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Modelling the Validity of Periodontal Disease Screening Questions in a Nondental Clinical Setting

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ABSTRACT

Objective: Periodontal examinations are time-consuming and potentially uncomfortable for recipients. We modelled if self-reported questions alone, or combined with objective evidence of periodontal bone loss observable from radiographs, are accurate predictors of periodontitis.

Methods: Self-reported data from the Australian National Survey of Adult Oral Heath 2004-06 were compared with clinical periodontal examinations to assess the validity of 8 periodontitis screening questions in predicting moderate/severe periodontitis. To model alveolar bone loss, a proxy variable simulating radiographic clinical attachment level (rCAL) was created. Three multivariable binary logistic regression models were constructed: responses to 8 screening questions alone (Model 1), screening questions combined with 5 classic periodontitis risk indicators (age, sex, smoking status, country of birth, and diabetes status) (Model 2), and the addition of rCAL (Model 3). Predictive validity was determined via sensitivity (Se) and specificity (Sp) scores and graphically represented using area under the receiver operator characteristic curves (AUROC).

Results: Data from 3630 participants periodontally examined determined that 32.4% exhibited periodontitis. Periodontitis risk indicators were all significantly associated with periodontitis case status. Six of 8 screening questions (Model 1) were weak periodontitis predictors (Se = 0.28; Sp = 0.89; AUROC = 0.61). Combining 13 variables for (Model 2) improved prediction (Se = 0.55; Sp = 0.81; AUROC = 0.77). The addition of rCAL (Model 3) improved diagnostic capacity considerably (AUROC = 0.86).

Conclusions: Self-reported questions combined with classic risk indicators are "useful" for periodontitis screening. Addition of radiographs markedly improved diagnostic validity. Based on modelling, nondental health care professionals may provisionally screen for periodontitis with minimal training.

Introduction

One in 3 (30.1%) Australian adults experience "moderate" or "severe" periodontitis,[1] a chronic inflammatory condition affecting the supporting tissues surrounding teeth which can impede mastication and lead to tooth loss. Periodontitis may influence other systemic diseases or conditions and has been associated with diabetes,[2,3] chronic kidney disease,[4,5] (cardio) vascular diseases,[6-8] and cognitive decline,[9,10] among others.

According to Australia's most recent National Study of Adult Oral Health (NSAOH 2017-18), 56.4% of Australian adults had attended a dental practitioner within the previous year.[11] Potentially, this leaves millions of Australians without the opportunity to have a chronic disease such as periodontitis diagnosed and subsequently treated. Diagnosis of periodontitis occurs via clinical assessment of periodontal pocketing or clinical attachment loss. Given the cost and resources required to collect clinical data and the potential for patient discomfort during the examination process, it may be beneficial for patients to be preliminarily screened for periodontitis using nonclinical methods.

Self-report is an efficient means for assessing many diseases such as cardiovascular disease, cancer, hypertension,

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and diabetes.[12,13] The validity of self-report regarding periodontitis has previously shown promise when combined with other medical and demographic characteristics[14-18] In 2003, the US Centers for Disease Control and Prevention (CDC) in collaboration with the American Academy of Periodontology (AAP) compiled a series of 8 periodontitis screening questions from separate existing data sets in an effort to determine whether they were valid for population-based surveillance.[14,16]

If periodontal screening questions are valid in predicting periodontitis, then it may be possible to incorporate those into nondental health consultations such as when visiting a general medical practitioner. Affirmative question responses may then encourage health care providers to refer a patient for conventional bitewings or panoramic radiographs as a second stage of screening and disease confirmation. Therefore, the aim of this study is to determine if patient self-report and easy to assess clinical measures are sufficiently accurate to predict periodontitis using data from a representative sample of the Australian population.

Materials and methods

Data for this investigation arose from the Australian National Survey of Adult Oral Health 2004-2006 (NSAOH 2004-06) which has been detailed elsewhere.[19] The NSAOH 2004-06 was a cross-sectional study comprising Australia's second oral examination survey of a representative sample of Australian adults.

