Validity of Screening Methods for Periodontitis Using Salivary Hemoglobin Level and Self-Report Questionnaires in People with Disabilities

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Background: The aim of this study is to evaluate the validity of screening methods in predicting periodontitis in people with disabilities using the objective salivary hemoglobin level, a subjective self-report questionnaire, and a combined model of the two methods with demographic characteristics.

Methods: The participants were 195 patients with disabilities aged >18 years who were examined using the community periodontal index (CPI), salivary hemoglobin level, and answers to 10 self-report questions (n = 192). Multivariable logistic regression and receiver operating characteristic (ROC) curve analysis were performed to evaluate the validity of the methods and the combined model in predicting the prevalence of ≥CPI 3 (probing depth [PD] ≥4 mm) or CPI 4 (PD ≥6 mm).

Results: Overall, 75.9% of the study group (148 of 195) were diagnosed with ≥CPI 3, and 38.5% of the study group (75 of 195) were diagnosed with CPI 4. The areas under the ROC curve (AUCs) of the salivary hemoglobin level were 0.578 (sensitivity of 41% and specificity of 77%) and 0.662 (sensitivity of 53% and specificity of 75%) for predicting the prevalence of ≥CPI 3 and CPI 4, respectively. Multivariable modeling incorporating four different questions for predicting ≥CPI 3 or CPI 4 indicated higher AUCs of 0.710 and 0.732, respectively, yielding higher sensitivity (55% for ≥CPI 3 and 69% for CPI 4) than that of salivary hemoglobin level. The most useful prediction models for ≥CPI 3 or CPI 4 were combined models, which yielded AUCs of 0.773 and 0.807, respectively, with sensitivity values of 70% and specificity values >75%.

Conclusion: The salivary hemoglobin level, self-report questionnaire, and the combined method demonstrated screening potential that could predict the population prevalence of ≥CPI 3 or CPI 4. *J Periodontol 2015;86:536-545.*

KEY WORDS

Disabled persons; hemoglobins; periodontal index; periodontitis; ROC curve; self-report.

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In the present century, rapid population aging has resulted in the improvement of health equality and in welfare being an important national policy issue, not only for individuals who are elderly but also for those who are elderly and have disabilities.[1] Because having disabilities entails a restriction on physical activity in many types of disorders, such patients would be expected to have some difficulties with treatment.[2] In addition, such patients typically have systemic disease and are on medications, which results in their oral condition being vulnerable to oral diseases, such as periodontitis.[3] A systematic review has demonstrated that people with intellectual disabilities had poorer oral health than people without disabilities.[4] A retrospective study reported that a periodontitis prevalence of 80% was observed among individuals with intellectual and developmental disabilities.[5] These results indicate that it is difficult for people with disabilities to manage their oral health. Therefore, if people with disabilities, who have low dental clinic accessibility, are diagnosed early with periodontitis and are provided proper treatments, it is possible to prevent the intergradation of such disease.

Periodontitis is generally diagnosed based on clinical criteria, such as probing depth (PD), bleeding on probing, clinical attachment loss, and alveolar bone loss

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on a radiograph.[6,7] The community periodontal index (CPI) is a diagnostic method that detects gingival bleeding and subgingival calculus and measures PD with a probe, and it is used for epidemiologic study and periodontitis patient screening.[8] However, the CPI is a mixed index of the signs and symptoms of periodontitis of different classifications.[9] In addition, the method measures PD, which is an indicator of previous disease rather than disease activity. Furthermore, the measure requires a large amount of inspection time, effort, and examiner skills. Therefore, a simple, low-cost and highly reliable periodontal measure should be developed that can be used in national and regional epidemiologic studies.[10]

A self-report questionnaire measure was developed in an effort to predict the prevalence of periodontitis for non-clinical population-based surveys by a collaborative research study between the Division of Oral Health at the Centers for Disease Control and Prevention (CDC) and the American Academy of Periodontology (AAP).[10-12] The measure, which was composed of eight questions, was useful for predicting the prevalence of periodontitis in a population through pilot studies, and the validity of the measure increased when demographic factors were added to the prediction model.[10,11] It was also identified recently that the questions could predict well the prevalence of clinical periodontitis, which was examined in representative U.S. adults using a full-mouth examination protocol.[12] These findings indicate that the self-report questionnaire could be used widely as a substitute for CPI, not only for population-based periodontitis surveys of high-risk groups, such as people with low incomes, of advanced age, or with disabilities, but also for national epidemiologic studies if its validity is ensured.

