Periodontitis and quality of life: What is the role of socioeconomic status, sense of coherence, dental service use, and oral health practices? An exploratory theory guided analysis on a Norwegian population

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ABSTRACT

Aim: To utilise Andersen's behavioural model for health services' use as the theoretical framework to examine direct and indirect relationships between population characteristics, oral health behaviours and periodontitis and oral health impacts.

Materials and methods: The model was tested in a general adult population (n = 1,886) in Norway, using structural equation modelling. Socioeconomic status, sense of coherence (SOC), dental anxiety, perceived treatment need, oral health behaviours and oral health impact profile (OHIP-14) were collected through questionnaire. Periodontal examinations consisted of full-mouth recordings.

Results: Andersen's model explained a large part of the variance in use of dental services (58%) and oral health-related impacts (55%), and to a less extent periodontitis (19%). More social structure and stronger SOC was related to more enabling resources, which in turn was associated with more use of dental services. More use of dental services was related to more periodontitis and more periodontitis was associated with increased oral health impacts. A stronger SOC was associated with less oral impacts. There was no association between use of dental services and oral health impacts.

Conclusions: The result demonstrated complex relationships between population characteristics, oral health-related behaviours and oral health outcomes. Socioeconomic factors and smoking were main predictors of periodontitis. Regular dental visiting habits did not, however, reduce the likelihood of periodontitis.

CLINICAL RELEVANCE

Scientific rationale for the study: To examine how population characteristics are related to oral health behaviour, and how this in turn, is related to periodontitis and oral health impacts.

Principal findings: Self-perceived resources was a key determinant of use of dental services. Regular dental visiting habits did not reduce the likelihood of having periodontitis.

Practical implications: The results contradicted the assumption that regular and prevention-oriented dental attendance should prevent or control periodontitis.

INTRODUCTION

Periodontitis is a common disease among adults with a prevalence reported by European and US studies ranging from 31 to 76% (Hugoson et al., 2008, Bernabe and Marcenes, 2010, Holtfreter et al., 2010, Eke et al., 2015, Aimetti et al., 2015, Holde et al., 2017). Severe forms of the disease affect around 11% of the global population (Kassebaum et al., 2014). To be able to develop preventive strategies for periodontal disease it is important to understand characteristics associated with periodontitis. Several risk factors such as age, gender, socioeconomic status (Genco and Borgnakke, 2013), smoking (Calsina et al., 2002), and oral hygiene habits (Zimmermann et al., 2015) have been associated with the progression and severity of periodontitis.

As periodontitis is a complex disease with biological, behavioural and social risk factors, it is important not only to examine the individual influence of each factor but also to examine the periodontal risk network as a whole. To be able to do this, there is a need for a conceptual model to underpin the research and, alongside this, a more comprehensive statistical analysis. Currently, one of the ways to explore the interrelationship between several contributing factors simultaneously is to utilise theoretically driven structural equation modelling (SEM). SEM is a powerful statistical technique that allows simultaneous testing of complex direct and indirect (mediated) relationships between variables specified within a priori model (Kline 2005). So far, studies using SEM in relation to periodontitis have examined the relationship between psychological factors and periodontal health (Alkan et al., 2015), impact of psychological factors on the relationship between periodontal status and quality of life (Wright et al., 2017), gingivitis and the interaction of oral health-related behaviours (Furuta et al., 2011), or the relationship between periodontitis and specific systemic diseases (Fisher et al., 2011, Rebelo et al., 2016). No study to date has focused on determinants of oral health care practices and use of dental health services and their relationship with periodontitis and oral health related quality of life.

Andersen's behavioural model of health services' use (Andersen, 1968, Andersen, 1995) has been used as the conceptual framework in several studies of health care utilization. It was originally developed to predict and explain why and how people use health care services by integrating predisposing/social structural factors (e.g. income, education, physical environment), enabling resources (e.g. having the means to use available health services) and need for health care (e.g. how people view their need for care). These different population characteristics would, according to the model, help understand why some people are more likely to seek health care. As such, the model suggests that that different factors would be of differential importance depending on the seriousness of the health problem. The

model has, during the last three decades, been further extended and developed adding personal health practices and health outcomes/status (Andersen, 1995) (Fig. 1).

The extended Andersen behavioural model for health services' use (1995) has been tested in relation to dental care and oral health outcomes in two different general populations in the UK (Baker, 2009, Marshman et al., 2012). The results were in line with Andersen's model, however, the authors concluded that other important factors needed to be incorporated within the model to increase its usefulness for understanding dental access and oral health outcomes. Such factors include the cost of treatment as well as key psychosocial factors previously identified as important for oral health and quality of life (e.g. sense of coherence, dental attitudes). Sense of coherence (SOC) is a salutogenic concept and 'a specific way of viewing life as comprehensible, manageable and meaningful' (Antonovsky, 1987). It has been found to be important for adults' oral health in several recent studies including toothbrushing habits, eating fruit and vegetables, dental attendance, and oral health-related quality of life (Savolainen et al., 2005, Gupta et al., 2015, Elyasi et al., 2015).

