**Influence of poor oral health on physical frailty: a population-based cohort study of older British men**

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**Running title:** Influence of poor oral health on physical frailty.

**Impact statement:**

1. We certify that this paper presents novel investigations on longitudinal associations between a range of oral health measures and incident frailty. Only one previous study in a smaller sample has recently presented similar research ((Castrejón-Pérez RC, et al 2017, *Journal of Gerontology: Medical Sciences*).

2. The potential impact of this research on clinical care or health policy includes the following:

i) The identification and management of poor oral health in older people could be important in preventing frailty.

ii) Markers of poor oral health such as dry mouth or accumulation of oral health problems could be powerful markers and predictors of frailty in older people.

iii) Poor oral health could be potentially important as a modifiable risk factor for frailty.

**Abstract**

**Objective:** To investigate the associations of objective and subjective measures of oral health with incident physical frailty.

**Design:** Cross-sectional and longitudinal study with three years of follow-up using data from the British Regional Heart Study.

**Setting:** General practices in 24 British towns.

**Participants:** 1622 community-dwelling men aged 71-92 years.

**Measurements:** Objective assessments of oral health included tooth count and periodontal disease. Self-reported oral health measures included overall self-rated oral health, dry mouth symptoms, sensitivity to hot/cold/sweet and perceived difficulty eating. Frailty was defined using the Fried phenotype, including ≥3 of weight loss, grip strength, exhaustion, slowness and low physical activity. Incident frailty was assessed after three years of follow-up in 2014.

**Results:** Among 1622 men, 303 (19%) were frail at baseline (71-92 years). Having <21 teeth, complete tooth loss, fair/poor self-rated oral health, difficulty eating, dry mouth, and an increasing number of oral health problems were associated with a greater likelihood of being frail. Among 1284 men followed-up for 3 years, 107 (10%) became frail. The risk of incident frailty was higher among participants with ≥three dry mouth symptoms (odds ratio (OR)=2.03, 95%CI 1.18-3.48) and one (OR=2.34, 95%CI 1.18-4.64), two (OR=2.30, 95%CI 1.09-4.84) or ≥three (OR=2.72, 95%CI 1.11-6.64) oral health problems after adjustment for age, smoking, social class, history of cardiovascular disease or diabetes, and medications related to dry mouth.

**Conclusions:** The presence of oral health problems was associated with increased risks of being frail, and of developing frailty in older age. The identification and management of poor oral health in older people could be important in preventing frailty.

**Keywords:** Frailty, oral health, longitudinal investigations.

**Introduction**

The UK, in common with many other developed countries, is undergoing rapid demographic changes with dramatic increases in older populations. The numbers of people aged ≥65 years and ≥85 years in England & Wales are projected to increase by 25% and 50% respectively by 2033.[1] The health and well-being of older populations is, therefore, a public health priority. Oral health problems are widely prevalent health conditions among older people, and with populations ageing, the global burden of oral health problems has increased over the last 20 years.[2] Oral health problems in older people include excessive tooth loss, periodontal (gum) disease, dental caries (decay) and perceived dry mouth. In the UK, over 60% of older adults have periodontal disease, only about 40% of older adults have a functional dentition (regarded as ≥21 teeth), and over a third have dry mouth.[3, 4] These oral health problems have significant impacts on eating and swallowing, nutritional intake, speaking, and smiling, thus affecting several aspects of the health and well-being of older people.[5] Tooth loss and periodontal disease are also found to be associated with increased risks of morbidity, physical and cognitive decline, and mortality.[6-8]

