Frailty and oral health: findings from the Concord Health and Ageing in Men Project (CHAMP)

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Funding information

The CHAMP study is funded by the National Health and Medical Research Council (NHMR), Australian Government, project grant number: 1065647-2014, and the Ageing and Alzheimer's Institute.

RUNNING TITLE: Frailty and oral health in older men

KEYWORDS: oral health, older men, frailty, comorbidities

Abstract

Objective: To examine whether frailty in older men is associated with poorer oral health and lower levels of dental service utilisation.

Background: Poor oral health has been associated with some frailty components. Less is known about the link between frailty and oral health outcomes.

Methods: a cross-sectional analysis. Data were collected from 601 older men with both frailty status and oral health information. Frailty was defined as meeting three or more of the Cardiovascular Health Study criteria: weight loss, weakness, exhaustion, slowness and low activity. Dental service utilisation [DSU] behavior was collected from self-response questionnaires and face-to-face interviews. Oral status (number of remaining and functional teeth, periodontal disease, active coronal decayed surface [ACDS], and self-rated oral health [SROH]) was recorded by two oral health therapists. The association between frailty and oral health behavior and risk markers was modelled using logistic regression.

Results: Nineteen percent of the participants were identified as frail. There were significant associations between frailty and dentition status (odds ratio [OR]: 2.49, 95% confidence interval [CI]: (1.17-5.30), and frailty and ACDS (OR: 3.01, CI: 1.50-6.08) but only ACDS remained significant after adjusting for confounders (adjusted OR: 2.46, CI: 1.17-5.18). There was no association between frailty and DSU and frailty and SROH.

Conclusion: Frailty was independently associated with presence of dental caries. However, dental service utilisation, self-rated oral health and other oral health markers were not significantly associated with frailty after adjusting for confounders. The prevalence of periodontal disease was high regardless of their frailty status.

1. INTRODUCTION

The ageing of the world's population has led to the World Health Organisation's call for public health action[1] and an international symposium for securing the oral health of older people.[2] In Australia it is estimated that by 2061 more than 22% of the population will be 65 years or older[3] with some 10 to 20 percent of the older population being frail,[4] suggesting the need for a comprehensive professional understanding of the oral health needs of frail older people.

Frailty has been defined in a variety of ways, with an increasing consensus that it is a clinical syndrome of "decreased reserve and resistance to stressors, resulting from cumulative declines across multiple physiological systems".[5] Frailty is distinguishable from disability, multi-morbidity and the geriatric syndromes but shares a conceptual pathway which inevitably leads to increased vulnerability, poor health outcomes and increasing dependency.[6] Frailty is a key concept in geriatric medicine diagnosis and health management planning and is increasingly being recognised as important in clinical and public health dental practice.[2,7,8]

Frailty and oral health have received increasing attention over the past decade as the consequences of an ageing society and the complexity of oral health care have become recognised and distinctions between disability, frailty and dependence are better understood by the medical and dental professions. The clinical impact on dental service provision has been at the forefront of much of the literature on the association between frailty and oral health.[2,4,9,10]

Six cross-sectional studies[7,11-15] have explored the association between frailty and oral health, testing the hypothesis that poorer oral health might be associated with frailty status. In this paper, we investigate the association between frailty and oral health outcomes.

There is considerable literature demonstrating that frail older people tend to have poorer general health and function.[16-21] However, frailty per se is associated with some diseases (such as depression and dementia) but not others, suggesting that the nature of frailty has not yet been completely characterised.[22] For example, what aspects of oral health are worse in frail, compared to non-frail, older people and what are the relationships between various general health co-morbidities, frailty and oral health? Although this study cannot answer these issues, a better understanding of such associations and linkages may provide guidance about what aspects of oral health and access to dental care should be the focus for oral health professions providing care to frail older people.

The purpose of the present paper is to explore the associations between frailty and oral health status and dental service utilisation among participants in the Concord Health and Ageing in Men Project (CHAMP). It is hypothesized that there are statistiscally significant associations ($p \leq 0.05$) between frailty and dental outcomes such as edentulism, number of teeth, the extent and severity of periodontal conditions, untreated dental caries, the use of dental services and self-perception of oral health status.