Sampling of subjects

A 3-stage stratified clustered sampling design was used to select people aged 15 years and older from a selected household. The first stage selected a random sample of postcodes; the second selected a random sample of households in each of the postcodes; and the third stage selected 1 person from each of the selected households. Those selected were interviewed using computer-assisted telephone interviews that were conducted through the University of Adelaide's research offices. Dentate individuals were invited to undergo an oral epidemiological examination that was conducted by trained and calibrated dental practitioners.[20]

Computer-assisted telephone interview survey

The telephone interview consisted of approximately 70 questions concerning oral health status, use of dental services, risk factors for oral disease and sociodemographic characteristics (such as age, sex, country of birth—defined as Australia, United Kingdom/New Zealand, or other), smoking history (defined as current, former, never), and self-reported doctor's diagnosis of diabetes mellitus). Included among those 70 where 6 CDC-AAP periodontal screening questions that were answered by all participants. An additional 2 screening questions were added late in the NSAOH 2004-06 and responses from 3630 individuals were available for analysis.

Oral epidemiological examinations

Dentists employed by state/territory public dental services conducted examinations. All examiners undertook a 2-day training and calibration session at the University of Adelaide. These included measurement of tooth loss, dental caries experience, and (for those without medical contraindications) assessment of periodontal status. The periodontal examination protocol was based on the methods of the US National Health and Nutrition Examination Survey of 2004[21] and included probing depth and gingival recession measured in millimetres using a PCP2 periodontal probe. Periodontal measurements were made at 3 buccal sites (mesio-buccal, midbuccal, and disto-buccal) of all teeth excluding third molars. Tooth-level bleeding on probing was not collected in the NSAOH 2004-26. In lieu, the Loe and Silness Gingival Index (1963)[22] was measured for 6 index teeth that provided a representation of whole-mouth gingival status. Interexaminer agreement for clinical attachment loss (CAL) and pocket probing depth (PPD) within 1 millimetre was 0.59 and 0.54, respectively.[20]

Ethical conduct of research

This project was reviewed and approved by the University of Adelaide's Human Research Ethics Committee. Interviewed participants provided verbal consent prior to answering questions, and all examined subjects provided written consent for participation in the clinical phase of the study.

Periodontitis case definition

Case definitions for periodontitis formed the gold standard for predictive validity. Examiners did not make a direct measurement of CAL; instead, it was computed during data analysis from examiners' recording of probing depth (PD) and gingival recession. Three categories of periodontal status were computed using the CDC-AAP 2007 definitions:[23] moderate periodontitis was defined as ≥2 interproximal sites with CAL ≥4 mm OR ≥2 interproximal sites with PD ≥5 mm (not on same tooth); severe periodontitis was defined as ≥2 interproximal sites with CAL ≥6 mm (not on same tooth) AND ≥1 interproximal sites with PD ≥5 mm. All other degrees of periodontitis not included in these categories were assigned a no or mild periodontitis status.

Creation of interproximal clinical attachment level proxy variable (rCAL)

A proxy variable was created to simulate radiographic alveolar bone loss evident from bitewing or panoramic films that would be visible if radiographs were taken in a nondental setting. Using the periodontal measures available in the NSAOH 2004-06 data set limited to the interproximal CAL recordings, 3 categories of radiographic CAL (rCAL) were established namely: 0-4 mm "none/mild," 5-8 mm "moderate," and ≥9 mm "severe" rCAL.[24] Exclusion of the midbuccal recordings from the calculation of rCAL was considered necessary because it would be expected that the cortical bone would mask "mild"-"moderate" CAL radiographically. These

variables were subsequently included into the third logistic regression model that would imitate what a nondental practitioner could potentially view by combining results from the 8 screening questions, 5 patient (demographic) characteristics. and "radiographic bone loss."

Data analysis

This analysis used unweighted data from interviews and examinations. Multivariate binary logistic regression analysis was undertaken, constructing separate models to predict combined "moderate/severe" periodontitis versus "no/mild" periodontitis. For each dependent variable, models were constructed as follows:

Model 1 - using all 8 periodontitis screening questions,
Model 2 – Model 1 + 5 periodontitis risk indicators (age, sex, smoking, country of birth, and diabetes status) and,
Model 3 – Model 2 + bone loss expected to be visible on radiographs.

The validity of each model was indexed using the following summary statistics: (1) statistical significance of overall model (-2 log likelihood); sensitivity (range 0 to 1) and specificity (range 0 to 1) for sample when predicted probability was dichotomised at a value that yielded a proportion of predicted cases equal to the examiner-assessed prevalence of periodontitis; (2) area under receiver operator characteristic (AUROC), the plot of sensitivity versus 100 minus specificity obtained from multiple dichotomies of predicted probabilities from multivariable binary logistic regression models with each dichotomy cross-classified against clinical diagnosis. AUROC has a value of 0.5 under the "null" hypothesis. The following values for interpretation of AUROC values: <0.7 "poor," 0.7-0.9 "useful," and >0.9 "excellent" as proposed by Swets[25] were used. All analysis used SAS v9.4 for Windows (SAS Institute).