Studies suggest that poor oral health is also associated with increased risks of frailty, which is, now recognised as a major healthcare challenge in ageing populations.[9] [10] Frailty is a state of increased vulnerability in older age to adverse outcomes including functional decline, hospitalisation, disability, long-term care, and death.[10, 11] Although studies show an association between poor oral health (for example, tooth loss) and frailty, studies so far mostly have limited oral health measures (typically, presence/ absence of teeth) in relation to individual aspects of frailty, and are mostly cross-sectional.[9] Three previous studies with a composite measure of frailty, investigating associations with oral health were cross-sectional.[12-14] Only one recent study comprising 237 older Mexican adults investigated the prospective association between oral health and frailty and found tooth loss and periodontal disease to be associated with an increased risk of incident frailty.[15] Further studies in different and larger study populations are needed to corroborate and establish the influence of oral health longitudinally on the development of frailty. Such investigations are needed in order to identify the role of oral health in reducing the burden of frailty in older age. In this unique national study comprising a sample of community-dwelling British men aged 71-92 years, we investigated whether objective and subjective oral health measures are associated with frailty prospectively over a three-year follow-up. We also examined whether these associations were independent of smoking, socioeconomic position and history of cardiovascular disease and diabetes.

**Methods**

The British Regional Heart Study (BRHS) is a prospective cohort comprising a socially and geographically representative sample of 7735 British men recruited from General Practices in 24 towns across Britain, initially examined in 1978-1980 at 40-59 years.[16] In 2010-2012, all surviving men then aged 71-92 years were invited to attend a re-examination. Ethical approval was provided by all relevant local research ethics committees. All men provided written informed consent to the investigations, which were carried out in accordance with the Declaration of Helsinki. Participants underwent a physical examination (n=1722) including anthropometric (height, weight, waist circumference) measurements and physical performance assessments including a walking test (time taken, in seconds, to walk 3 meters at normal walking pace), and grip strength measured with a Jamar Hydraulic Hand Dynamometer [16]. Grip strength (jn kilograms) was measured thrice for each hand, and the best of six readings was used for the analysis. Participants also completed a questionnaire at the time of examination or by post if they did not attend (n=2147) which included information such as their medical history and lifestyle factors. In 2014, a postal questionnaire was sent to the participants comprising medical, social and health-related questions as part of the on-going follow-up of the study. The investigations in the present study are based on the assessments made at 71-92 years in 2010-12 with follow-up until 2014.

*Oral health markers:* The physical examination at 71-92 years in 2010-12 included an oral health assessment comprising a count of natural teeth, and two measures of periodontal conditions on six index teeth (three in the upper and three in the lower jaw) – periodontal pocket depth (measures the gap between gums and tooth), and loss of attachment (the distance between the point at which the gum is attached and the “neck” of the tooth where the gum is attached in a healthy tooth).[17] Questionnaires included self-reported oral health measures including overall self-rated oral health (excellent, good or fair/poor), [18] dry mouth (based on the validated Xerostomia Inventory scale), [19] sensitivity to hot/cold/sweet and difficulty eating food.

*Frailty:* Frailty status at 71-92 years in 2010-2012 was based on the ‘Fried frailty phenotype’ using data from both questionnaires and the physical assessment.[11, 20] This included unintentional weight loss (assessed as ≥5% decrease in self-reported weight which was reported to be unintentional); exhaustion (if response to question ‘do you feel full of energy?’ was ‘no’); weakness (assessed as lowest fifth of grip strength distribution); slow walking speed (lowest fifth of walking speed).[11, 20] If walking speed was unavailable, we used information on self-reported slow walking pace (being unable to walk more than few steps or <200 yards or difficulty walking across a room) or low physical activity (self-report of being less/much less active than an average man). Presence of three or more of these components was defined as frailty.

Frailty status at the three-year follow-up in 2014 was based on information from postal questionnaires (response rate 64%). Frailty phenotype was based on subjective measures of the frailty components. This measure of frailty has been tested to be just as predictive of established adverse outcomes (disability, falls and mortality) as the frailty measure using objective measures in our study.[21] Exhaustion and low physical activity was assessed in the same way as at baseline (71-92 years) with questions on exhaustion (‘do you feel full of energy?’) and physical activity (less/much less active than an average man). Grip strength was based on participants’ rating of their grip strength compared with other people their age; response of ‘fair/poor’ was classified as low grip strength. Slow walking speed was based on self-report of usual walking pace. Participants who rated their walking pace as slow were classified as having slow walking speed. Weight loss was based on self-report of a ‘decrease’ in weight in the last four years.