The aim of the present study was to utilise Andersen's behavioural model for health services' use as the theoretical framework to explore the direct and indirect relationships between population characteristics, use of dental health care services, individuals' personal oral health practices, and periodontal health and self-reported oral health impacts. In addition, we incorporated within the model, SOC, in order to examine how it was related to adult's oral health and to other key factors determining individual's oral health. This exploratory model was tested in a general adult population with data from the Tromstannen Oral Health in Northern Norway (TOHNN) study (Holde et al., 2016) using structural equation modelling (SEM).

MATERIALS AND METHODS

Study design and participants

The TOHNN study was a cross-sectional study of adults 20-79 years old in Troms County, Norway. The randomized sample included 2,901 individuals. The estimated minimum sample size for the structural equation model with an effect size of 0.1, power of 0.8, five latent variables, 4 observed variables, and a probability set at 0.05 was 1,599 participants. Data were collected between October 2013 and November 2014, with 1,986 participants (68%). The regional committee for medical and health research ethics of the University of Tromsø, Norway, approved the study (2013/348/REK Nord). All participants provided written informed consent.

Selection of variables

Variables were chosen according to Andersen's behavioural model for health services' use (1995) and with reference to the two previous studies that had tested the model for oral health (Baker, 2009, Marshman et al., 2012). The latent and measured variables used in the analysis are summarized below. Detail of each construct, its operationalisation, measures including response options and scoring, can be seen in Supplementary material, Table 1.

Population Characteristics

Predisposing characteristics was measured with two latent variables: social structures and sense of coherence. The three measured (indicator) variables for social structures were education, annual household income, and urbanization. Education was divided into three categories (primary/middle school, high school and university level) and income four categories: 1) ≤300,000 NOK, 2) 300,001 – 450,000 NOK, 3) 450,001-900,000 NOK, and 4) >900,000 NOK. Urbanization was used as an indicator of number of inhabitants and availability of dentists as a ratio of inhabitants per dentist. The municipality with the larger town had the highest availability and was categorized as urban, two municipalities with smaller towns had the second highest availability and were categorized as suburban, and the remaining municipalities without towns had the lowest availability and were classified as rural. SOC was assessed with the Norwegian version (Eide, 1991) of Antonovsky's (1993) 'The orientation to life questionnaire', comprising 13 items. The three indicator variables were represented by the three SOC dimensions: comprehensibility (five items); manageability (four items); and meaningfulness (four items).

Enabling resources was measured with three indicator variables: declined treatment due to costs, perceived difficulty accessing a dentist (each assessed with one question), and dental anxiety (assessed with the Norwegian version of Corah's Dental Anxiety Scale (DAS) (Corah et al., 1978, Kvale et al., 1998). For analysis, the DAS-score was reversed so higher scores represented less dental anxiety.

Treatment need was measured as an observed variable and assessed with one item: 'If you saw a dentist tomorrow, do you think you would need treatment?' Response option were: yes, don't know or no.

Oral health related behaviours

Oral health related behaviours were represented by personal health practices and use of dental services. Toothbrushing frequency was measured as one item. Smoking was measured by pack-years categorised as non-smoker (no pack-years), light smoker (< 20 pack-years) and heavy smoker (≥ 20 pack-years). Use of dental services was measured as

a latent variable with two indicators: attendance orientation (assessed with the question 'For what reason do you seek dental services?') and frequency of attendance (assessed with the question 'How often do you attend dental services?'). Response options are presented in Table 1.

Oral health outcomes

Oral health outcomes included both clinical- and person-reported measures. The clinical measure was periodontitis. Clinical examinations were performed in a dental office by 11 calibrated dentists with assisting dental nurses Bleeding on probing (BoP) and periodontal pocket depth (PD) were assessed at six sites per tooth for all teeth. Third molars and implants were excluded from the analysis. For a more comprehensive description of the periodontal assessment see Holde et al., 2016 and Holde et al., 2017. Periodontitis was defined using case definitions developed by the Centers for Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP) (Eke et al., 2012, Eke et al., 2015). According to this definition, participants were classified with no, non-severe or severe periodontitis. Person-reported oral health was assessed with the Norwegian version of oral health impact profile (OHIP-14) (Slade, 1997, Dahl et al., 2011), a measure of people's perceptions of the social impact of oral disorders on their well-being. Chronbachs Alpha for OHIP-14 was 0.89. In line with similar SEM studies using the OHIP-14 (see Baker, 2009), person-reported oral health impacts were represented in the model as a latent variable with the three sub-scales – psychological, physical and social impacts – as the indicator variables. Responses to Items 1–2, 3–4, 5 and 10 were summed to represent physical function (range 3–15); Items 6–7 and 8–9 were summed to represent psychological function (range 2–10); Items 11–12 and 13–14 were summed to represent social function (range 2–10). Chronbach's Alpha for physical function was 0.73, psychological function 0.89, and social function 0.88, respectively.

Data analysis

Data were analysed using the IBM® SPSS® Statistics, version 24 and AMOS 24. For analysis, eligible individuals had to have complete periodontal recordings and two or more teeth in order to be diagnosed according to the CDC/AAP case definition for periodontitis. The classification was with the following definitions: 1) severe periodontitis: at least two interproximal sites with ≥6 mm clinical attachment loss (CAL) (not on the same tooth) and at least one interproximal site(s) with ≥5 mm PD; 2) moderate periodontitis: at least two interproximal sites with ≥4 mm CAL (not on the same tooth) or at least two interproximal sites with PD ≥5 mm (not on the same tooth); and 3) mild periodontitis: at least two

interproximal sites with ≥3 mm CAL and at least two interproximal sites with ≥4 mm PD (not on the same tooth) or one interproximal site with ≥5 mm PD.