Results

A total of 28,812 households were contacted of which 14,689 were classified as nonrespondents. In all, 14,123 telephone interviews were completed, of which 12,606 where within the "scope" to undergo an oral assessment. Of this group, 4967 people participated in the oral examination phase of the study that included a periodontal assessment. This report is based on a subsample of 3630 individuals who completed all components of the survey. The 8 periodontitis screening questions are listed in Table 1 with percentage response rates. Most questions had very low "don't know" response rates with the exception of "Do you think you have gum disease?" where there were 98 such responses. All but 2 question pairs possessed weak correlations (matrix presented in Appendix, available online) indicating little redundancy from information obtained by the questions. Two-thirds of respondents did not use mouthwash, and almost half reported never using floss or other interproximal devices.

The demographic characteristics of participants are summarised in Table 2. The combined prevalence of "moderate/severe" periodontitis was 32.4% and was strongly associated with age, affecting 14.5% of people younger than 45 years but 55% of people aged 65 years or older. A noticeable sex difference existed with males more likely to have moderate/severe periodontitis odds ratio (OR) 1.8 (95% CI 1.6-2.1) compared to females. Other significant associations for a greater risk of periodontitis were being born overseas (OR range 2.3-2.9), having a history of smoking (OR range 1.7-1.8), and a positive diagnosis of diabetes mellitus OR 1.8 (95% CI 1.4-2.4).

Table 1 – Responses to periodontal screening questions asked in telephone interview (n = 3630).

Question	Responses	(%)
Do you think you have gum disease?	Yes	(11.1)
	No	(86.1)
	Don't Know	(2.7)
Has a dental professional ever told you that you have lost bone around your teeth?	Yes	(8.0)
	No	(91.1)
	Don't Know	(0.9)
Have you ever had scaling, root planing, surgery, or other treatment for gum disease?	Yes	(7.5)
	No	(92.2)
	Don't Know	(0.3)
Have you ever had any teeth that have become loose by themselves without some injury (not baby teeth)?	Yes	(8.4)
	No	(91.5)
	Don't Know	(0.1)
How often during the last week did you use mouthwash or any dental rinse product?	Never	(66.4)
	1-6 times	(16.7)
	≥ 7×/week	(16.7)
	Don't Know	(0.1)
How often during the last 7 days did you use dental floss, tape, or an interdental brush to clean between your teeth, other than just to remove food particles stuck between your teeth?	Never	(48.0)
	1-6 times	(30.3)
	≥ 7×/week	(21.7)
	Don't Know	(0.0)
How do you rate the health of your gums?	Fair/Poor	(15.2)
	Ex/Vg/Gd	(84.4)
	Don't Know	(0.4)
During the past 3 months, have you noticed a tooth that does not look right?	Yes	(16.3)
	No	(83.4)
	Don't Know	(0.2)

Percentages may not add to 100% because of rounding error.

Comparisons between responses to screening questions and clinically defined periodontitis are presented in Table 3. For individuals who provided an affirmative answer "yes" to the questions that had a binary response (yes/no), the odds of having "moderate/severe" periodontitis ranged from 1.3-fold to 4-fold compared to respondents providing "no" responses. All but 1 screening question "self-reported flossing frequency" was a significant predictor of moderate/severe disease.

Six of the 8 screening questions were significant predictors for moderate/severe periodontitis when assessed in a multivariable binary logistic regression model (Table 4, model 1). The predictive validity of the model (measured by summing sensitivity and specificity scores) was "fair" at 1.17. Adding the 5 traditional periodontitis risk indicators to the screening questions (Table 4, model 2), resulted in improved sensitivity at the expense of specificity for the model. Nevertheless, the predictive validity increased to 1.36. When all 13 variables were combined with the interproximal rCAL proxy variable, the resultant validity was "good" at predicting moderate/severe periodontitis with a value of 1.49 (Table 4, model 3).

Table 2 – Bivariate association between self-reported 5 risk indicators and periodontitis (*n* = 3630).