*Covariates:* Socioeconomic position was based on the longest-held occupation recorded at study entry (aged 40-59 years) and comprised six social class groups (I, II, III non-manual, III manual, IV and V).[22] For the purposes of this study, social classes I, II, III-non-manual were grouped as non-manual, and III-manual, IV and V were grouped as manual social class. Detailed questions on smoking and medical history were included in the questionnaire in 2010-12. Smoking status was categorized as current smokers, long-term ex-smokers (gave up smoking before 1983), recent ex-smokers and those who never smoked. History of coronary heart disease (CHD) was based on report of a doctor-diagnosis of angina, heart attack (coronary thrombosis or myocardial infarction) or heart failure. History of diabetes was based on doctor-diagnosis of diabetes or having an impaired fasting glucose level >7 mmol/l. Regular use of prescribed medications with xerostomia (dry mouth) as a side-effect were identified from questionnaires and included antimuscarinics (anticholinergics), antidepressants (tricyclic and SSRI), alpha-blockers, antihistamines, antipsychotics, baclofen, bupropion, clonidine, 5HT1 agonists, opioids, tizanidine, and diuretics.[23] Participants were categorized in three groups as taking none, one, or ≥two of these medications.

Statistical analysis

Associations of oral health measures with frailty were examined both cross-sectionally (at 71-92 years in 2010-12) and prospectively (incident frailty at 3-year follow-up in 2014) using logistic regression models with ‘non-frail’ as the reference group. Two cut-offs were used for measures of tooth loss: 1) <21 teeth (the minimum considered for functional dentition), and 2) no teeth (edentulism). Two measures of periodontal conditions were examined – >20% sites affected by periodontal pockets >3.5mm as a proportion of the number of sites examined; and >20% sites affected by loss of attachment >5.5mm as a proportion of the number of sites examined. Self-rated oral health was grouped into excellent/good vs. fair/poor; dry mouth symptoms were categorised as: no symptoms, 1-2, and ≥3 symptoms; while sensitivity to hot/cold/sweet and difficulty eating were binary (yes or no). A cumulative measure of poor oral health was created combining complete tooth loss, fair/poor self-rated oral health, dryness of mouth, sensitivity to hot/cold/sweet and difficulty eating; this cumulative score was categorised as 0, 1, 2 and ≥3 oral health problems. Adjusted odds ratios (OR) with 95% confidence intervals (CI) were computed after adjustments for age, social class, smoking status, history of diabetes, history of CVD, and use of medications with dry mouth as a side effect. For the adjustments, age was fitted as a continuous variable. Social class (two levels); smoking status (four levels), history of CVD or diabetes (two levels), and use of medications (three levels) were fitted as categorical variables in the regression models. In the models for incident frailty, prevalent cases of frailty at baseline (2010-12) were excluded (n=168; 14%). All analyses were performed using Stata/SE 14 (Stata Corp., College Station, TX, USA).

**Results**

In 2010-12, 1722 participants aged 71-92 years attended for re-examination (55% response rate) of whom 1622 had complete data on frailty status. Questionnaires were completed by 2147 men (68% response rate). The prevalence of edentulism was 20% and 64% had <21 teeth. In terms of periodontal conditions, 25% had loss of attachment >5.5mm) and 29% periodontal pocket depth >3.5mm. For self-reported oral health measures, 11% reported sensitivity to hot/cold/sweet, 33% had one and 29% had two or more dry mouth symptoms, 34% rated their oral health as fair/poor, and 11% reported difficulty eating. The prevalence of frailty was 19% (n=303). After an average of three years follow-up, 1284 men completed a postal questionnaire in 2014 (64% response rate). Based on these follow-up data, 107 (10%) presented with incident frailty over the follow-up period.

Table 1 summarizes the baseline characteristics of participants aged 71-92 years according to their frailty status. Compared to non-frail participants, those identified as frail were older (on average) (p<0.0001) and were more likely to be of manual social class (p=0.03), have a history of diabetes or CVD (p<0.001), and to be currently prescribed two or more medications with dry mouth as a side-effect (p<0.001).

