-age adults (mean 46.9 years, SD: 10.9, range: 30-82). Participants excluded for missing data were older, reported less frequent toothbrushing and interdental cleaning, and had fewer teeth. An average of 4.0 (SD: 5.5, range: 0-28, adults without any $PD \geq 4$ mm: 37.1%), 6.4 (5.7, 0-27, 16.9%), and 4.6 (5.8, 0-28, 34.0%) teeth with $PD \geq 4$ mm were found in the first, second and third surveys, respectively. An average of 1.0 teeth (SD: 2.1) were lost over the follow-up. Furthermore, 69.0% and 29.4% of adults brushed their teeth at least twice daily and reported weekly interdental cleaning. Toothbrushing was more common among female, more educated and non-diabetic adults as well as among those with more teeth and reporting regular dental check-ups. Interdental cleaning was more common among females, more educated participants and never smokers as well as among those with more teeth and reporting regular dental check-ups (Table 2). Toothbrushing and interdental cleaning were positively correlated (Spearman's rho: 0.25, $p < 0.001$).

Table 3 shows crude associations of every predictor with the number of teeth with $PD \geq 4$ mm. At every survey, significant inverse linear trends in the number of teeth with $PD \geq 4$ mm were found according to interdental cleaning and toothbrushing whereas significant direct trends were found according to number of teeth and smoking status. Men also had more teeth affected than women in every survey. Age and diabetes were directly associated whereas education was negatively associated with number of teeth with $PD \geq 4$ mm, albeit not in every survey.

The null LME model showed an increase of 0.05 (95%CI: 0.03, 0.07) teeth with $PD \geq 4$ mm per additional year in the average age of participants. A positive covariance was found between intercept and slope (0.11; 95%CI: 0.05, 0.18), implying that the steepest positive increment over time was found among those with the highest baseline number of teeth with $PD \geq 4$ mm. The additional binary time indicator was also significant, suggesting an increase of 2.21 (95% CI: 1.85, 2.56) teeth with $PD \geq 4$ mm in 2004. According to the main effects model, interdental cleaning was not associated with the number of teeth with $PD \geq 4$ mm at baseline (Table 4). On the contrary, toothbrushing was inversely associated with the baseline number of teeth with $PD \geq 4$ mm, and it was also inversely associated with the rate of change in teeth with $PD \geq 4$ mm when added to the main effects model ($p=0.028$). Sex, education, smoking status and number of teeth were significantly associated with the rate of change in teeth with $PD \geq 4$ mm when tested separately. The final LME model contained the main effects for all predictors and the interactions of education ($p<0.001$), smoking status ($p=0.010$) and toothbrushing ($p=0.029$) with the two time indicators. Following the LRT, the interactions for sex and number of teeth were no longer significant after the above interactions had been considered and were therefore omitted from the model. In sensitivity analysis, similar results were obtained when using data from the first (2000) and third (2011) surveys only.

Predicted mean number of teeth with $PD \geq 4$ mm were computed from the final LME model to show the rates of changes (trajectories over time) for different groups according to their education, smoking status and toothbrushing frequency (Figure 2). By 2011, the predicted mean number of teeth with $PD \geq 4$ mm was 1.19 (95%CI: 0.55, 1.83) units higher among adults with basic than those with higher education; 2.66 (95%CI: 2.02, 3.31) and 0.27 (95%CI: -0.30, 0.84) units higher in current and former smokers than in never smokers; and 2.58 (95%CI: 1.06, 4.09), 2.09 (95%CI: 0.71, 3.46), and 1.90 (95%CI: 0.51, 3.29) units lower among those brushing, respectively, more than twice, twice and once daily than among those brushing less than daily.

Discussion

This longitudinal study found no benefit of interdental cleaning to prevent periodontal pocketing, over and above the effect of toothbrushing. Although interdental cleaning was inversely associated with periodontal pocketing in crude models, the association was fully accounted for by established risk factors for periodontal disease, which included diabetes, other behaviours (smoking, toothbrushing and dental attendance) and sociodemographic factors.