Missing data occurred at very low frequency (0-3.9 %) except for one item in the OHIP-14 instrument (5.8%). An analysis of missing data pattern, computed by SPSS, showed that the missing values appeared to be missing at random. For all one-item variables, missing values were replaced with the median. When calculating SOC scores, individuals with more than three missing items were excluded from analysis. If three or fewer items were missing they were replaced by the median value of the remaining SOC items for that individual (Kanhai et al., 2014). For OHIP summary scores, individuals with more than two missing OHIP-items were excluded from analysis. When two or less items were missing, they were replaced with the sample median of the relevant OHIP-item (Slade et al., 2005). Individuals with more than one missing item in the DAS-scale were excluded from analysis. Where one item was missing, it was replaced with the median value of the remaining DAS items for that individual. Re-analysis of data excluding individuals with any missing items did not change mean scores by more than one decimal place or frequency distributions by more than one percentage point, except for income that changed 2.4 percentage points (not reported). The excluded individuals did not differ significantly in any of the key outcomes (periodontitis and oral health impacts) compared to those that were kept in the analysis.

In order to identify whether the indicators chosen to measure the five latent constructs were acceptable, confirmatory factor analysis was used (CFA). CFA is the first in the two-stage process of SEM (the measurement model) (Kline, 2015). CFA provides information on how indicator items (e.g. income) measure underlying (latent) constructs (e.g. social structures). The initial step of the analysis was to test a first order CFA with social structures, SOC, enabling resources, use of dental services and oral health impacts (OHIP-14) as the five latent constructs. Scale items (indicators) representing each of the five latent constructs are detailed in Table 1 (see also Fig. 2). Items were not allowed to load on more than one construct nor were error terms allowed to correlate, with the exception of the three domains of the SOC construct (Fig. 2).

Following specification of the measurement model, the next step in the analysis was to test a structural model which examined the direct and indirect relationships between the constructs as hypothesized in our revised Andersen's behavioural model for health services' use. In accordance with the model and with SOC as an additional predisposing factor based on findings from Gupta and co-workers (2015), 24 direct pathways were hypothesised. Population characteristics: social structures and SOC (higher scores) would predict more

enabling resources. Enabling recourses would in turn predict patients' perceived treatment need. More enabling resources would relate to less perceived treatment need. Social structure, SOC, enabling and treatment need would predict use of dental services, where more social structure, greater SOC, more enabling resources and less treatment need would relate to more use of dental services. Social structures, SOC, enabling resources, treatment need and use of dental services would predict periodontal health, which in turn would predict oral impacts, with more severe periodontitis relating to more oral impacts. Additionally, social structure and SOC would directly predict use of dental services, personal oral health practices (toothbrushing and smoking), periodontitis, and oral impacts. Use of dental services would predict personal oral health practices and oral impacts. Finally, personal oral health practices would predict periodontitis. The full model can be seen in Supplementary material, Figure 1.

AMOS estimates the total effects, which are made up of both direct effects (a path directly from one variables to another, e.g. social structures $\rightarrow$ enabling) and indirect effects (a path mediated through other variables, e.g. social structures $\rightarrow$ need via enabling resources). Because of the presence of both non-normal and categorical data, the model was estimated using bootstrapping wherein multiple samples (n = 900+) are randomly drawn from the original sample. The CFA model is then estimated in each dataset, and the results averaged. The ML bootstrap estimates and standard errors [together with bias-corrected 95% confidence intervals (CIs)] are then compared with the results from the original sample to examine stability of parameters and test statistics (Brown, 2006). Proportions of total effects (%) were calculated for direct and indirect effects. In cases where the direct and indirect effects had opposing directions, the proportion of the total effect could not be calculated because of suppression effect.

As recommended, model fit was evaluated using a range of indices from three fit classes; absolute, parsimony adjusted and comparative (Brown, 2006, Hu and Bentler, 1999). A $\chi 2$/df ratio of <3.0, RMSEA values <0.06, CFI and TLI ≥0.9 and an SRMR <0.08 were taken to indicate an acceptable model fit (Hu and Bentler, 1999).

RESULTS

In the final analysis, 1,819 out of 1,986 participants were included (923 women, mean age 47.1 ± 15.2 years). Forty-nine percent (n = 897) of participants had periodontitis, of which 9.0% (n = 163) had severe periodontitis. Proportions, mean values and range for each variable used in the model are presented in Table 1.

The measurement model was an acceptable fit on four of the five a priori indices (see Table 2, Model 1). The standardized estimates for this five-factor measurement model can be seen in Figure 2. Factors (latent variables) are in ellipses, items (indicator variables) are in rectangles and residual error terms in circles. All item loadings were significant (<0.001) and in the expected direction. The correlations between the five latent factors ranged between -0.53 and 0.71, indicating that they had acceptable discriminant validity (i.e. <0.85).

The structural model was an acceptable fit to the data meeting four of the five a priori criteria (Table 2, Model 2). Within this model, eighteen paths were significant (Fig. 3). In this model, 55%, 28%, 58%, 19% and 55% of the bootstrapped variance was accounted for in enabling resources, need, use of dental services, periodontitis and oral health impacts, respectively.