Table 2 shows the cross-sectional associations between oral health measures and frailty at baseline (71-92 years). In age-adjusted models, men who had <21 teeth, were edentulous, reported fair/poor self-rated oral health, difficulty eating, and dryness of mouth were more likely to be frail. Associations of edentulism (odds ratio=1.62, 95%CI 1.18-2.23), fair/poor self-rated oral health (odds ratio=1.55, 95%CI 1.17-2.06) and dry mouth symptoms (odds ratio for ≥3 symptoms=2.49, 95%CI 1.77-3.52) with frailty remained significant on further adjustment for smoking, social class, history of CVD or diabetes, and medication use. Increasing number of oral health problems was also significantly associated with being frail in the fully adjusted model (odds ratio per additional oral health problem=1.33, 95%CI 1.15-1.52; p for trend <0.001).

Table 3 presents odds ratios (95%CI) for incident frailty over a 3-year follow-up for each of the different oral health measures. In age-adjusted models, the risk of becoming frail over the three-year follow-up period was higher in participants who had <21 teeth (OR=1.64, 95%CI 1.03-2.60) or were edentulous (OR=1.78, 95%CI 1.10-2.88) and those reporting fair/poor oral health (OR=1.65, 95%CI 1.08-2.52). Periodontal measures of loss of attachment and periodontal pocket depth were not significantly associated with incident frailty. Problems of sensitivity to hot/cold/sweet (OR=1.13, 95%CI 0.69-1.84) and self-reported difficulty eating (OR=1.69, 95%CI 0.96-2.95) were also not significantly associated with incident frailty. Compared to those without dry mouth symptoms, participants with 1-2 (OR=1.83, 95%CI 1.09-3.07) or ≥3 dry mouth symptoms (OR=2.20, 95%CI 1.30-3.73) were at a higher risk of incident frailty. The odds ratio for every additional dry mouth symptom was 1.18 (95%CI 1.07-1.29; p for trend=0.001). Finally, the risk for incident frailty was higher in participants with a greater number of oral health problems; the additional risk conferred by a one item increase in the total number of oral health problems was 1.36 (95%CI 1.10-1.67; p for trend=0.005). After further adjustments for covariates, the risk of developing frailty remained higher among participants with ≥3 dry mouth symptoms (OR=2.03, 95% CI 1.18-3.48), as well as those with any one (OR=2.34, 95%CI 1.18-4.64), two (OR=2.30, 95%CI 1.09-4.84) or ≥3 (OR=2.72, 95%CI 1.11-6.64) oral health problems.

**Discussion**

Our study in a population-based sample of older British men aged 71-92 years showed that various aspects of poor oral health were associated with being frail, but also with an increased risk of incident frailty in older age. In our longitudinal investigations amongst 1054 older adults, we found that dry mouth and cumulative oral health problems were, in particular, associated with incidence of frailty independent of socioeconomic factors and comorbidities. These findings highlight the importance of oral health problems in older populations and the potential contribution of poor oral health to developing frailty.

The influence of poor oral health in older age on frailty is not well-established. [9, 12-14] The only previous prospective study to our knowledge recently published on oral health and frailty was amongst Mexican older adults.[15] Similar to our findings, the study also observed an association between tooth loss and frailty. However, unlike the previous study, we did not find periodontal disease markers to be associated with incident frailty, which could be due to the measures of periodontal disease in our study limited to six index teeth and possible differences in the study populations.

Notably in our prospective analyses, we found that complete tooth loss, poor self-rated oral health and dry mouth were associated with incident frailty over a three-year follow-up. However, the associations of tooth loss and poor self-rated oral health were attenuated on adjustment for socioeconomic factors and comorbidities. The influence of dry mouth remained significantly associated with incident frailty even after adjustments for covariates. Dry mouth in older age is often a consequence of polypharmacy, particularly as a side effect of the use of antidepressants, anti-hypertensive medications (α and β blockers, diuretics, calcium channel blockers, angiotensin-converting enzyme inhibitors).[24, 25] Dry mouth affects oral health-related quality of life, denture-related problems (sores and ulcers) and has important influences on eating and swallowing functions. It is possible that the influence of dry mouth on frailty is due to its impact on nutritional status.[26] Although self-reported difficulty eating itself was not associated with frailty, it is not a robust marker of nutritional status which needs to be further explored as a possible mediator using robust validated methods. It is also possible that the relation between dry mouth and frailty is mediated by underlying comorbidities. Although we adjusted for diabetes, CVD and medication use, the possibility of residual confounding remains. Another important finding our study, which has not been previously reported is the association between a composite or cumulative measure of oral health problems and frailty; we found that an increasing number of oral health problems was associated with a greater risk of incident frailty which remained significant on full adjustment.