2. MATERIAL AND METHODS

2.1 Participants

CHAMP is a longitudinal epidemiological study of men aged 70-years and over drawn from an urban area of Sydney – Australia, between 2005 and 2007. The only exclusion criterion was living in a residential aged care facility. A full description of the project and socio-demographics of the original 1,705 participants was reported by Cumming et al in 2009.[23] Re-evaluation of participants has been undertaken at 2-, 5- and 8-year intervals. At the 8-year follow-up a standardised comprehensive oral health assessment was undertaken, and dental health behaviour questions were added to the nutrition, self-report and clinical questionnaires. The target population of the current study therefore was the 781 participants from the original CHAMP cohort of 1705 men who were available for re-examination of their general health situation during the 8th year of follow up (43.1% of the original sample). Over the 8-year period, 669 men from the original cohort (39.2%) had died. A further 301 men (17.6%) were unable to be contacted, had moved into a residential aged care facility or had withdrawn from the project because of ill health or other reason over the period. Of the remaining men, 614 participants were available for dental assessments (78.6% of the 8th year population). Intraoral assessments were conducted by two calibrated oral health therapists using data collection standards consistent with the Australian Research Centre for Population Oral Health (ARCPOH) protocols. The levels of inter-examiner reliability found for this survey were similar to benchmarks reported for The National Survey of Adult Oral Health (NSAOH) 2004–2006.[24] Details of the oral health data collection and reproducibility have been previously reported.[25]

The study was approved by the Sydney Local Health District Human Ethics Research Committee (HERC/14/CRGH/17).

2.2 Frailty

Frailty was defined as meeting three or more of the five criteria identified in the Cardiovascular Health Study (CHS) by Fried et al[5]: unintentional weight loss, weakness, exhaustion, slow walking speed and low activity. The so-called Fried Frailty Index is one of the most commonly used definitions of frailty. Modified criteria were used for weight loss, exhaustion and low activity as CHAMP did not use exactly the same assessments as the CHS. Weight loss was defined as current weight being at least 15% lower than self-reported heaviest weight (or weight at age 25 if self-reported heaviest weight was missing). Exhaustion was defined with the Short-form Health Survey (SF-12)[26] question 'how much of the time during the past 4 weeks did you have a lot of energy?' with the responses 'a little' or 'none of the time' indicating exhaustion. Low activity was defined as the lowest quintile on the Physical Activity Scale for the Elderly[27] (<73). Frailty was classified into three groups: robust (0 criteria present); pre-frail (1-2 criteria present) and frail (three or more criteria present). As an additional aim, data collected in this study could be compared with national prevalence information on Frailty.

2.3 Oral Health Measurements

Tooth loss, replacement teeth, dental caries and periodontal diseases were recorded by two calibrated oral health therapists. Most participants were assessed in their own homes. The status of the dentition was reported as dentate if the participant had one or more functional teeth. Those with

only root stumps or an implant supported denture were classed as edentate. The number of natural teeth was categorized in three groups using the same threshold as in the US National Health and Nutrition Examination Survey (NHANES III)[28]: 1-10, 11-20 and 21 or more teeth. Functional tooth units (FTU), defined as pairs of opposing teeth (sound, restored and decayed teeth), and artificial teeth on implant supported, fixed and removable prosthesis, were calculated as described by Kayser[29] and Ueno et al[30] and dichotomized as: posterior functional tooth units being >7 FTUs. Information about the dental health behavior of the men was obtained through the clinic questionnaire and were also dichotomized at recognized cut points, such as: use of dental services (the time from the last dental visit: <2 years or ≥2 years), reason for last dental visit (check-up or dental problem) and self-rated oral health (self-rated perception of oral health status: Excellent/Very good/Good or Fair/Poor).