There is another disadvantage of clinical periodontal measurement: it does not represent current disease activity.[13] Therefore, several previous studies have attempted to reveal the progress and initiation of local inflammatory disease and chronic systemic disease by using inflammatory biomarkers in the body fluid.[14] C-reactive protein (CRP) is known as a systemic biomarker that is released during the acute phase of an inflammatory reaction in the body related to systemic diseases, such as cardiovascular disease.[15] It was reported previously that a high level of CRP in the blood has been observed in periodontal disease patients and is associated with their CPI scores.[16,17] However, the results cannot be applied directly to predict periodontitis, because the protein level in the blood indicates the variation of inflammation in a whole body. In some studies, it has been reported that the level of cytokines in saliva, such as interleukin-1β, matrix metalloproteinase-8, and tumor necrosis factor-α, showed contradicting results when used to distinguish individuals with periodontitis from periodontally healthy individuals according to the level of the disease.[18,19] Therefore, the clinical use of cytokines as a predictor of periodontitis should be reconsidered.

Saliva is an important resource that provides clinical information relevant to oral and systemic health.[20] It also contains physiologic variables relevant to periodontitis, such as non-salivary gland-derived factors, including gingival sulcus fluid, blood serum, and blood cells from the infected site, and bacteria, as well as factors that originate in the salivary glands.[21] Thus, saliva is used as a surrogate variable to monitor the active status of the infected gum site, presence of periodontal disease, and prognosis after oral cavity treatment.[22] Among these, the free salivary hemoglobin level is a sign of periodontal activity, indicating the presence of gum bleeding. Therefore, it has the possibility to be used as a means of screening for the detection of periodontal disease in a group-based population.[23] It is worth noting that gingival bleeding is related to gingival inflammation,[24] and it is a clinical sign of the early stages of periodontitis and a symptom that can be detected by self-aware patients. Disease diagnosis using saliva is a non-invasive and easy method to compare with biopsy and blood-based methods. It could also be cost effective when used in large population groups.

Accordingly, the present study focuses on whether these non-invasive methods can be used to screen for periodontal disease. The aim of this study is to evaluate the validity of screening methods in predicting the presence of periodontitis in a group of patients with disabilities who were diagnosed with the CPI, using the objective salivary hemoglobin level, subjective self-report questionnaire, and a combination of salivary hemoglobin level, self-report questionnaire, and demographic characteristics.

MATERIALS AND METHODS

Study Population

The ethical approval for the study was received from the Institutional Review Board (IRB) of Yonsei University Dental Hospital, Seoul, Republic of Korea (IRB no. 2-2012-0031). The study was conducted in accordance with the Declaration of Helsinki of 1975, as revised in 2000. The one-sided 95% formulation of the lower confidence interval (CI) limit was used for sample size calculations according to the recommendation of Flahault et al.[25] A sensitivity of 0.8 and minimal acceptable lower CI limit of 0.7 were expected, and the minimum sample size of 204 participants was established. The purpose of the study and methods were explained to all participants and guardians who visited the Seoul Dental Hospital for the Disabled, Seoul, Republic of Korea between September

2012 and November 2012. Written informed consent was provided. The study inclusion criteria for participants with disabilities were as follows: 1) aged ≥18 years; 2) had no problem collecting stimulated saliva considering their physical and developmental states; 3) had at least five sextants with more than two remaining teeth per sextant; 4) had not received any periodontal treatment for at least 4 weeks; and 5) had no oral mucosal disease. Definition of persons with disabilities is specified in the Korean Welfare of the Disabled Act,[26] which classifies the disability into 15 subtypes. The major categories of the subtypes are physical and mental disability. The investigation of age, sex, type of disability, systemic disease, and periodontal status was performed for all of the participants. A total of 195 participants completed the CPI examination and salivary hemoglobin test, with 116 males and 79 females, aged 18 to 83 years (mean age, 50.8 years).