Strengths and limitations

A particular strength of our study is that we have prospectively investigated associations between a range of oral health measures and incidence of frailty in a representative sample of older British men. The oral health measures in our study included both objective assessments of tooth count and periodontal disease and self-reported measures including self-rated oral health and dry mouth. Self-rated oral health is known to be a strong marker of oral disease,[18, 27, 28] while dry mouth is very prevalent, affecting over a third of older adults.[17, 25] We also created a composite score to capture the combined impact of oral health problems in older adults. Limitations of our study are that our sample comprised older men who were mostly white European. Therefore, our results have limited generalisability to older women and other ethnic groups. The moderate response rate of 55% for the physical examination at baseline is likely to have excluded those with worse health. As in previous examinations, non-responders tend to be older and have higher proportions of manual social class groups and poor/fair self-rated oral health. It is, therefore, possible that the role of socioeconomic position and co-morbidities was not fully accounted for in our adjustments of the associations between oral health measures and frailty. Our outcome measure of frailty was based on self-reported measures of frailty components, as opposed to the baseline measure of frailty which included objective measures of grip strength and walking speed. It is possible that our outcome measures under-estimated the incidence of frailty. Nevertheless, we have shown that this frailty measure is robust and is just as predictive of known adverse outcomes of frailty (disability, falls and mortality) compared to frailty measures comprising objective components.[21]

**Conclusions**

Our findings highlight the importance of oral health problems which are associated not only with the presence of physical frailty, but also potentially influence the development of frailty in older age. Our findings particularly highlight the importance of dry mouth and cumulative oral health problems, both of which were independently associated with incident frailty. Further research is needed to understand mechanisms underlying associations between oral health and frailty, for example to explore if the association is mediated through nutrition and inflammation. While causal associations cannot be fully established from our study, our findings suggest that dry mouth or accumulation of oral health problems could be powerful markers and predictors of frailty in older people. Increasing interests in identifying frail older people have led to tools such as the frailty index which includes deficits ranging from co-morbidities, poor physical function, to sensory impairments [10]. However, oral health remain under-recognised in the assessments and the care of older people. Markers of poor oral health could potentially be useful indicators of frailty and valuable additions to health screening assessments used in older people. Further research is needed to develop simple markers of oral health that could be used widely in assessments of older people. Poor oral health could also be potentially important as a modifiable risk factor for frailty through its impact on improved oral intake and nutritional status. This needs to be investigated through intervention studies.

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**Conflict of interest**

All authors declare that there are no competing interests.

**Author contributions**

SER, SGW, PHW, EP developed the original idea for the paper. SER wrote the first draft. EP, SER and AOP performed the analyses. SER, PHW, SGW, LTL, AOP, RGW, GT, PM, AAS contributed to the study design. All authors contributed to interpretation of data and the final version of the manuscript, and all are guarantors.

**Sponsor’s role**

None.

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**Table 1:** Baseline characteristics according to frailty status in a a population-based sample of 1,622 British men aged 71-92 years

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Non-frail (n=1319)** | **Frail (n=303)** | **p-value** |
| **Age,** mean (SD) | 77.92 (4.30) | 80.49 (5.37) | <0.001 |
| **History of diabetes or cardiovascular disease** | 518 (39%) | 180 (59%) | <0.001 |
| **Social Class** |  |  |  |
|  Non-manual social class | 703 (55%) | 139 (48%) | 0.03 |
|  Manual social class | 581 (45%) | 152 (52%) |
| **Smoking**  |  |  |  |
|  Never smoked | 521 (40%) | 94 (31%) | 0.03 |
|  Long-term ex-smokers (gave up before 1983) | 573 (43%) | 148 (49%) |
|  Recent ex-smokers | 178 (14%) | 52 (17%) |
|  Current smokers | 46 (3%) | 9 (3%) |
| Number of prescribed medications with xerostomia (dry mouth) as a side-effect |  |  |  |
|  0  | 774 (59%) | 141 (47%) | <0.001 |
|  1 | 420 (32%) | 115 (38%) |
|  >= 2 | 125 (9%) | 47 (16%) |