Active coronal decayed surface was defined as a cavitation of enamel and dentine caused by the loss of tooth substance due to caries and assessed and recorded for each coronal tooth surface present. Periodontal disease was measured only in those men with no contra-indicating medical condition to pocket depth and gingival probing[25], providing data on 296 dentate participants. The prevalence of periodontal diseases was assessed measuring three sites per tooth (mesio-buccal, buccal and disto-buccal) and calculated using four approaches: first, in terms of Clinical Attachment Loss (CAL) of ≥ 5mm occurring at 5 or more sites; second, where the Löe and Silness Gingival Index score (GI) was ≥2; third, using the Centers for Disease Control and Prevention/American Academy of Periodontology (CDC/AAP) case definitions for severe, moderate, mild and no disease, where severe periodontitis was defined as having two or more interproximal sites with ≥ 6 mm CAL (not on the same tooth) AND one or more interproximal site(s) with ≥ 5mm periodontal pocket depth (PPD). Moderate/mild category comprised two lesser amounts of disease: moderate periodontitis, defined as two or more interproximal sites with ≥ 4 mm clinical CAL (not on the same tooth) OR two or more interproximal sites with PPD ≥ 5 mm, also not on the same tooth; and mild periodontitis, defined as ≥ 2 interproximal sites with ≥ 3mm CAL and ≥ 2 interproximal sites with ≥ 4mm PPD (not on the same tooth) or 1 site with ≥ 5mm. Finally, Total periodontitis was defined as the presence of severe or other periodontitis.[31]

2.4 Covariates

Sociodemographic (age group, country of birth, income, marital status, education), medical (comorbidities, cognition impairment, depression) and behavioral (smoking history, self-rated general health) characteristics were the main covariates. Participants were divided into four age groups (78-79, 80-84, 85-89, 90+). Income was characterised in three groups according to the source:[16] the lowest category was “pension only”; the intermediate was “pension plus other source”; and the highest category was “other income” – any possible combinations of superannuation, business, and wage. Country of birth (COB) was grouped into five categories: Australia; United Kingdom (UK); Greece; Italy; and other. Marital status was defined as married/de facto, divorced, never married, widowed and education level as having or not having post-school qualification.

Comorbidities (≥2 conditions) were assessed using a standardised questionnaire in which subjects reported if a physician had ever told them that they had diabetes, thyroid dysfunction, osteoporosis, Paget's disease, stroke, Parkinson's disease, kidney stones, dementia, depression, epilepsy, hypertension, heart attack, angina, congestive heart failure, intermittent claudication, chronic obstructive lung disease, liver disease, chronic kidney disease, cancer, osteo-arthritis or gout.[23]

Depressive symptoms were evaluated by the Geriatric Depression Scale, short form (GDS).[32] A total of five or more depressive symptoms was considered as indicative of possible depression. Cognition was evaluated by the Mini Mental State Examination (MMSE)[33] using a cut score of 27, indicating some form of cognition lost under this threshold. Smoking behavior was classed into two categories: never smoke or past/current smoker. Self-rated perception of general health (SRH) data were obtained and dichotomised into excellent/good versus fair/poor/very poor.

2.5 Statistical Analysis

A descriptive analysis was performed using Chi-square statistical tests presenting the characteristics of the population according to their frailty status. Then, a descriptive analysis of the association between frailty (study factor) and the oral-health components (outcomes) showed that only three oral health variables -Dentition Status, Active Coronal Decayed Surfaces (ACDS) and Self-rated Oral Health (SROH) were significantly associated with frailty. The next analytic step then examined the association between the additional general covariates (demographics and general health components) with each of these three oral health variables (dentition status, ACDS and SROH) to select potential confounders of the effect of frailty impacting on the oral health variables. Covariates with $p < .20$ in the bivariate analyses were included in the multivariate models. Logistic regression models were used to test the association between frailty and dentition status, frailty and ACDS and frailty and SROH. Backward elimination was used to identify independent variables which have most impact on the outcome variables. Confounders adjusted for in each of the multivariate models are shown on table 3. The data analysis for this paper was generated using SAS Studio 3.7 (Enterprise edition) software - Copyright © 2012-2017, SAS Institute Inc., Cary, NC, USA.

3. RESULTS

Table 1 summarises the distribution of the categories of frailty of the 601 men who completed both the frailty and oral health assessments in CHAMP, by demographic and medical characteristics.

Overall, 24.5% of men (n=147) presented as robust. The prevalence of pre-frailty was 56.2% (n=338) and a further 19.3% (n=116) were classed as frail. There were no statistically significant differences observed in the prevalence of frailty by country of birth, educational level or smoking behaviour. However, variation in distribution of men across the three frailty categories was significant for age, income, marital status, co-morbidity, cognitive impairment, depression and self-rated general health.