Oral Examination

Periodontal examination of the participants was conducted by three trained dentists (S-HN, In-Sun Kim, and Hye-Joeng Kim), who were on staff at the Seoul Dental Hospital for the Disabled, by measuring the CPI in accordance with the recommendations of the World Health Organization.[8] Interexaminer reliability analysis for CPI examination revealed that interobserver agreement among the three independent examiners was good (intraclass correlation coefficient of 0.80). The highest value among CPI scores in the examined six sextants of dentition was used as the participant's representative CPI score. After categorizing the CPI, the participants who had a maximum CPI value of CPI 3 (PD = 4 to 5 mm) or CPI 4 (PD ≥6 mm) were defined as patients with ≥CPI 3 (PD ≥4 mm), and of this group, those with a maximum CPI value of CPI 4 were also classified as CPI 4.

Analysis of Salivary Hemoglobin Level

Stimulated saliva was collected from participants by chewing paraffin wax in pill form for 5 minutes after rinsing their mouth with water. A volume of 2 mL saliva was obtained with a micropipette and was centrifuged[§] at 3,000 rpm for 3 minutes. The 0.2-mL supernatant was extracted and placed in 1 mL storage buffer, and then the sample was stored at 4°C until processing. The salivary hemoglobin level was analyzed using an automated analyzer[‖] based on latex agglutination between antihuman hemoglobin antibodies of latex suspension and hemoglobin antigen. Finally, the six-fold diluted salivary hemoglobin level was used for analysis.

Self-Report Questions

The participants and guardians answered eight periodontal questions that were used in the 2009 to 2010 National Health and Nutrition Examination Survey protocol of the United States[12] and two additional questions about current smoking and drinking status, which are well-known risk factors for periodontal disease,[27,28] as described in Table 1. The questionnaires were self-reported under unsupervised conditions. The questionnaires were answered by participants who had only physical disabilities and therefore had the ability to understand the meaning of the questions and to answer them. Otherwise, the questionnaires were answered by guardians.

Statistical Analysis

Data analyses were performed using statistical software,[¶] with statistical significance set at <5%. The salivary hemoglobin levels between CPI groups were analyzed by the non-parametric Kruskal-Wallis test. The relevant questions with ≥CPI 3 or CPI 4 were selected by the χ^2 test, with a P value <0.25 for including initial prediction models. Multiple logistic regression analysis was performed, and the receiver operating characteristic (ROC) curve was constructed. The question with the highest P value was considered for elimination at each step of the manual backward elimination processes. When the goodness of fit based on the Akaike information criterion was unchanged or improved after removing the considered question, it was decided to remove the question; when the goodness of fit decreased with the removal of a question, the question was kept.[29] The area under the ROC curves (AUCs), sensitivity, and specificity were yielded for confirming the validity of the salivary hemoglobin level, the self-report questionnaire, and a combination of the salivary hemoglobin level, self-report questionnaire, and age in predicting the prevalence of ≥CPI 3 or CPI 4.

RESULTS

Table 2 shows the demographic and risk factors and the prevalence of periodontal disease according to periodontitis criteria, ≥CPI 3 and CPI 4. Overall, 75.9% of the study group (93 males and 55 females) were diagnosed with ≥CPI 3 with PD ≥4 mm, and 38.5% of the study group (46 males and 29 females) were diagnosed with CPI 4 and PD ≥6 mm. The percentage of males with ≥CPI 3 was higher than that of females. The percentage of participants with ≥CPI 3 increased with aging, and there was a similar tendency in participants with CPI 4.

Participants with physical disability were the largest percentage (93 participants, 47.7%) of the study group, and participants with CPI 4 comprised ≈48% of the participants with physical disabilities

§ Centrifuge PMC-880, Tomy Kogyo, Tokyo, Japan.
‖ OC-Sensor Diana, Eiken Chemical, Tokyo, Japan.
¶ STATA release 13.0, StataCorp, College Station, TX.

Table 1.