Proportions reported as n (%) unless otherwise specified

**Table 2:** Odds ratios (95%CI) for frailty according to oral health measures in a population-based study of 1,622 British men aged 71-92 years

|  |  |
| --- | --- |
|  | **Frailty (n=303; 19%)** |
|  | N (%) | Age-adjusted OR (95% CI) | Fully adjusted OR (95% CI)a |
| **Number of teeth**  |  |  |  |
|  ≥21 teeth (n=563) | 75 (13%) | 1.00 | 1.00 |
|  <21 teeth (n=1003) | 218 (22%) | **1.55 (1.15-2.08)** | 1.33 (0.97-1.82) |
| **Edentulism (No teeth)**  |  |  |  |
|  ≥1 teeth (n=1251) | 200 (16%) | 1.00 | 1.00 |
|  Edentulous (n=315) | 93 (30%) | **1.84 (1.37-2.48)** | **1.62 (1.18-2.23)** |
| **Loss of attachment (% of sites with >5.5 mm)**  |  |  |  |
|  <20% (n=896) | 130 (15%) | 1.00 | 1.00 |
|  ≥20% (n=291) | 47 (16%) | 1.07 (0.74-1.55) | 0.98 (0.67-1.45) |
| **Periodontal pocket depth based on % sites with >3.5mm** |  |  |  |
|  <20% (n=841) | 119 (14%) | 1.00 | 1.00 |
|  ≥20% (n=346) | 58 (17%) | 1.25 (0.88-1.78) | 1.11 (0.77-1.61) |
| **Self-rated oral health** |  |  |  |
|  Good/Excellent (n=1022) | 157 (15%) | 1.00 | 1.00 |
|  Fair/Poor (n=538) | 128 (24%) | **1.66 (1.27-2.16)** | **1.55 (1.17-2.06)** |
| **Difficulty eating** |  |  |  |
|  No (n=1443) | 254 (18%) | 1.00 | 1.00 |
|  Yes (n=179) | 49 (27%) | **1.55 (1.07-2.24)** | 1.40 (0.95-2.07) |
| **Sensitivity to hot/cold/sweet** |  |  |  |
|  No (n=1158) | 204 (18%) | 1.00 | 1.00 |
|  Yes (n=359) | 68 (19%) | 1.23 (0.90-1.69) | 1.22 (0.88-1.68) |
| **Dry mouth symptoms** |  |  |  |
|  No dry mouth symptoms (n=591) | 71 (12%) | 1.00 | 1.00 |
|  1-2 dry mouth symptom (n=515) | 90 (17%) | **1.59 (1.13-2.24)** | **1.56 (1.09-2.23)** |
|  ≥3 dry mouth symptoms (n=454) | 124 (27%) | **2.59 (1.86-3.60)** | **2.49 (1.77-3.52)** |
| Odds ratio per additional dry mouth symptom  |  | **1.24 (1.17-1.31)** ***p for trend< 0.001*** | **1.23 (1.16-1.30)*****p for trend< 0.001*** |
| **Cumulative oral health problems**b |  |  |  |
|  0 oral health problems (n=347) | 45 (13%) | 1.00 | 1.00 |
|  1 oral health problems (n=745) | 124 (17%) | 1.21 (0.83-1.76) | 1.07 (0.72-1.58) |
|  2 oral health problems (n=373) | 82 (22%) | **1.64 (1.09-2.47)** | 1.40 (0.92-2.13) |
|  ≥3 oral health problems (n=157) | 52 (33%) | **2.86 (1.79-4.56)** | **2.38 (1.45-3.90)** |
| Odds ratio per additional oral health problem |  | **1.39 (1.22-1.59)** ***p for trend< 0.001*** | **1.33 (1.15-1.52)*****p for trend < 0.001*** |