Table 2 shows specific dental characteristics and oral health outcomes according to frailty status. Of the 514 dentate participants with frailty data available, 92 (17.9%) presented with active coronal decay in one or more tooth surfaces. The proportion of men with dental caries increased across the three frailty categories from 11.1% in the robust category, to 17.9% of the pre-frail category and 27.4% of the frail category.

The proportion of men with CAL > 5mm at 5 or more sites and GI > 2 at 3 or more sites was high in all groups regardless of frailty status. Of the 294 men with complete periodontal and frailty data, 83.7% had five or more sites with CAL ≥5mm and 79.6% had three or more sites with a GI equal to or greater than 2. A higher proportion of frail men (83.3%) scored GI 2 or more than robust men (73.2%). Similarly, there was a higher proportion of participants with five or more sites with a CAL equal to or

greater than 5mm among the frail men (88.1%) than the robust men (82.9%). The overall "total periodontitis" estimates were very high with 83.4% of all men examined for periodontal disease classed as having "moderate to severe periodontal disease". A lower proportion of frail men (61.9%) self-rated their current dental status as "excellent/very good/good" compared with those who were pre-frail (74.1%) or robust (72.4%).

The three statistically significant bivariate associations of frailty with oral health outcomes were dentate status, active coronal decayed surfaces and self-reported perception of oral health. These were used as the outcome/dependent variables in the logistic regression modelling associations with frailty with adjustment for confounding factors: age, income, MMSE, smoking history, COB, GDS and SRH.

Table 3 summarises the findings of the three different models. In unadjusted models the OR for frailty and edentulism, compared to robust, was 2.49 (95% CI, 1.17-5.30) and for pre-frailty the OR was 2.14 (95% CI, 1.11-4.13). However, these associations were not maintained statistically significant after controlling for confounders. The unadjusted OR for active dental caries and frailty was 3.01 (95% CI, 1.50-6.08) and this remained statistically significant after adjusting for confounders (adjusted OR: 2.46, 95% CI 1.17-5.18). Odds ratios for associations between self-rated oral health and frailty were not statistically significant in either unadjusted or adjusted models.

4. DISCUSSION

There have been few empirical studies specifically looking at the relationships between oral health and frailty. Much of the literature on the relationship between oral health and frailty has been derived from a conceptual perspective that oral health has a cumulative effect on frailty throughout life, which may contribute to the development of additional chronic conditions, generating a network of interacting and self-perpetuating mechanisms, which can lead quickly to a negative health impact. [34,35]

The participants of CHAMP who underwent the oral health assessment showed the expected distribution of frailty by age and medical and geriatric disability.[22,36-39] This suggests that the sample is representative of older Australian men. The prevalence of frailty in the participants was 19.3%, with 56.2% falling into the pre-frail category and the remaining 24.5% were categorised as robust.

Our original hypotheses that there would an association between frailty and dental outcomes were only partly supported by our findings. In this study, the dependent variable "oral health status" was comprised of dentition status, active dental caries and self-rated oral health status, the three variables which were significantly associated with frailty in the bivariate analysis ($p \leq 0.05$). In the logistic regression analyses, frailty was significantly associated with dental caries after accounting for age and country of birth, suggesting that the reason for the higher prevalence of some dental characteristics in frail older people is likely to be due to factors like age and comorbidity rather than frailty directly, but further research is required to fully identify these associations.

Our findings contrast those of Castrejón-Pérez et al[7] with respect to periodontal disease (where it was concluded that subjects with "severe periodontitis have 5.3 times the risk of frailty") but support their findings that the number of natural teeth were not associated with frailty. Similarly, the report by de Andrade et al[12] showed a relationship between numbers of teeth and frailty when the edentate

were included in the bivariate analyses (when the comparison was made with edentate versus those with ≥ 21 teeth in the frail group), but no association with the pre-frail group. Further, their study showed no association of frailty with periodontal attachment loss. The de Andrade study is important as it used the same Fried et al measurements of frailty as CHAMP. They concluded that the only association between frailty and oral health condition, independent of socio-economic and general health status, was with the "need for dental prostheses".