Self-Report Questions Tested for Predicting the Prevalence of Periodontitis

Question	Response
1) Do you think you might have gum disease?	☐ Yes / ☐ No
2) Overall, how would you rate the health of your teeth and gums?	☐ Excellent / ☐ Very good / ☐ Good / ☐ Fair / ☐ Poor
3) Have you ever had treatment for gum disease, such as scaling and root planing, sometimes called "deep" cleaning?	☐ Yes / ☐ No
4) Have you ever had any teeth become loose on their own, without an injury?	☐ Yes / ☐ No
5) Have you ever been told by a dental professional that you lost bone around your teeth?	☐ Yes / ☐ No
6) During the past 3 months, have you noticed a tooth that does not look right?	☐ Yes / ☐ No
7) Aside from brushing your teeth with a toothbrush, in the last 7 days, how many times did you use dental floss or any other device to clean between your teeth?	_____: Number per week
8) Aside from brushing your teeth with a toothbrush, in the last 7 days, how many times did you use mouthwash or other dental rinse product that you use to treat dental disease or dental problems?	_____: Number per week
9) Do you currently smoke?	☐ Yes / ☐ No
10) If you drink alcohol, how often do you drink per week?	_____: Number per week

Questions 1 through 8 are reproduced from Eke et al.[12]

(Table 2). The participants with vision disorders were the smallest portion of the study group (10 participants, 5.1%). For each type of disability, more than half of the participants had periodontitis with ≥CPI 3. Approximately half (53.3%) of the study group had systemic disease. The greatest percentage of the participants had cardiovascular disease, and the lowest percentage of participants had diabetes. More than 80% of participants in both groups had PD ≥4 mm.

Table 3 shows the hemoglobin level of subgroups divided by CPI value. The hemoglobin level of the study group ranged from 0.01 to 199.20 μg/mL. The medians of the salivary hemoglobin levels, which were classified by CPI, were statistically significantly different ($P = 0.002$). The median hemoglobin level of participants with CPI 4 was 9.48 μg/mL, which was the highest level in the CPI subgroups. The hemoglobin level did not display a tendency to increase with severity of periodontitis but instead displayed a higher hemoglobin level in the CPI 2 group than in the CPI 3 group.

Of the participants, 192 participants answered at least one question, and three participants answered no questions. Table 4 shows the responses to the self-report questions and relation between the question and periodontitis prevalence status (≥CPI 3 or CPI 4). Four different self-report questions, which were related to periodontal disease, were selected from 10 questions according to their significance. Loose teeth (question 4), bone loss (question 5), teeth do not look right (question 6), and smoking habit (question 9) were selected for predicting the prevalence of ≥CPI 3. Gum disease (question 1), loose teeth (question 4), bone loss (question 5), and teeth do not look right (question 6) were selected for predicting the prevalence of CPI 4.

Table 5 shows the results of logistic regression modeling and ROC analysis for predicting the prevalence of ≥CPI 3 or CPI 4. When the hemoglobin level was used in predicting the prevalence of ≥CPI 3 at a cutoff point of 7.86 μg/mL, the AUC for the model was 0.578, with a sensitivity of 41% and a specificity of 77%. For predicting CPI 4 only, there was a higher AUC of 0.662, a sensitivity of 53%, and a similar specificity of 75% at a cutoff point of 8.7 μg/mL.

Self-report questions had higher prediction power for periodontal disease than hemoglobin level in saliva (Table 5). The four self-report questions were useful in predicting ≥CPI 3, resulting in an AUC of 0.710, a sensitivity of 55%, and a specificity of 79%. When the other self-report questions were used to

Table 2.

Prevalence of ≥CPI 3 (PD ≥4 mm) or CPI 4 (PD ≥6 mm) by General Characteristics

	Total Sample (N = 195)	≥CPI 3 (n = 148)		CPI 4 (n = 75)	
Characteristics	n	n	%	n	%
Sex					
Male	116	93	80.2	46	39.7
Female	79	55	69.6	29	36.7
Age (years)*					
≤39	44	26	59.1	9	20.5
40 to 59	93	73	78.5	38	40.9
≥60	57	49	86.0	28	49.1
Type of disability					
Physical disability	93	72	77.4	45	48.4
Brain lesions	20	16	80.0	7	35.0
Vision disorders	10	9	90.0	4	40.0
Hearing impairment	15	12	80.0	4	26.7
Intellectual disability	18	13	72.2	4	22.2
Mental retardation	23	16	69.6	7	30.4
Disorder	16	10	62.5	4	25.0
Systemic disease*					
None	91	66	72.5	39	42.9
Cardiovascular disease	55	44	80.0	22	40.0
Diabetes	8	7	87.5	4	50.0
Other†	38	9	23.7	10	26.3