Risk indicator	Number of people	Moderate/severe periodontitis (%)	Crude OR (95% CI)
Age (years)			
15-44	1540	14.5	(ref)
45-64	1510	41.7	4.2 (3.5-5.0)
65+	580	55.5	7.3 (5.9-9.1)
Sex			
Female	2189	27.1	(ref)
Male	1441	40.3	1.8 (1.6-2.1)
Country of Birth			
Australia	2850	28.7	(ref)
UK/NZ	286	48.3	2.3 (1.8-3.0)
Other	189	53.4	2.9 (2.1-3.8)
Diabetes			
No	3442	31.6	(ref)
Yes	188	45.3	1.8 (1.4-2.4)
Smoking History			
Never	1943	27.1	(ref)
Former	1082	38.0	1.7 (1.4-1.9)
Current	602	39.4	1.8 (1.4-2.1)

CI, confidence interval; NZ, New Zealand; OR, odds ratio; UK, United Kingdom.

AUROC curves for the 3 models are presented in (Figure 1), which represents the plots of sensitivity versus specificity. The curve for Model 1 using only the 8 screening questions was closest to the null value of the 3 models presented. Models 2 and 3 were stronger and provided AUROC scores of 0.77 and 0.86, respectively. The addition of the 5 common risk indicators for periodontitis improved the validity of the moderate/severe periodontitis model. This judgment is made when looking at the variance between sensitivities from Model 1 (8 screening questions only) to Model 2 (8 screening questions plus risk indicators) and is shown diagrammatically depicted by separation of AUROC curves in (Figure 1). The values of sensitivity (0.56) and specificity (0.93) for Model 3 reported in Figure 1 is shown as the dashed/dotted line and represents the point on the curve whereby the predicted prevalence of periodontitis is equal to the observed prevalence (32.4%) of this sample. The lighter dotted line represents an alternative threshold that uses the optimal values of sensitivity (0.78) and specificity (0.75) to provide higher overall accuracy (total 1.53) in the model at the expense of predicting a higher prevalence of approximately 43%.

Discussion

The results from analysing Australia's second NSAOH show that the use of periodontal screening questions alone to predict periodontitis yields a mediocre performance, with a low sensitivity but high specificity. However, prediction of periodontitis cases is improved by incorporating risk indicators such as age, sex, diabetes, and smoking status that are understood to be associated with periodontitis. The validity of a test (as used in this study) examines the level of accuracy in correctly predicting both actual periodontitis cases in addition to correctly predicting nonperiodontitis cases.

Members of the general public may undergo a series of tests (as occurs when screening for bowel cancer),[26] prior to a definitive diagnosis. Similarly, the fasting plasma glucose test and the glucose tolerance test are combined for a diagnosis of diabetes mellitus.[27] Providing ("yes"/"no"/"don't know") responses to 8 periodontal screening questions and recording ones' age, sex, smoking history, diabetes status, and country of birth as displayed in Model 2 is noninvasive and can be completed in less than 2 minutes while waiting for an appointment. An algorithm combining those responses may form the first stage of a "triage system" to test for periodontitis and exclude those likely to be "nonperiodontitis" cases by using the questions' collective high specificity. A subsequent stage of investigation in the form of radiographic investigation on the remaining individuals would confirm the diagnosis and determine severity of disease.

Dental radiography is safe and radiation exposure is minute in comparison to other health screening and medical

Table 3 – Bivariate association between screening questions and periodontitis.

Abbreviated screening question	Response	Number of people	Moderate/severe periodontitis (%)	OR (95% CI)
Have gum disease	Yes	406	5.9	2.5 (2.0-3.0)
	No	3125	26.2	
Lost bone	Yes	292	4.2	2.4 (1.9-3.1)
	No	3307	28.0	
Scaling and root planing	Yes	272	4.0	2.6 (2.0-3.3)
	No	3346	28.3	
Loose tooth	Yes	306	5.3	4.0 (3.2-5.1)
	No	3320	27.0	
Mouthwash use	≥7×/week	608	6.5	1.4 (1.2-1.7)
	<7×/week	3018	25.9	
Floss use	≥7×/week	786	7.1	1.0 (0.9-1.2)
	<7×/week	2843	25.3	
Gum health	Ex/Vg/Gd	3062	24.6	2.5 (2.1-3.0)
	Fair/Poor	552	7.8	
Bad tooth	Yes	593	6.1	1.3 (1.1-1.6)
	No	3028	26.2	

N ≠ 3630 because of "Don't know response."
CI, confidence interval; OR, odds ratio.