Ramsay et al[39] measured similar oral health outcomes and self-perceptions of oral health to our study in British community-dwelling older men. The same proportion of British men was classified as frail (19%) as found in our study. Like the Ramsay et al study, our study found associations between frailty and having a dental problem (in our study measured by the presence of one or more tooth surfaces actively decayed). The British study also found significant associations between frailty and edentulism. However, our study did not show a significant association between frailty and dentition status. The substantive difference between this study and that of Ramsay et al was that our research questions were sequenced in the alternative direction. Our modelling looked at how frailty may impact on oral health. Ramsay et al modelled the association and influence of oral health on frailty. Both methods are valid but tell a different story.

In the CHAMP men, using the periodontal estimates favoured by Eke et al,[31] 83.7% had five or more sites with a CAL of 5mm or more, with 27.9% showing "severe" periodontal disease (≥2 interproximal sites with CAL ≥6mm and ≥ 1 interproximal site with a PD ≥ 4mm). Levy et al[40] used slightly different definitions for periodontal disease in their early report on adults aged 79 years and over but showed a similar distribution pattern of periodontal disease. The high level of moderate and severe periodontal disease in all groups including the robust group makes it unlikely that frailty is having an impact on periodontal diseases.

In the CHAMP study a higher proportion of frail men (27.4%) had ≥ 1 active coronal decayed surfaces, than either pre-frail (17.9%) or robust (11.1%) participants. The probability of having dental caries was 2.5 times higher in frail older men after allowing for confounders. This contrasts with the findings by de Andrade and colleagues who used the less sensitive tooth-unit level for measuring dental caries. Our study however failed to show a relationship between frailty and the use of dental services, which may have explained differences in treatment outcome. Further, although the bivariate analysis showed a significantly lower proportion of frail men (61.9%) who viewed their dental health as "excellent/very good/good" than the pre-frail (74.1%) or robust (72.4%) – this difference was not significant in the multivariate analysis. Niesten et al[41] interviewed 51 Dutch older people whom were classified on a slightly to severely frail scale. They identified three main themes relating frailty to oral health behaviour: oral hygiene routines sustaining a sense of worth; lack of motivation when the benefits of dental visits or daily tooth brushing were balanced against effort; and structural barriers "I'd like to, but I can't". Within these main themes a further layer of perceptions impacted on oral health outcomes. Dental care as a lower priority, physical and psychological frailty, and lack of social support impacted on use of dental services, together with a belief that a dentist could not improve their oral health. These socio-psychological factors, together with the current clinical literature which advises dental professionals to be more cautious with irreversible restorative interventions and apply a minimal interventional approach to the frail older person[2] – may account for the variation in untreated dental caries in the CHAMP participants. Further, the greater use of general health and community services by frail CHAMP men but not their use of dental services may be related to the

funding differences in Australia between general health services being covered by a national health insurance scheme (Medicare) while access to dental services is left to the private market.

This study has several strengths and limitations. The opportunity to include oral health measures within a longitudinal, multidisciplinary study of ageing is unique in the Australian context and has been only occasionally reported internationally. However, the manner in which both independent and dependent variables have been measured, analysed and reported has varied enormously and is one of the major limitations in comparing findings across studies. The cross-sectional nature of the analyses presented in this paper is a limitation as it makes it impossible to identify causal relationships. The measures used for some components of frailty (weight loss, exhaustion and physical activity) were slightly different from those used in the Cardiovascular Health Study. However, these changes are consistent with the original criteria. Noguchi et al[42] showed that the age-specific prevalence of frailty in CHAMP, using adapted criteria, is very similar to the prevalence in the Cardiovascular Health Study, the original study that generated the frailty variable that we used. Several other studies have also used minor variation of the CHS criteria.[17,43] However, it is likely that frail men are under-represented in the study due to the adaptation of the index. A selection bias may exist whereby the frailty status and oral health status of the remaining participants may be better than those who moved into a residential aged care facility or had withdrawn because of ill health or other reason over the period. Therefore, data presented on the prevalence of frailty and other variables could under-represent the true prevalence in the community. A further limitation is the relatively small sample size, especially for periodontal disease, where, due to medical reasons, there was a high exclusion rate for periodontal assessments of PD (consequently CAL estimates) and gingival probing with respect to ascertaining GI, resulting in limited statistical power to identify associations for some outcome variables. Another consideration is that the prevalence of periodontitis was measured assessing only three sites per tooth, compared with the six sites per tooth used by the CDC/AAP case definitions, which might have been underestimated in the results. It is recognised also that that there is no universal consensus that periodontal diseases in older adults are as destructive or as clinically significant in older adults as in younger adults.[44] The assessment of dental health behaviour was based on self-reported data alone and this can be a limitation. Information on medications were collected but have not been collated or analysed within the CHAMP data base as yet and this may be another limitation for this study considering that medications side effects may play a role in poor oral health outcomes.