Bold indicates p<0.05

a Adjusted for age, social class, smoking status, history of diabetes or CVD and use of medication with dry mouth as a side-effect

bIncludes <21 teeth, difficulty eating, symptoms of dry mouth, and sensitivity to hot, cold or sweet

**Table 3:** Odds ratios (95%CI) for incident frailty according to oral health measures in a population-based study of 1054 British men aged 71-92 years followed-up for a 3-year period

|  |  |
| --- | --- |
|  | **Incident frailty (n=107; 10%)** |
|  | N (%) | Age-adjusted OR (95% CI) | Fully adjusted OR (95% CI)a |
| **Number of teeth**  |  |  |  |
|  ≥21 teeth (n=403) | 28 (7%) | 1.00 | 1.00 |
|  <21 teeth (n=618) | 75 (12%) | **1.64 (1.03-2.60)** | 1.46 (0.90-2.38) |
| **Edentulism (No teeth)** |  |  |  |
|  ≥1 teeth (n=852) | 75 (9%) | 1.00 | 1.00 |
| Edentulous (n=169) | 28 (17%) | **1.78 (1.10-2.88)** | 1.59 (0.95-2.65) |
| **Loss of attachment (% of sites with >5.5 mm)** |  |  |  |
|  <20% (n=624) | 48 (8%) | 1.00 | 1.00 |
|  ≥20% (n=194) | 20 (10%) | 1.24 (0.71-2.16) | 1.09 (0.60-1.97) |
| **Periodontal pocket depth based on % sites with >3.5mm** |  |  |  |
|  <20% (n=586) | 48 (8%) | 1.00 | 1.00 |
|  ≥20% (n=232) | 20 (9%) | 1.04 (0.60-1.80) | 1.02 (0.57-1.81) |
| **Self-rated oral health** |  |  |  |
|  Good/Excellent (n=688) | 57 (8%) | 1.00 | 1.00 |
|  Fair/Poor (n=329) | 44 (13%) | **1.65 (1.08-2.52)** | 1.54 (0.98-2.40) |
| **Difficulty eating** |  |  |  |
|  No (n=945) | 89 (9%) | 1.00 | 1.00 |
|  Yes (n=109) | 18 (17%) | 1.69 (0.96-2.95) | 1.39 (0.76-2.55) |
| **Sensitivity to hot/cold/sweet** |  |  |  |
|  No (n=762) | 74 (10%) | 1.00 | 1.00 |
|  Yes (n=236) | 24 (10%) | 1.13 (0.69-1.84) | 1.06 (0.63-1.79) |
| **Dry mouth symptoms** |  |  |  |
|  No dry mouth symptoms (n=401) | 27 (7%) | 1.00 | 1.00 |
|  1-2 dry mouth symptoms (n=346) | 39 (11%) | **1.83 (1.09-3.07)** | 1.62 (0.95-2.76) |
|  ≥3 dry mouth symptoms (n=274) | 38 (14%) | **2.20 (1.30-3.73)** | **2.03 (1.18-3.48)** |
| Odds ratio per additional dry mouth symptom |  | **1.18 (1.07-1.29),** ***p for trend=0.001*** | **1.16 (1.06-1.28),*****p for trend=0.002*** |
| **Cumulative oral health problems**b |  |  |  |
|  0 oral health problems (n=246) | 11 (4%) | 1.00 | 1.00 |
|  1 oral health problems (n=483) | 53 (11%) | **2.48 (1.26-4.86)** | **2.34 (1.18-4.64)** |
|  2 oral health problems (n=235) | 29 (12%) | **2.74 (1.33-5.65)** | **2.30 (1.09-4.84)** |
|  ≥3 oral health problems (n=90) | 14 (16%) | **3.45 (1.49-7.99)** | **2.72 (1.11-6.64)** |
| Odds ratio per additional oral health problem |  | **1.36 (1.10-1.67),*****p for trend=0.005*** | **1.26 (1.01-1.58),*****p for trend=0.04*** |
| Bold indicates p<0.05a Adjusted for age, social class, smoking status, history of diabetes or CVD, and use of medication with dry mouth as a side-effectbIncludes <21 teeth, difficulty eating, symptoms of dry mouth, and sensitivity to hot, cold or sweet |