Table 4 – Number of variables that were significant in multivariable binary logistic regression models for moderate/severe periodontitis (*n* = 3630).

	Model 1*	Model 2*	Model 3*
Screening questions			
Have gum disease	X[a]	X[a]	X[a]
Lost bone	X	X	X
Scaling and root planing	X[a]	X[a]	X
Loose tooth	X	X[a]	X[a]
Mouthwash use	X	X	X
Floss use	X	X	X
Gum health	X[a]	X	X[a]
Bad tooth	X	X	X
5 risk indicators			
Age (years)		X[a]	X[a]
Male sex		X[a]	X[a]
Country of birth		X[a]	X[a]
Diabetes		X	X
Smoking		X[a]	X[a]
Bone loss			
Bone loss			X[a]
Summary of Predictive Validity[†]			
Sensitivity	0.28	0.55	0.82
Specificity	0.89	0.81	0.92
Sensitivity + Specificity	1.17	1.36	1.74
C-statistics	0.61	0.77	0.92

* Model 1 = 8 screening questions; Model 2 = 8 screening questions + 5 traditional risk indicators; Model 3 = Model 2 with addition of interproximal Bone loss (BL).Model 1: [a] Gum disease, root planning, loose teeth, and bad gum health were significantly associated with moderate and severe periodontitis. Model 2: [a] Gum disease, root planning, loose teeth, and bad gum health were significantly associated with moderate and severe periodontitis. With respect to risk factors; age ≥64 and 45-64, male sex, those born in United Kingdom, New Zealand, and other than Australia, current and formal smoking history were significantly associated with moderate and severe periodontitis.Model 3: [a] Gum disease, loose teeth, and bad gum health were significantly associated with moderate and severe periodontitis. With respect to risk factors; age ≥64 and 45-64, male sex, those born in other countries compared to Australia, and current smoking history were significantly associated with moderate and severe periodontitis. Individuals with bone loss 8+ mm and 4-8 mm compared to 0-4 mm had higher risk of moderate to severe periodontitis.

† Values for sensitivity and specificity are based on classification tables that dichotomise predicted probabilities of being a case at a cut-point of 0.397, selected to yield 32.5% of subjects as predicted cases. That cut-point was selected to yield predicted prevalence as close as possible to the observed prevalence of 32.4% of subjects with examiner based "moderate/severe" case definition for periodontitis.

diagnostic exposures. For example, 2 bite-wing radiographs which image the molar regions or 1 orthopantomograph (dental panoramic film of the whole mouth and temporomandibular joints) exposes a patient to 0.02 milliSieverts (mSv) of radiation, equivalent to 4.8 days of background radiation.[24] In comparison, mammography requires 0.3 mSv exposures for a typical adult, equivalent to 3 months of background radiation.[28] Radiographic assessments of alveolar bone loss tend to underestimate actual alveolar bone loss when compared to clinical measurements[29,30] because the projection of a 2-dimensional image of a 3-dimensional structure. This complexity therefore requires substantial bone mineral loss to occur prior to changes becoming visible radiographically.[31] The benefit of this is that using the high specificity obtained from combining the screening questions and periodontitis risk indicators, with the potential increase in the sensitivity that is obtained from radiographic bone loss can provide the necessary increases in predictive validity of the overall test.

It is important to highlight the importance of screening for periodontitis and the potential benefits that may arise from treatment and management of the condition. Providing periodontal treatment to people with type 2 diabetes reduces glycated haemoglobin on average 0.29% (95% CI 0.48%-0.10%) 3-4 months post-treatment based on Cochrane systematic review data from 14 studies involving 1499 participants.[32] People with poorly managed diabetes may receive a greater benefit from periodontal treatment.[33-35] Periodontal treatment has also been shown to improve endothelial function of the brachial artery for up to 6 months,[36] delay progression of carotid intima-media thickness up to a year,[37] and reduce systemic inflammatory biomarkers including C-reactive protein, interleukin-6, and tumour necrosis alpha for up to 3-months.[38] These are but few examples highlighting that periodontitis has a systemic influence beyond the mouth.