The direct effects are presented in Table 3. More of the social structures (greater income, higher educational level and urbanisation) (β = 0.17) and a stronger SOC (β = 0.72) was linked to more enabling resources. More enabling resources was, in turn, linked to lower perceived treatment need (β = -0.53) and more use of dental services (β = 0.99). Higher self-reported treatment need was related to more severe periodontitis (β = 0.07). More use of dental services was related to more frequent toothbrushing (β = 0.12) and more periodontitis (β = 0.07). More severe periodontitis was linked to increased patient-reported oral health impacts (β = 0.17). In addition, more of the social structures was associated with more frequent toothbrushing (β = 0.28), less likelihood of smoking (β = -0.20), less periodontitis (β = -0.27), and less oral health impacts (β = -0.13). A stronger SOC was associated with less use of dental services (β = -0.44), more frequent toothbrushing (β = 0.09), less likelihood of smoking (β = -0.16), more periodontitis (β = 0.25) and less oral health impacts (β = -0.73). Finally, more smoking was linked to more severe periodontitis (β = 0.20). The following five direct effects were not significant; treatment need-use of services, use of services-oral health impacts, toothbrushing-periodontitis, social structure-use of services, treatment need-oral health impacts.

There were twelve significant indirect paths (Table 3). More social structures was linked to lower perceived treatment need (β = -0.09), more use of dental services (β = 0.18), more frequent toothbrushing (β = 0.01), less severe periodontitis (β = -0.05) and less oral health impacts (β = -0.06). Stronger SOC was related to less perceived treatment need (β = -0.38), more use of dental services (β = 0.74), more frequent toothbrushing (β = 0.04) and less severe periodontitis (β = -0.04). More enabling resources was linked to more toothbrushing (β = 0.13). More use of dental services was associated with increased oral

health impacts (β = 0.01). More smoking was associated with increased oral health impacts (β = 0.03). These are total indirect paths, which comprise of separate indirect effects. Some paths consist of one potential effect (e.g. stronger SOC is linked to less perceived need via enabling resources), while some indirect paths can consist of multitude potential effects (e.g. social structures may be linked to less oral health impacts via more enabling resources, less perceived treatment need and less periodontitis).

DISCUSSION

The model explained a large amount of the variance in both use of dental services and oral health impacts, supporting use of Andersen's behavioural model for health services' use for explaining factors related to oral health. Enabling resources were found to be a key factor in predicting use of dental services. Absence of dental anxiety, not having declined treatment due to costs and no perceived difficulty accessing a dentist increased the likelihood of regular dental visits. Social structures only affected use of dental health services via enabling resources. A stronger SOC was directly linked to less likelihood of using dental services. However, for the indirect effect, when the inter-relationships between all variables in the model are considered, the association between SOC and use of dental services changed direction. When mediated through enabling resources a stronger SOC was related to more use of dental services. Enabling resources also influenced perceived treatment need, where individuals with dental anxiety and perceived difficulty accessing a dentist were more likely to report a higher treatment need. Self-reported treatment need was not, however, significantly associated with use of dental services, as reported by both Baker (2009) and Marshman et al. (2012) as the main predictor of oral health behaviour. A study of dental attendance among adult Finns also found perceived need for care to be a predictor of use of dental services in logistic regression analysis (Raittio et al., 2014). Frequency of participants with regular dental visiting habits was similar to reports from the other studies. Perceived treatment need was, on the other hand, notably higher in the current study where only one in four reported no need for treatment. For the current study population, use of dental services seem to be influenced by other factors than perceived need i.e. enabling resources - directly and as a mediator for predisposing characteristics.

Social structures (education, income and urbanisation) and SOC were important factors in predicting both clinically measured and self-reported oral health outcomes. Higher education, income and availability of dentists decreased the likelihood of periodontitis. This is supported by the literature where socioeconomic factors have been related to periodontitis (Eke et al., 2016, Borrell and Crawford, 2012, Petersen and Ogawa, 2012). A stronger SOC

was, interestingly, related to worse periodontal status. In previous studies of SOC and periodontitis, SOC has been related to self-perceived periodontal disease (Cyrino et al., 2016) but no relationship has been reported between SOC and clinical measures of periodontitis (Kanhai et al., 2014). As SOC is a psychological concept of how a person views their own life, it is plausible that it affects the way individuals perceive their own health, independent of their clinically measured health. It should also be considered that both SOC and periodontitis are positively correlated to age, which is not included in the model, and could be a potential mediator of the association between SOC and periodontitis.

Having higher education, income and availability to dentists was also associated with less oral health impacts. This was in contrast to findings by Baker (2009) where there was no direct association between socioeconomic status and self-reported oral health outcomes. Other studies of socioeconomic factors and subjective oral health supports the current findings, reporting socioeconomic inequalities in oral health-related impacts (Guarnizo-Herreno et al., 2014, Raittio et al., 2015). SOC was the main predictive factor for oral health-related impacts, where a stronger sense of coherence decreased the likelihood of having oral health impacts. This is in line with results from previous studies (Savolainen et al., 2005, Gupta et al., 2015). Self-reported treatment need and use of dental services had no direct effect on oral health impacts. This is again in contrast to findings by Baker (2009) and Marshman et al. (2012). Routine dental attendance was reported to have a protective effect on oral health-related quality of life in other studies (Almoznino et al., 2015).