* Participants who did not respond were excluded.
† Other includes lalopathy, kidney disorder, heart disorder, respiratory disorder, and intestinal fistula disorder.

Table 3.

Hemoglobin Level in Saliva by Maximum CPI

Classification	n	%	Median (minimum to maximum) (μg/mL)	*P**
CPI 0	17	8.72	0.48 (0.03 to 35.94)	
CPI 1	10	5.13	1.12 (0.36 to 114.00)	
CPI 2	20	10.26	3.79 (0.04 to 64.80)	0.002
CPI 3	73	37.44	1.28 (0.01 to 107.40)	
CPI 4	75	38.46	9.48 (0.04 to 199.20)	

* *P* value was obtained by Kruskal–Wallis equality-of-populations rank test.

predict CPI 4 only, there was a higher sensitivity of 69%, displaying a similar specificity and AUC as for those of ≥CPI 3. Including age to both the hemoglobin level model and the self-report questions model resulted in improved sensitivity and AUC than that of modeling using one predictor variable.

Combined modeling with the salivary hemoglobin level, self-report questions, and age showed the highest sensitivity and AUC (Fig. 1; Table 5). The combined modeling was the most useful not only for predicting the prevalence of ≥CPI 3 with an AUC of 0.773, a sensitivity of 70%, and a sensitivity 76% but also for predicting the prevalence of CPI 4 only with an AUC of 0.807, a sensitivity of 71%, and a sensitivity of 80%. Overall, the models were better able to predict CPI 4 only than both CPI 3 and CPI 4 (≥CPI 3).

DISCUSSION

This study assesses whether the salivary hemoglobin level test, a self-report periodontal questionnaire, and the combination method could be used to detect periodontitis classified by CPI (CPI 3 and CPI 4) or not

Table 4.

Responses to Questions for Periodontal Disease Screening Among Participants With ≥CPI 3 and CPI 4 and Associations Between Each Question and the Periodontal Status

Question	Response	≥CPI 3 (n = 148)		CPI 4 (n = 75)	
		n (%)	*P**	n (%)	*P**
1) Gum disease	Yes	96 (64.9)	0.55	56 (74.7)	0.02
	No	50 (33.8)		19 (25.3)	
	No response	2 (1.4)		0 (0.0)	
2) Health of teeth and gums	Excellent	2 (1.4)	0.66	2 (2.7)	0.08
	Very good	1 (0.7)		0 (0.0)	
	Good	17 (11.5)		8 (10.7)	
	Fair	44 (29.7)		18 (24.0)	
	Poor	82 (55.4)		47 (62.7)	
	No response	2 (1.4)		0 (0)	
3) Scaling and root planing	Yes	120 (81.1)	0.79	58 (77.3)	0.20
	No	26 (17.6)		17 (22.7)	
	No response	2 (1.4)		0 (0)	
4) Loose teeth without injury	Yes	78 (52.7)	<0.001	53 (70.7)	<0.001
	No	67 (45.3)		22 (29.3)	
	No response	3 (2.0)		0 (0)	
5) Bone loss	Yes	53 (35.8)	0.003	31 (41.3)	0.01
	No	92 (62.2)		43 (57.3)	
	No response	3 (2.0)		1 (1.3)	
6) Teeth do not look right	Yes	121 (81.8)	0.18	68 (90.7)	0.005
	No	25 (16.9)		7 (9.3)	
	No response	2 (1.4)		0 (0)	
7) Dental floss	≥1/week	52 (35.1)	0.85	27 (36.0)	0.91
	Never	91 (61.5)		47 (62.7)	
	No response	5 (3.4)		1 (1.3)	
8) Dental rinse products	≥1/week	33 (22.3)	0.65	16 (21.3)	0.92
	Never	112 (75.7)		58 (77.3)	
	No response	3 (2.0)		1 (1.3)	
9) Smoking habit	Yes	29 (19.6)	0.22	12 (16.0)	0.58
	No	96 (64.9)		52 (69.3)	
	No response	23 (15.5)		11 (14.7)	
10) Alcohol consumption	Never	81 (54.7)	0.44	40 (53.3)	0.06
	≤1/week	20 (13.5)		14 (18.7)	
	≥2/week	24 (16.2)		10 (13.3)	
	No response	23 (15.5)		11 (14.7)	