Periodontitis disproportionately affects Australians with lower educational attainment, those without dental insurance, and those eligible for means-tested government dental care.[1] Aside from short-term programs over successive Australian governments since the 1970s, Australia's universal health insurance system (Medicare) does not routinely cover dental services. Given the mouth is inextricably connected to the rest of the body, there truly is no reason for oral health conditions to not be included in a universal primary dental scheme.[39] The political discussions required on how to make this happen are beyond the scope of this investigation. It is foreseeable nonetheless that making a provisional diagnosis

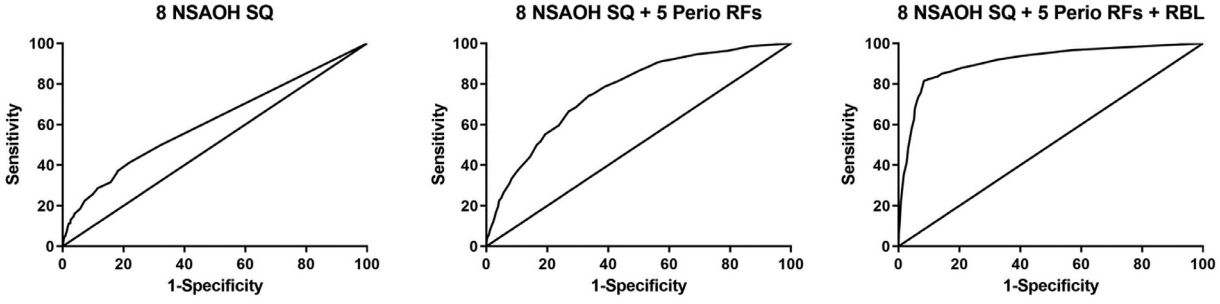

Fig. 1 – Moderate/severe periodontitis ROC curve. Model 1: 8 screening questions (8 NSAOH SQ); Model 2: Model 1 + 5 traditional risk indicators (8 NSAOH SQ + 5 Perio RFs); Model 3: Model 2 + interproximal BL (8 NSAOH SQ + 5 Perio RFs + RBL). BL = bone loss; NSAOH = National Survey of Adult Oral Heath; Perio RFs = periodontitis risk factors; RBL = radiographic bone loss; ROC = receiver operator characteristic.

of periodontitis in a nondental setting will necessitate referrals for radiography and subsequently to dental practitioners for care. Costs for these are likely to be modest if covered by Australia's Medical Benefits Schedule.

Several limitations to this investigation must be highlighted. The clinical and questionnaire data used for this investigation were collected between 2004 and 2006 meaning it is up to 15 years old. The NSAOH 2017-18[1] did not include periodontitis screening questions in the survey, and thus, it was not possible to examine their validity with more contemporary data. Nevertheless, findings from the 2004-06 survey remain applicable for the following reasons. In 2007, the estimated prevalence of periodontitis in the Australian adult population was 22.9%.[40] This has since increased to 30.1% in the most recent survey[1] because of an ageing population and a progressive decline in tooth loss over successive generations. Over a similar time frame, the prevalence of diabetes in the Australian population has risen from 3.3% in 2001 to 4.9% in 2018, and rates of smoking have declined from approximately 20% in 2007 to 13.8% in 2017-2018.[41] The proportion of adults reporting having attended a dental practitioner in the preceding 12 months reduced from 62.1% in 2004-2006 to 56.4% in 2017-2018,[11] meaning fewer people could potentially benefit from timely diagnosis, treatment, and management of their periodontitis within dental clinics. Finally, it is likely that our rCAL proxy variable has underestimated the true disease level because only the interproximal sites were used in its creation. As the rCAL variable is novel, it has yet to be validated. However, it can be generated using other national-level data sets such as US National Health and Nutrition Examination Survey (NHANES). The rCAL variable aimed to simulate periodontitis prediction using radiographs in concert with patient-level demographic and lifestyle characteristics. The "high" sensitivity and specificity of Model 3 indicate that this variable has improved the prediction level. Future research to validate rCAL is recommended.

Conclusion

The results from this analysis show that questions designed to screen for periodontitis together with traditional risk indicators for periodontitis can be applied effectively to screen for periodontitis in nondental healthcare settings. Based on benchmarks proposed for predicted validity, the combined set of 14 variables provided "good" levels of prediction for moderate/severe (1.49) periodontitis when a theoretical 2-stage approach was applied. Without the interproximal bone loss variable, the combined sensitivity and specificity of the question and risk indicator models provided only a "modest" result.

Conflict of interest

None disclosed.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.identj.2020.12.013.

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