Interestingly, use of dental services was related to a higher likelihood of having periodontitis. This result is in contrast to the assumption that regular and prevention-oriented dental attendance should prevent or control periodontitis. Also, in bivariate analysis, persons with yearly dental visits and persons only seeing a dentist for acute problems did not differ in regards to prevalence of both non-severe and severe periodontitis (Holde et al., 2017), further contradicting this assumption. Here, the sample was cross-sectional. Thus, whilst the data were modelled based on the causal ordering hypothesized within Andersen's model, such ordering does not imply a causal effect (Holland, 1988). In Andersen's revised model, many of the key relationships are hypothesized as being bidirectional; for example, seeking treatment (dental service use) may influence clinical outcomes but also vice versa. That is, persons undergoing periodontal treatment and maintenance would have more frequent dental visits. Further, successful control of initiation and progression of periodontitis is dependent both on patient cooperation in plaque control and provision of appropriate interventions and treatment by the dental practitioner. A study of US males from 1994 found that utilization of dental services was not predictive of the extent and severity of periodontitis

(Brown and Garcia, 1994). The same was reported for Swedish older adults, where regular dental visitors retained more teeth but had the same periodontal conditions as infrequent visitors (Renvert et al., 2011). This questions the effectiveness of utilization of dental services in relation to periodontitis prevention and control, and could be an indication of under-diagnosis or under-treatment of periodontal disease. However, to investigate this in more detail, more information would be required about participant's dental history and treatment. In addition, the testing of such reciprocal relationships needs to be incorporated into a longitudinal validation study. Such a study would allow cross-validation of the present model and possible alternative explanations such as those proposed above.

Strengths and limitations

Study limitations include the cross-sectional study design. As all variables were measured at the same point in time, the present analysis does not attempt to identify cause and effect relationships but rather was an exploratory theory-driven analysis which aimed to examine the complex relationship between several contributing factors. It would be useful, however, in future observational studies to utilise newer statistical tools such as marginal structural models, which allow for estimation of direct effects using a counterfactual scenario and which allow more assumptions about causality to be made (Robins et al., 2000, VanderWeele, 2012). It would also be interesting in future research to examine in more detail, and longitudinally, the mechanisms by which SOC may influence oral health behaviours (e.g. smoking) and, in turn, both clinical and person-centred oral health outcomes.

While the level of periodontitis in the current sample was comparable to those reported in European and US studies (Hugoson and Koch, 2008, Bernabe and Marcenes, 2010, Eke et al., 2015, Aimetti et al., 2015, Holtfreter et al., 2010), findings regarding use of dental services should be cautiously extrapolated to other regions and countries, as the structure of dental services might differ.

The study also has several strengths. This is the first study to test Andersen's behavioural model for health services' use with periodontitis as an outcome and to incorporate SOC within the model to examine its relationship to oral health and its determinants. Furthermore, the results validate previous findings regarding utilization of dental services and periodontitis by including multiple determinants rather than one or two as in previous studies, but also by assessing these using complex statistical methods that allow for testing of not just direct effects but also indirect effects. Thereby, giving information on, not only, *what* variables are related but also *how* they are related.

Conclusions

The present study highlights the complex relationships between population characteristics, oral health-related behaviours and oral health outcomes. Enabling resources were found to be a key determinant in the use of dental services. Socioeconomic factors and smoking were main predictors of periodontitis. Regular dental visiting habits did not, however, reduce the likelihood of periodontitis. There is a need for more knowledge about the effectiveness of dental health care utilization related to periodontitis prevention and control.

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TABLE 1. Items from the THONN-questionnaire that reflects a revised Andersen's behavioural models different concepts and constructs. N=1,819

Variable	N/Mean	%/SD	Min-max
PREDISPOSING CHARACTERISTICS			
Social structures (Latent variable)			
Education			
Primary/middle school	247	13.6	
High school	803	44.1	
University	769	42.3	
Income (household annually)			
≤300,000NOK	250	13.7	
>300,001-450,000NOK	589	32.4	
>450,001- 900,000NOK	620	34.1	
>900,000NOK	360	19.8	
Urbanization (availability to dentists)			
Rural	418	23.0	
Suburban (small towns)	567	31.2	
Urban (lager town)	834	45.8	
Salutogenic factors (Latent variable)			
Sense of Coherence (SOC)	68.5	10.5	25-90
Comprehensibility	25.5	4.8	5-35
Manageability	20.9	3.8	4-28
Meaningfulness	22.1	3.6	8-28
ENABLING RESOURCES (Latent variable)			
Declined treatment due to costs			
Yes	354	19.5	
No	1,465	80.5	
Difficulty attending dental services			
Yes/ Don't know	317	17.4	
No	1,502	82.6	
Dental Anxiety Scale	7.7	3.3	4-20
NEED (Observed variable)			
Perceived treatment need			
Would not need treatment	465	25.6	
Don't know	695	38.2	
Would need treatment	659	36.2	