Although a negative dose-response relationship between interdental cleaning at baseline and levels of periodontal pocketing were observed at every timepoint, they become non-significant when potential confounders of the association were modelled. Toothbrushing and interdental cleaning were positively correlated in this sample, whereby interdental cleaning was more common among adults who brushed their teeth more often. It is therefore likely that interdental cleaning acted as a surrogate for (self-reported) toothbrushing frequency in unadjusted models. Another important confounding factor is socioeconomic position (indicated by participants' level of education in this study). There is strong evidence on the existence of social inequalities in periodontal disease (Borrell and Crawford, 2012, Schuch et al., 2017). Dental behaviours are also socially patterned as they are moulded by the circumstances where people live (Sanders et al., 2005, Singh et al., 2013). Failing to account for confounding factors and temporality between variables may explain differences with findings from three recent studies based on national cross-sectional data (Cepeda et al., 2017, Lee et al., 2018, Marchesan et al., 2018). That said, the proportion of participants reporting weekly interdental cleaning in this sample was much lower at 29.4% than that reported among American adults at 69% (Cepeda et al., 2017, Marchesan et al., 2018), which might explain, at least partially, the present findings.

Smoking was the strongest predictor of changes in periodontal pocketing, with differences of up to 2.6 teeth with shallow pockets between current and never smokers by the end of the follow-up. Toothbrushing was inversely associated with periodontal pocketing. By the end of the follow-up, adults brushing their teeth once, twice, and more than twice daily had, on average, two teeth with pocketing less than those brushing less often than daily. Diabetes and problem-oriented visits were associated with the baseline number of teeth with pocketing, but not with its rate of change over time. To clarify, these findings suggest that diabetic adults and those visiting the dentist regularly for check-ups started the follow-up period having more teeth with pocketing, but those differences did not worsen over time. The link between

diabetes and periodontal disease is well established (Nascimento et al., 2018). In addition, regular dental visits for check-ups might help maintaining periodontal health and controlling disease progression (Broadbent et al., 2006, Karimalakuzhiyil Alikutty and Bernabe, 2016).

Although this study found no additional benefit of interdental cleaning to the known effect of toothbrushing for the prevention of periodontal pocketing, this does not yet mean that interdental cleaning is not beneficial. Interdental cleaning could be beneficial to control disease progression among periodontal patients or for those with gingival recession (a periodontal measure not assessed in this study). Additional longitudinal studies in new settings would help corroborate and generalise these findings. Such studies should include multiple assessment of dental behaviours over time that precede full-mouth periodontal examinations. It also remains to be tested whether interdental cleaning is useful for the prevention of dental caries at proximal surfaces. For the time being, current health promotion activities at patient and population-level should focus on promoting toothbrushing behaviour (Jepsen et al., 2017, ADA, 2014, PHE/DoH, 2017, Chapple et al., 2015). What is needed is theory-driven population-based and chair-side strategies to encourage adherence to regular toothbrushing.

This study is not without limitations. First, because there were differences between those included and excluded from the study sample, the findings are not generalisable to the Finnish adult population. Second, the periodontal assessment was based on pocket depth only. Gingival recession and thus clinical attachment loss (CAL) were not assessed. PD change is not a reliable predictor of CAL (Michalowicz et al., 2013). A person could have stable levels of pocketing over time but increasing levels of recession, and therefore, periodontal disease progression (Holtfreter et al., 2015). Third, only one code (i.e. the worst condition) per tooth was recorded despite four sites per tooth being examined. As only interproximal sites would benefit from interdental cleaning, recording the deepest site per tooth (i.e. any of the four sites inspected) could have masked the association with interdental cleaning. In addition, partial-mouth recording yields lower prevalence and severity rates (Susin et al., 2005, Kingman et al., 2008, Eke et al., 2010). Fourth, interdental cleaning and toothbrushing were assessed through self-reports, which are prone to measurement error and weaker associations (Norwood et al., 2016). Misclassification of exposure could have occurred if participants reporting favourable behaviours did not have enough manual dexterity to remove plaque effectively. Although the two behaviours were validated against clinical levels of dental plaque, participants' skills and extent of cleaning were not clinically

confirmed. Finally, although data on behaviours were collected in two surveys (2000 and 2011), we only used 2000 data to avoid reciprocal causation (also known as reverse causality or endogeneity) that could have arisen in models linking contemporaneous data about time-varying predictors and outcome (i.e. effectively converting panel data into cross-sectional data) (Singer and Willett, 2003). Therefore, our research design (regressing repeated outcome measures upon baseline exposure) was robust to control for temporality, but do not represent changes in behaviours that occur over time.