* *P* values were obtained by χ^2 test.

in a population with disabilities. So far, various biomarkers for periodontitis have been identified. They include cytokines in saliva and a variety of proteins detected in gingival crevicular fluid and saliva. Among them, salivary hemoglobin is selected for this study.[22,30]

The performance of salivary hemoglobin displayed a specificity of 77% or 75% in predicting periodontitis of ≥CPI 3 or CPI 4, respectively, but its sensitivity was low (≤53%) (Table 5). This is attributed to the fact that there was no distinctively linear relation toward an increased salivary hemoglobin level with severity of CPI, indicating that the hemoglobin level of CPI 2 (calculus) was higher than that of CPI 3 (PD = 4 to 5 mm) but lower than that of CPI 4 (PD ≥6 mm) (Table 3). The number of patients with CPI 2 were small (n = 20), and it is possible that the median value could not represent the hemoglobin level of the CPI 2 population. Another explanation could be that CPI 3 was found in individuals who

Table 5.

Logistic Regression Modeling and ROC Analysis Results to Predict the Prevalence of Participants With ≥CPI 3 or CPI 4

Predictor Variables	CPI Criteria	AUC (95% CI)	Sensitivity (%)	Specificity (%)
Hemoglobin level	≥CPI 3	0.578 (0.487 to 0.670)	40.5	76.6
	CPI 4	0.662 (0.583 to 0.741)	53.3	75.0
Hemoglobin level + age	≥CPI 3	0.672 (0.582 to 0.762)	48.0	78.3
	CPI 4	0.681 (0.604 to 0.757)	53.3	75.6
Questionnaire	≥CPI 3	0.710 (0.620 to 0.799)	54.5	78.6
	CPI 4	0.732 (0.650 to 0.813)	69.3	72.5
Questionnaire + age	≥CPI 3	0.756 (0.680 to 0.832)	60.2	78.1
	CPI 4	0.771 (0.700 to 0.842)	68.9	79.8
Hemoglobin level + questionnaire	≥CPI 3	0.727 (0.640 to 0.814)	57.7	76.2
	CPI 4	0.790 (0.721 to 0.857)	73.0	73.9
Questionnaire + hemoglobin level + age	≥CPI 3	0.773 (0.696 to 0.851)	69.9	75.6
	CPI 4	0.807 (0.742 to 0.872)	70.7	80.0