5. CONCLUSIONS

Frailty was independently associated with the presence of active coronal decayed surface. However, frailty was not independently associated with any other oral health conditions, dental service utilisation or self-rated oral health. The prevalence of periodontal disease was high in this group of older men regardless of whether they were robust or frail. There does not appear to be any simple connections between frailty and oral health and further research is required.

ACKNOWLEDGEMENTS

The CHAMP study is funded by the National Health and Medical Research Council (project grant number 1065647, 2014) and the Ageing and Alzheimer's Institute. We thank all the staff working on CHAMP and the participants in the project. Special thanks to Mr. Steven Chu, Ms. Sandra Taylor and

Mr. Garry Law with data collection and Dr Benjamin Hsu for assistance with the statistical analyses. Dr Valdez is a recipient of a post-graduate scholarship of the McKnight Bequest, Ageing and Alzheimer's Institute.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest. The authors certify that they comply with the ethical guidelines for authorship.

DECLARATION

The views expressed are those of the authors, not of the funders. Data analysis and interpretation were carried out by the authors independently of the funding sources based on the available data. The corresponding author had full access to the survey data and had final responsibility for the decision to submit for publication. The funding body played no role in the formulation of the design, methods, subject recruitment, data collection, analysis, or preparation of this paper.

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TABLE 1. Demographic and general health characteristics of CHAMP men, according to frailty status.

	Robust	Pre-frail	Frail	Total	
Characteristic	n (%)				p-value[c]
Age Group (n=601)					
75-79	28 (19.1)	50 (14.8)	11 (9.5)	89 (14.8)	
80-84	88 (59.9)	158 (46.7)	37 (31.9)	283 (47.1)	<0.001
85-89	28 (19.0)	100 (29.6)	42 (36.2)	170 (28.3)	
90+	3 (2.0)	30 (8.9)	26 (22.4)	59 (9.8)	
Total	147 (24.5)	338 (56.2)	116 (19.3)	601 (100.0)	
Country of Birth (n=601)					
Australia	83 (56.5)	170 (50.3)	57 (49.1)	31 (51.6)	
UK	4 (2.7)	13 (3.8)	8 (6.9)	25 (4.2)	
Greece	5 (3.4)	17(5.0)	1 (0.9)	23 (3.8)	0.30
Italy	24 (16.3)	72 (21.3)	25 (21.5)	121 (20.1)	
Other	31 (21.1)	66 (19.5)	25 (21.5)	122 (20.3)	
Total	147 (24.5)	338 (56.2)	116 (19.3)	601 (100.0)	
Income source (n=601)					
Pension only	46 (31.3)	134 (39.6)	63 (54.3)	243 (40.4)	
Pensions+other	38 (25.8)	77 (22.8)	22 (18.9)	137 (22.8)	<0.01
Other income	63 (42.9)	127 (37.6)	31 (26.7)	221 (36.8)	
Total	147 (24.5)	338 (56.2)	116 (19.3)	601 (100.0)	
Marital Status (n=601)					
Married/De facto	119 (80.9)	244 (72.2)	75 (64.7)	438 (72.9)	
Widowed	12 (8.2)	66 (19.5)	33 (28.4)	111 (18.5)	<0.01
Divorced/separated	6 (4.1)	10 (2.9)	3 (2.6)	19 (3.2)	
Never married/Other	10.(6.8)	18 (5.3)	5 (4.3)	33 (5.4)	
Total	147 (24.5)	338 (56.2)	116 (19.3)	601 (100.0)	
Post-School Qualification (n=596)					
Yes	92 (63.5)	210 (62.5)	62 (53.9)	364 (61.1)	0.21
No	53 (36.5)	126 (37.5)	53 (46.1)	232 (38.9)	
Total	145 (24.3)	336 (56.4)	115 (19.3)	596 (100.0)	
Number of Co-morbidities (n=601)					
1 disease	81 (55.1)	156 (46.1)	35 (30.2)	272 (45.3)	0.0003
2 or more diseases	66 (44.9)	182 (53.9)	81 (69.8)	329 (54.7)	
Total	147 (24.5)	338 (56.2)	116 (19.3)	601 (100.0)	
MMSE[a] score (n=520)					
26 or less	29 (20.7)	76 (26.2)	41 (45.6)	146 (28.1)	0.0001
27 or more	111 (79.3)	214 (73.8)	49 (54.4)	374 (71.9)	
Total	140 (26.9)	290 (55.7)	90 (17.3)	520 (100.0)	
GDS[b] score (n=595)					
<5 score	138 (93.9)	287 (85.9)	64 (56.1)	489 (82.2)	<0.001
5 or more	9 (6.1)	47 (14.1)	50 (43.9)	106 (17.8)	
Total	147 (24.7)	334 (56.1)	114 (19.2)	595 (100.0)	
Smoking (n=601)					
Never	67 (45.6)	129 (38.2)	44 (37.9)	240 (39.9)	0.27
Past/current	80 (54.4)	209 (61.8)	72 (62.1)	361 (60.1)	
Total	147 (24.5)	338 (56.2)	116 (19.3)	601 (100.0)	
Self-rated Health (n=600)					
Excellent/Good	127 (86.4)	259 (76.6)	58 (50.4)	444 (74.0)	<0.001
Fair/Poor/V. poor	20 (13.6)	79 (23.4)	57 (49.6)	156 (26.0)	
Total	147 (24.5)	338 (56.3)	115 (19.2)	600 (100.0)	