In conclusion, this longitudinal study found no association between interdental cleaning and change in periodontal pocketing among Finnish adults after accounting for well-known determinants of periodontal disease. On the contrary, toothbrushing frequency was inversely associated with change in periodontal pocketing.

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Table 1. Validity of self-reports of toothbrushing and interdental cleaning frequency against clinical levels of dental plaque

Self-reports	No visible plaque		Visible plaque in gingival margin		Visible plaque also elsewhere		p value for trend ^a
	n	%	n	%	n	%	
<i>Toothbrushing</i>							<0.001
Less than daily	12	19.4	32	51.6	18	29.0	
Once daily	147	32.4	249	54.9	58	12.8	
Twice daily	414	42.2	486	49.5	81	8.3	
More than twice daily	69	42.6	81	50.0	12	7.4	
<i>Interdental cleaning</i>							<0.001
Never	262	34.1	402	52.3	105	13.7	
Less than weekly	152	37.9	215	53.6	34	8.5	
Weekly	136	45.8	141	47.5	20	6.7	
Daily	92	47.9	90	46.9	10	5.2	

^a Chi-squared test for linear trends was used

Table 2. Toothbrushing and interdental cleaning by baseline predictors (n=1667)

Baseline predictors	n	%	Brushing teeth twice or more/day		Weekly interdental cleaning	
			n	%	n	%
<i>Sex</i>						
Male	748	44.9	403	53.9	133	17.8
Female	919	55.1	742	80.7	357	38.9
<i>P value^a</i>			<0.001		<0.001	
<i>Age groups^b</i>						
30-34 years	250	15.0	177	70.8	76	30.4
35-44 years	520	31.2	360	69.2	144	27.7
45-54 years	490	29.4	337	68.8	156	31.8
55-64 years	295	17.7	192	65.1	83	28.1
65+ years	112	6.7	79	70.5	31	27.7
<i>P value for trend^a</i>			0.351		0.620	
<i>Education</i>						
Basic	390	23.4	229	58.7	108	27.7
Secondary	595	35.7	383	64.4	142	23.9
Higher	682	40.9	533	78.2	240	35.2
<i>P value for trend^a</i>			<0.001		<0.001	
<i>Diabetes</i>						
No	1569	94.1	1090	69.5	464	29.6
Yes	98	5.9	55	56.1	26	26.5
<i>P value^a</i>			0.006		0.521	
<i>Smoking status</i>						
Never	874	52.4	625	71.5	245	32.1
Former	344	20.6	217	63.1	132	29.2
Current	449	26.9	303	67.5	113	25.0
<i>P value for trend^a</i>			0.063		0.031	
<i>Toothbrushing frequency</i>						
Less than daily	62	3.7			4	6.5
Once daily	460	27.6			79	17.2
Twice daily	983	59.0			332	33.8
More than twice daily	162	9.7			75	46.3
<i>P value for trend^a</i>					<0.001	
<i>Interdental cleaning</i>						
Never	776	46.6	442	57.0		
Less than weekly	401	24.1	296	73.8		
Weekly	297	17.8	242	81.5		
Daily	193	11.6	165	85.5		
<i>P value for trend^a</i>			<0.001			
<i>Dental attendance pattern</i>						
Check-up	1055	63.3	783	74.2	386	36.6
Trouble	612	36.7	362	59.2	104	17.0
<i>P value^a</i>			<0.001		<0.001	
<i>Number of teeth^b</i>						
1-10 teeth	156	9.4	92	59.0	24	15.4
11-20 teeth	141	8.5	87	61.7	35	24.8
21+ teeth	1370	82.2	966	70.5	431	31.5
<i>P value for trend^a</i>			0.001		<0.001	