ORAL HEALTH RELATED BEHAVIOUR			
Personal health practices			
Toothbrushing (Observed variable)			
Less than daily	68	3.7	
Once per day	468	24.1	
Twice per day	1,313	72.2	
Smoking habits (Observed variable)			
Non-smoker	1,553	85.4	
Light smoker (<20 pack years)	196	10.8	
Heavy smoker (≥20 pack years)	70	3.8	
Use of Dental Services (Latent variable)			
Attendance orientation			
Seldom/never attend DS	282	15.5	
Only when problem (pain, Lost fillings)	358	19.7	
Having routine recall/check-up	1,179	64.8	
Frequency of dental attendance			
Only when having problems	403	22.2	
Longer intervals than 2 years	202	11.1	
Every second year	244	13.4	
Every year	970	53.3	
ORAL HEALTH OUTCOMES			
Clinical			
Periodontitis diagnosis* (Observed variable)			
No periodontitis	922	50.7	
Non-severe periodontitis**	734	40.3	
Severe periodontitis	163	9.0	
Oral health impacts (person-reported)			
OHIP-14 (Latent variable)	19.4	6.5	14-70
OHIP physical	8.7	2.9	6-30
OHIP psychological	6.0	2.9	4-20
OHIP social	4.7	1.8	4-20

DS = Dental services; * CDC/AAP case definitions for reporting periodontitis in epidemiological studies; ** Mild and moderate periodontitis combined

TABLE 2. Fit indices for the measurement and structural models

Model	X^2/df	*p*	RMSEA	(90% CI)	CFI	TLI	SRMR	Criteria fitted
1.	4.938	0.000	**0.047**	(0.042–0.052)	**0.966**	**0.953**	**0.037**	4
2.	4.948	0.000	**0.047**	(0.043-0.051)	**0.949**	**0.931**	**0.050**	4

Model 1 = measurement model; Model 2 = periodontal structural model; X^2 = chi-square; df = degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis Index; RMSEA = root-mean-square error of approximation; CI = confidence interval; SRMR = standardized root mean square residual. Figures in bold are those that meet the a priori model fitting criteria.

TABLE 3. Direct and indirect effects for the Andersen's model (20-79 years old)

Effect	β	Bootstrap SE	Bias-corrected 95% CI	p	% of total effect
Direct effects					
Social structures – enabling	0.173	0.044	0.090/0.266	0.001	100
SOC – enabling	0.718	0.056	0.614/0.831	0.002	100
Enabling – treatment need	-0.528	0.023	-0.578/-0.483	0.001	100
Treatment need – use of DS	-0.065	0.036	-0.132/0.012	0.107	100
Use of DS – toothbrushing	0.122	0.030	0.070/0.187	0.001	100
Use of DS – smoking	-0.025	0.032	-0.086/0.038	0.473	100
Use of DS – periodontitis	0.074	0.032	0.010/0.136	0.025	-*
Use of DS – oral impacts	0.011	0.050	-0.080/0.116	0.790	50
Toothbrushing – periodontitis	-0.025	0.026	-0.077/0.025	0.324	100
Periodontitis – oral impacts	0.169	0.042	0.095/0.263	0.001	100
Social structures – use of DS	-0.062	0.048	-0.154/0.024	0.153	-*
Social structures – toothbrushing	0.277	0.033	0.219/0.340	0.002	95
Social structures – smoking	-0.198	0.031	-0.257/-0.138	0.002	99
Social structures – periodontitis	-0.273	0.035	-0.342/-0.202	0.003	86
Social structures – oral impacts	-0.126	0.040	-0.208/-0.049	0.001	69
SOC – use of DS	-0.436	0.163	-0.799/-0.231	0.002	-*
SOC – toothbrushing	0.085	0.042	0.002/0.164	0.046	70
SOC – smoking	-0.156	0.042	-0.241/-0.079	0.002	96
SOC – periodontitis	0.246	0.048	0.160/0.342	0.002	-*
SOC – oral impacts	-0.726	0.057	-0.835/-0.618	0.002	-*
Enabling – use of DS	0.990	0.167	0.782/1.390	0.002	97
Treatment need – periodontitis	0.072	0.028	0.014/0.125	0.014	-*
Treatment need – oral impacts	0.032	0.038	-0.053/0.103	0.445	74
Smoking – periodontitis	0.198	0.024	0.151/0.243	0.002	100

Indirect effects					
Social structures – treatment need	-0.091	0.024	-0.145/-0.049	0.001	100
Social structures – use of DS	0.177	0.053	0.086/0.300	0.002	-*
Social structures – toothbrushing	0.014	0.006	0.006/0.028	0.001	5
Social structures – smoking	-0.003	0.004	-0.012/0.003	0.324	1
Social structures – periodontitis	-0.045	0.012	-0.068/-0.023	0.002	14
Social structures – oral impacts	-0.056	0.016	-0.094/-0.030	0.001	31
SOC – treatment need	-0.379	0.035	-0.456/-0.318	0.001	100
SOC – use of DS	0.736	0.173	0.530/1.175	0.001	-*
SOC – toothbrushing	0.037	0.011	0.019/0.064	0.001	30
SOC – smoking	-0.007	0.010	-0.026/0.012	0.410	4
SOC – periodontitis	-0.040	0.017	-0.079/-0.012	0.009	-*
SOC – oral impacts	0.026	0.028	-0.018/0.086	0.309	-*
Enabling – use of DS	0.034	0.019	-0.006/0.067	0.101	3
Enabling – smoking	-0.026	0.034	-0.090/0.042	0.457	100
Enabling – toothbrushing	0.125	0.039	0.069/0.214	0.001	100
Enabling – periodontitis	0.029	0.035	-0.041/0.091	0.429	100
Enabling – oral impacts	-0.001	0.055	-0.095/0.122	0.986	100
Treatment need – smoking	0.002	0.003	-0.002/0.009	0.323	100
Treatment need – toothbrushing	-0.008	0.005	-0.021/0.000	0.063	100
Treatment need – periodontitis	-0.004	0.003	-0.013/0.000	0.081	-*
Treatment need – oral impacts	0.011	0.007	-0.002/0.027	0.101	26
Use of DS – periodontitis	-0.008	0.007	-0.021/0.006	0.266	-*
Use of DS – oral impacts	0.011	0.006	0.002/0.024	0.025	50
Toothbrushing – oral impacts	-0.004	0.005	-0.015/0.004	0.287	100
Smoking – oral impacts	0.033	0.009	0.017/0.055	0.001	100