[a]MMSE= Mini Mental State Examination

[b]GDS= Geriatric Depression Scale

[c]p-value= Overall p-value

TABLE 2. Oral health characteristics of the CHAMP men according to frailty status

Characteristic	Robust	Pre-frail	Frail	Total	p-value[d]
	n (%)				
Dentition Status (n=601)					
Edentate	12 (8.2)	54 (15.9)	21 (18.1)	87 (14.5)	0.04
Dentate	135 (91.8)	284 (84.0)	95 (81.9)	514 (85.5)	
Total	147 (24.5)	338 (56.2)	116 (19.3)	601 (100.0)	
Number of Natural Teeth (n=514)					
1-10	19 (14.1)	62 (21.8)	22 (23.2)	103 (20.0)	0.09
11-20	50 (37.0)	89 (31.3)	39 (41.0)	178 (34.6)	
≥21	66 (48.9)	133 (46.8)	34 (35.8)	233 (45.3)	
Total	135 (26.3)	284 (55.2)	95 (18.5)	514 (100.0)	
Decayed Tooth Surfaces (n=514)					
0	120 (88.9)	233 (82.0)	69 (72.6)	422 (82.1)	0.007
≥ 1	15 (11.1)	51 (17.9)	26 (27.4)	92 (17.9)	
Total	135 (26.3)	284 (55.2)	95 (18.5)	514 (100.0)	
CAL[a] (n=294)					
< 5 sites ≥ 5mm	14 (17.1)	29 (17.1)	5 (11.9)	48 (16.3)	0.70
5 or more sites ≥ 5mm	68 (82.9)	141 (82.9)	37 (88.1)	246 (83.7)	
Total	82 (27.9)	170 (57.8)	42 (14.3)	294 (100.0)	
GI[b] (n=294)					
< 3 sites ≥ GI 2	22 (26.8)	31 (18.2)	7 (16.7)	60 (20.4)	0.23
3 or more sites ≥ GI 2	60 (73.2)	139 (81.8)	35 (83.3)	234 (79.6)	
Total	82 (27.9)	170 (57.8)	42 (14.3)	294 (100.0)	
Perio Severity (n=294)					
No disease	9 (10.9)	25 (14.7)	6 (14.3)	40 (13.6)	0.63
Moderate/Mild	54 (65.9)	94 (55.3)	24 (57.1)	172 (58.5)	
Severe disease	19 (23.2)	51 (30.0)	12 (28.6)	82 (27.9)	
Total	82 (27.9)	170 (57.8)	42 (14.3)	294 (100.0)	
Total periodontitis (n=294)					
No Disease	9 (10.9)	25 (14.7)	6 (14.3)	40 (13.6)	0.71
Moderate to Severe	73 (89.0)	145 (85.3)	36 (85.7)	254 (83.4)	
Total	82 (27.9)	170 (57.8)	42 (14.3)	294 (100.0)	
FTU[c] (n=601)					
< 7 FTU	54 (36.7)	127 (37.6)	48 (41.4)	229 (38.1)	0.71
7-12 FTU	93 (63.3)	211 (62.4)	68 (58.6)	372 (61.9)	
Total	147 (24.5)	338 (56.2)	116 (19.3)	601 (100.0)	
Use of Dental Service (n=597)					
< 2 years	110 (74.8)	228 (68.1)	79 (68.7)	417 (69.8)	0.31
≥ 2 years	37 (25.2)	107 (31.9)	36 (31.3)	180 (30.2)	
Total	147 (24.6)	335 (56.1)	115 (19.3)	597 (100.0)	
Last Dental Visit (n=580)					