^a Chi-squared test was used for comparisons^b Groups used for presentation purposes only

Table 3. Number of teeth with pocketing \geq 4mm by baseline predictors

Baseline predictors	2000 (n=1667)		2004 (n=840)		2011 (n=1031)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
<i>Sex</i>						
Male	5.11	(6.13)	8.06	(6.13)	5.64	(6.39)
Female	3.14	(4.73)	4.96	(4.84)	3.73	(5.05)
<i>P value</i> ^a	<0.001		<0.001		<0.001	
<i>Age groups</i> ^b						
30-34 years	2.37	(3.86)	5.36	(5.43)		
35-44 years	3.46	(5.26)	6.50	(5.64)	3.27	(5.04)
45-54 years	4.41	(5.79)	6.25	(5.66)	4.93	(6.31)
55-64 years	5.12	(5.73)	6.55	(5.85)	4.65	(5.68)
65+ years	5.74	(6.39)	6.25	(5.66)	4.68	(5.41)
<i>P value for trend</i> ^d	<0.001		0.918		0.216	
<i>Education</i>						
Basic	4.63	(5.89)	6.64	(6.01)	4.57	(5.43)
Secondary	4.58	(6.02)	6.63	(5.41)	5.66	(6.38)
Higher	3.19	(4.60)	5.89	(5.69)	3.82	(5.30)
<i>P value for trend</i> ^d	<0.001		0.113		0.011	
<i>Diabetes</i>						
No	3.90	(5.37)	6.30	(5.66)	4.58	(5.78)
Yes	5.95	(6.87)	7.38	(5.87)	4.74	(5.58)
<i>P value</i> ^a	<0.001		0.170		0.848	
<i>Smoking status</i>						
Never	3.18	(4.66)	5.31	(5.15)	3.66	(4.88)
Former	4.09	(5.29)	6.18	(4.92)	4.39	(5.53)
Current	5.38	(6.61)	8.17	(6.60)	6.48	(6.94)
<i>P value for trend</i> ^d	<0.001		<0.001		<0.001	
<i>Toothbrushing frequency</i>						
Less than daily	6.35	(7.16)	10.74	(7.01)	8.59	(9.25)
Once daily	4.15	(5.77)	6.64	(5.65)	5.53	(6.25)
Twice daily	3.89	(5.22)	6.15	(5.49)	4.18	(5.32)
More than twice daily	3.58	(5.38)	5.02	(5.39)	3.33	(4.83)
<i>P value for trend</i> ^d	0.005		<0.001		<0.001	
<i>Interdental cleaning</i>						
Never	4.66	(6.06)	6.87	(5.99)	5.37	(6.30)
Less than weekly	3.35	(4.66)	6.34	(5.48)	4.38	(5.68)
Weekly	3.45	(4.95)	5.83	(5.42)	3.80	(5.12)
Daily	3.73	(5.19)	4.90	(4.62)	3.69	(4.70)
<i>P value for trend</i> ^d	0.001		0.001		0.001	
<i>Dental attendance pattern</i>						
Check-up	3.73	(5.08)	6.06	(5.58)	4.12	(5.32)
Trouble	4.53	(6.11)	6.87	(5.81)	5.45	(6.43)
<i>P value for trend</i> ^d	0.004		0.045		<0.001	
<i>Number of teeth</i> ^b						
1-10 teeth	1.37	(2.25)	2.38	(2.53)	2.08	(2.48)
11-20 teeth	4.15	(4.71)	5.31	(4.54)	5.17	(5.05)
21+ teeth	4.31	(5.74)	6.98	(5.87)	4.84	(6.07)
<i>P value for trend</i> ^d	<0.001		<0.001		<0.001	

^a t-test and analysis of variance were used to compare 2 and 3+ groups, respectively