β = bootstrapped standardised estimate; SE = standard error; CI = confidence interval; DS = dental services.
*Could not be calculated because of suppression effect.

FIGURE LEGENDS

Figure 1

Model of health service use and health outcomes based on Andersen's behavioural model (1995)

Figure 2

Bootstrapped ML standardised estimates for the confirmatory factor analysis. All figures $p < 0.01$.

Figure 3

Bootstrapped standardized estimates for the revised Andersen's behavioural model for health services' use. Solid lines = direct effect; dashed lines = indirect effect. * $p < 0.05$, ** $p < 0.01$.

SUPPORTING INFORMATION

Supplementary Table 1. Detail of each construct, its operationalisation, measures including response options and scoring.

Supplementary Figure 1. Full structural model with all direct hypothesized pathways.

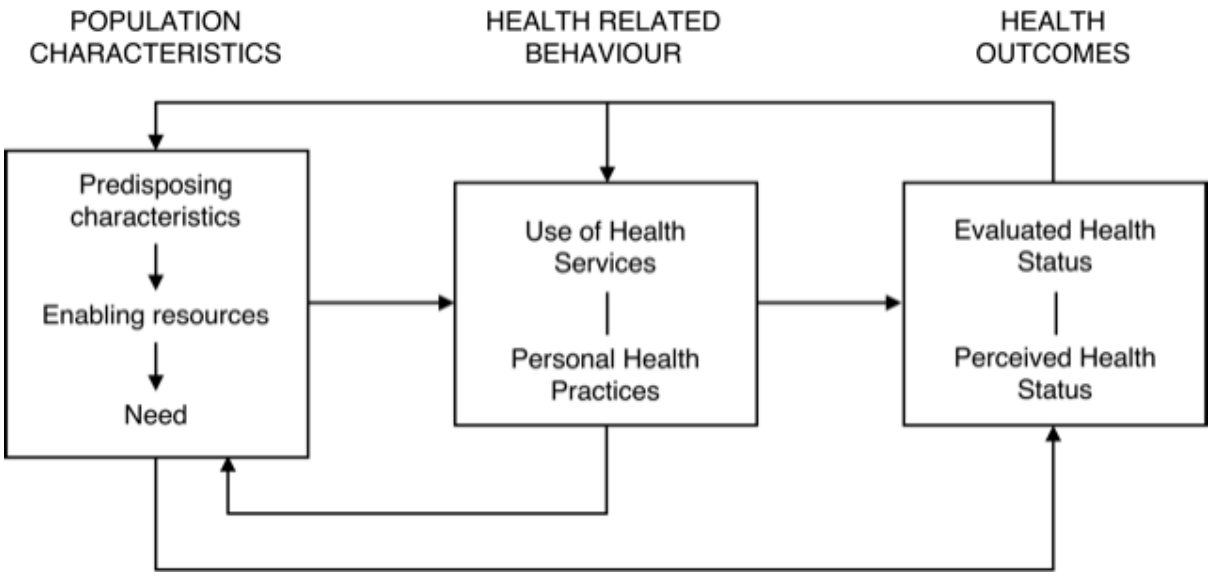

Figure 1. Model of health service use and health outcomes based on Andersen's behavioural model (1995)