Check Up	61(42.4)	134(41.4)	42 (37.5)	237 (40.9)	0.71
Dental Problem	83 (57.6)	190 (58.6)	70 (62.5)	343 (59.1)	
Total	144 (24.8)	324 (55.9)	112 (19.3)	580 (100.0)	
Self-rated Oral Health (n=594)					
Excellent/Very good/Good	105 (72.4)	249 (74.1)	70 (61.9)	424 (71.4)	0.04
Fair/Poor	40 (27.6)	87 (25.9)	43 (38.1)	170 (28.6)	
Total	145 (24.4)	336 (56.6)	113 (19.0)	594 (100.0)	

[a]CAL=Clinical Attachment Loss

[b]GI=Gingival Index

[c] FTU=Functional Tooth Units

[d]p-value=Overall p-value

Note: The dentate sample was N=524; A full periodontal examination (including pocket depth and gingival probing) were only carried out on 296 participants with 2 missing values.

TABLE 3. Associations between oral health characteristics and frailty status, unadjusted and adjusted for confounders

	Dentition Status[a] (Edentate)	Active Coronal Decayed Surfaces[b] (Yes)	Self-rated oral health[c] (Excellent/V. good/Good)
	Odds Ratio (95% Confidence Interval) - p-value		
Unadjusted	**n= 601**	**n=514**	**n= 594**
Robust (reference)	1.00*	1.00**	1.00
Pre-Frail	2.14 (1.11-4.13)	1.75 (0.95-3.24)	1.09 (0.70-1.69)
Frail	2.49 (1.17-5.30)	3.01 (1.50-6.08)	0.62 (0.37-1.05)
Adjusted	**n= 520**	**n= 514**	**n= 587**
Robust (reference)	1.00	1.00*	1.00
Pre-Frail	1.99 (0.94-4.22)	1.60 (0.85-3.01)	1.37 (0.86-2.18)
Frail	1.54 (0.60-3.96)	2.46 (1.17-5.18)	1.28 (0.68-2.39)

[a] adjusted for: - AGE, INCOME, MMSE, SMOKING - Hosmer-Lemeshow goodness of fit test (p=0.82)
[b] adjusted for: - AGE, COB (country of birth) - Hosmer-Lemeshow goodness of fit test (p=0.65)
[c] adjusted for: - AGE, GDS, SRH (self-rated general health) - Hosmer-Lemeshow goodness of fit test (p=0.28)
* P<0.05.
** P<0.01.
Note: For each model, there were different sample numbers due to missing data values. In the dentition status model, the unadjusted and adjusted analysis were carried out on N=601 and N=520, respectively; In the Active Coronal Decayed Surfaces model, the unadjusted and adjusted analysis were carried out on N=514; In the Self-rated oral health model, the unadjusted and adjusted analysis were carried out on N=594 and N=587, respectively;