^b Groups used for presentation purposes only

Table 4. Linear mixed effects (LME) models for the association between baseline predictors and number of teeth with pocketing \geq 4mm over 11 years (n=1667)

Baseline predictors	Model with main effects		Model with main effects and interactions ^b	
	Coef.	[95% CI]	Coef.	[95% CI]
Age ^a (centred at mean)	0.12	[0.10, 0.14]***	0.07	[-0.03, 0.16]
Survey (reference: no)	2.09	[1.74, 2.43]***	3.18	[1.37, 4.98]**
Sex (reference: Male)				
Female	-1.47	[-1.92, -1.02]***	-1.45	[-1.90, -1.00]***
Education (reference: Basic)				
Secondary	-0.23	[-0.81, 0.35]	-0.72	[-1.41, -0.03]*
Higher	-1.35	[-1.95, -0.76]***	-2.02	[-2.72, -1.33]***
Diabetes (reference: non-diabetic)				
Diabetic	0.94	[0.04, 1.84]*	0.89	[0.00, 1.79]*
Smoking status (reference: Never)				
Former	0.31	[-0.2, 0.82]	0.25	[-0.32, 0.81]
Current	2.42	[1.92, 2.92]***	2.07	[1.52, 2.62]***
Toothbrushing (reference: Less than daily)				
Once daily	-2.20	[-3.33, -1.08]***	-1.69	[-2.94, -0.44]**
Twice daily	-2.22	[-3.34, -1.10]***	-1.61	[-2.84, -0.37]*
More than twice daily	-2.77	[-4.05, -1.48]***	-1.97	[-3.41, -0.52]**
Interdental cleaning (reference: Never)				
Less than weekly	-0.66	[-1.34, 0.02]	-0.61	[-1.30, 0.08]
Weekly	-0.45	[-1.05, 0.14]	-0.46	[-1.06, 0.13]
Daily	-0.59	[-1.30, 0.11]	-0.62	[-1.33, 0.08]
Dental attendance pattern (reference: For check-ups)				
Only when in trouble	1.06	[0.62, 1.51]***	1.10	[0.66, 1.55]***
Number of teeth (centred at mean)	0.29	[0.25, 0.33]***	0.29	[0.25, 0.33]***
Age (centred at mean) X Education (reference: Basic)				
Secondary			0.07	[0.03, 0.12]**
Higher			0.06	[0.02, 0.11]**
Survey (reference: no) X Education (reference: Basic)				
Secondary			0.00	[-0.88, 0.88]
Higher			0.72	[-0.18, 1.61]
Age (centred at mean) X Smoking status (reference: Never)				
Former			0.00	[-0.04, 0.04]
Current			0.03	[-0.01, 0.07]
Survey (reference: no) X Smoking status (reference: Never)				
Former			0.25	[-0.59, 1.10]
Current			1.00	[0.18, 1.82]*
Age (centred at mean) X Toothbrushing frequency (reference: Less than daily)				
Once daily			0.02	[-0.08, 0.11]
Twice daily			-0.01	[-0.10, 0.09]
More than twice daily			0.00	[-0.11, 0.10]
Survey (reference: no) X Toothbrushing (reference: Less than daily)				
Once daily			-1.63	[-3.45, 0.18]
Twice daily			-1.73	[-3.50, 0.04]
More than twice daily			-2.43	[-4.44, -0.41]*

^a Participants' age was assessed in years and centred at mean age at baseline. The coefficient represents the increment in teeth with pocketing $>$ 4mm for every year increase in age.

^b Only significant interactions were included in the final model. Interactions were tested by contrasting nested models (with and without the interaction term) via the likelihood ratio test.

* p<0.05, ** p<0.01, *** p<0.001

Figures legend

Figure 1. Participation flowchart and data linkage for the Health 2000 Survey, the 2004/05 Follow-Up Survey of Adults' Oral Health and the Health 2011 Survey.

Figure 2. Predicted number of teeth with pocketing ≥ 4 mm according to education, smoking status, toothbrushing frequency and interdental cleaning. Predicted means were derived from the linear mixed effect model presented in Table 4.