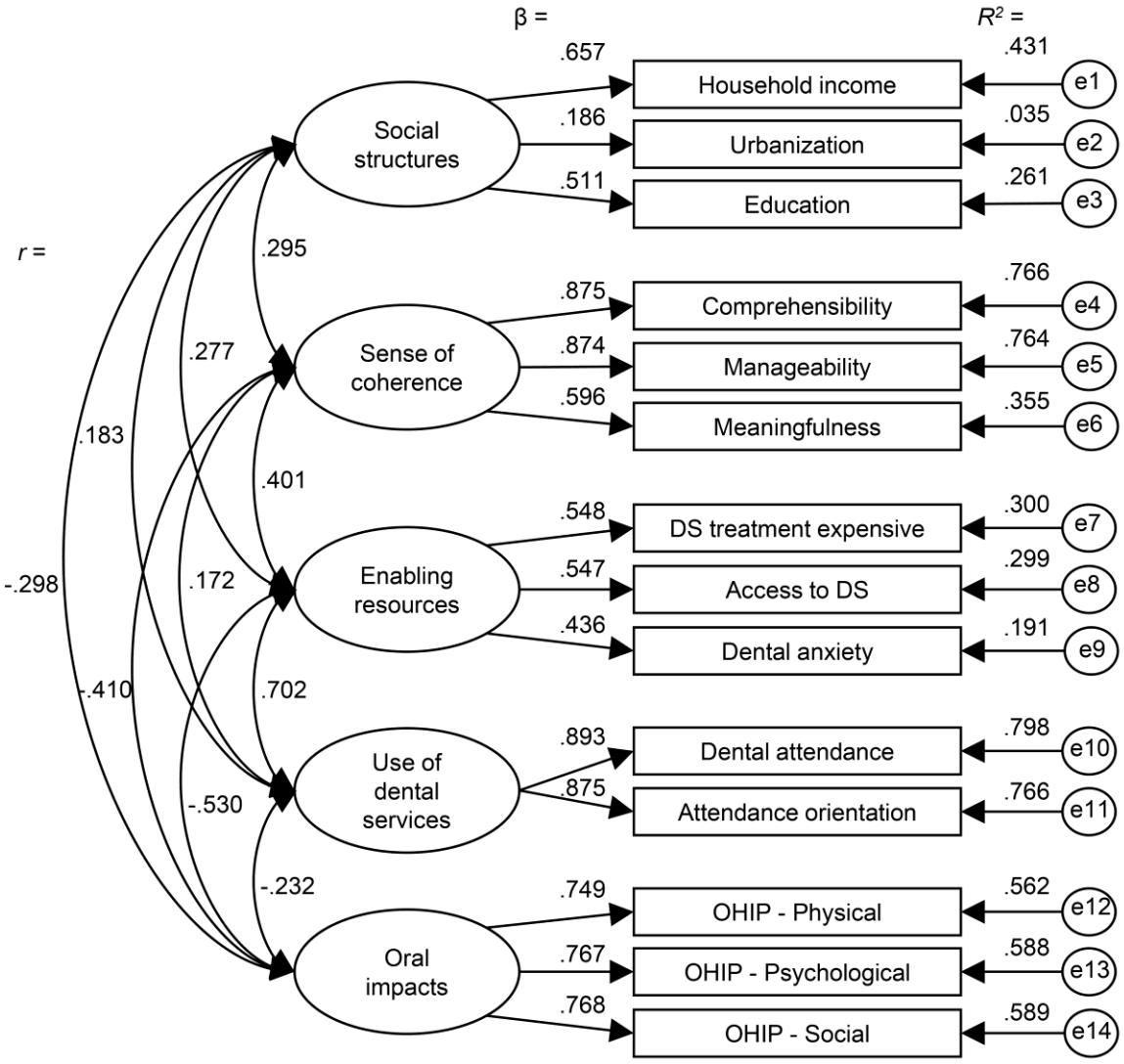

Figure 2. Bootstrapped ML standardised estimates for the confirmatory factor analysis. All figures $p < 0.01$.

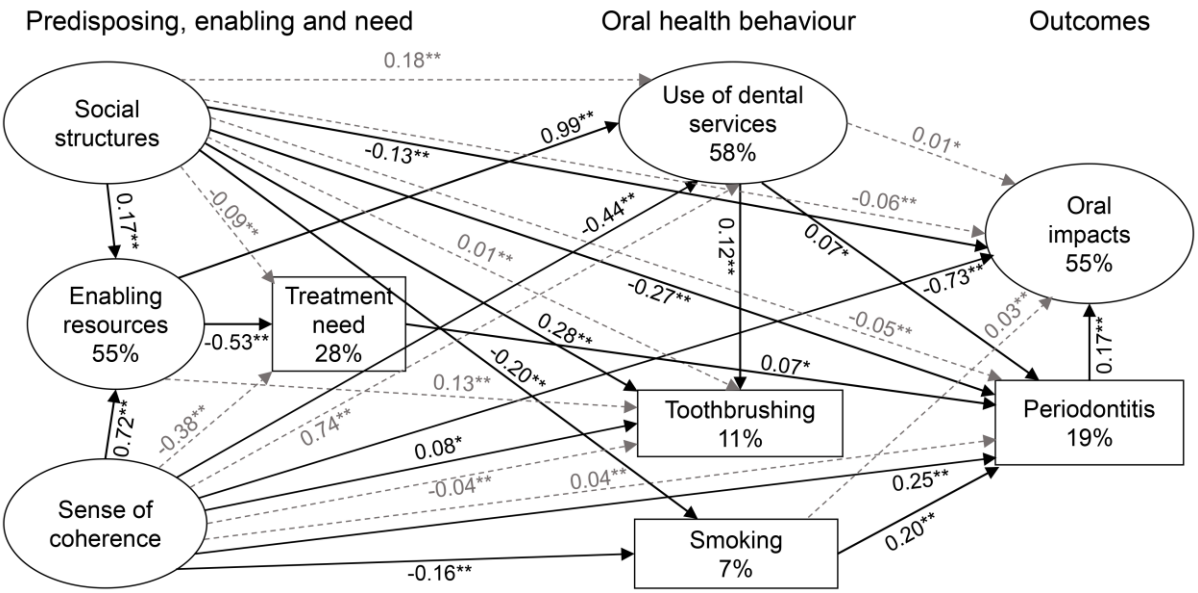

Figure 3. Bootstrapped standardized estimates for the revised Andersen's behavioural model for health services' use. Solid lines = direct effect; dashed lines = indirect effect. * $p < 0.05$, ** $p < 0.01$.