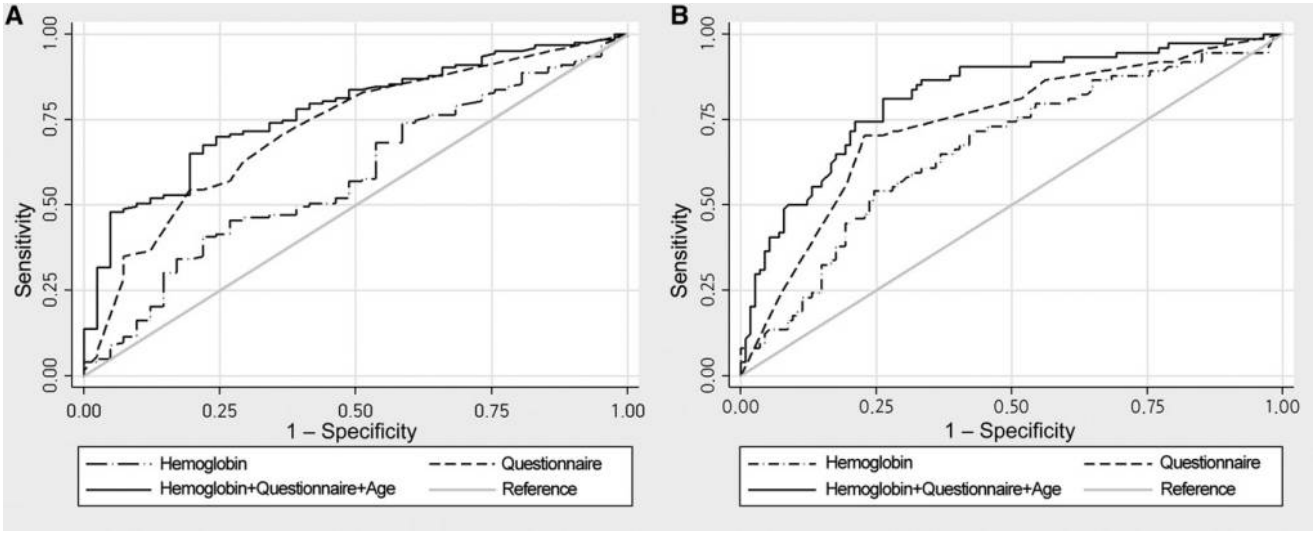

Figure 1.
ROC curves of prediction models for participants with ≥CPI 3 ***(A)*** *and CPI 4* ***(B)****. Combined modeling with the salivary hemoglobin level, self-report questions, and age showed the best performance. The models were better able to predict CPI 4 only (AUC of 0.807) than CPI 3 and CPI 4 (≥CPI 3, AUC of 0.773)*

did not have any inflammation or calculus. Considering that CPI 2 means having calculus, bleeding could have occurred after chewing wax. A previous study in Japan revealed that the hemoglobin level of CPI 2 was lower than that of CPI 1 (gum bleeding) and CPI 4.[23] The CPI is a representative value based on the evaluation of 10 index teeth. Therefore, unexamined teeth, in which there could be nothing abnormal, presence of calculus, or gum bleeding, are not considered. A periodontal pocket is not necessarily accompanied by gum bleeding. In addition, it is likely that the participants without periodontal pockets have gingivitis and gum bleeding. Therefore, this study demonstrates that it is more likely to miss a diagnosis of CPI 3 or CPI 4 based on salivary hemoglobin level alone. It is necessary to compensate for this limitation.

How well the questions explain the clinical indicator that defines an interested disease is most important in predicting the presence of a disease. In this study, periodontitis is defined as ≥CPI 3 or CPI 4, and each of four associated questions were selected for predicting these diagnosis criteria. These questions displayed higher sensitivity and validity for predicting patients with periodontal pockets than that of salivary

hemoglobin level (Table 5). The three items among the four questions used for predicting ≥CPI 3 in this study—"loose teeth," "bone loss," and "tooth does not look right"—are associated with the diagnosis criteria used in a previous study of representative United States adults, in which there was one more site with PD ≥4 mm or CDC/AAP total periodontitis (at least two interproximal sites with ≥3 mm alveolar bone loss and at least two interproximal sites with PD ≥4 mm or one site with PD ≥5 mm).[12] In particular, in this previous study, the "bone loss" question was included not only in the optimal predicting model, which is composed of selected questions and demographic factors, but also in the predicting models for both ≥CPI 3 and CPI 4 in the present study. Thus, it appears to represent the periodontal pocket presence.

The self-report oral health questionnaire contains past dental history and current oral health status, allowing for the collection of information about tooth health from professionals and self-awareness of periodontitis, as well as behaviors related to the disease. It is important that the respondents to the questionnaire are aware and understand the questions to ensure higher validity of the measure in predicting the prevalence of disease.[31,32] The "think teeth are loose or wobbly" question, which measures the severity of periodontitis, has been reported to produce a specificity of >90% for predicting the prevalence of PD ≥4 mm in a previous study.[31] This means that the respondents who had no such sign or symptom could understand and perceive the questions well.[32] This question was correlated with both ≥CPI 3 and CPI 4 in the present study and was used in the periodontitis prediction model (Table 4).

Conversely, the question that scored the teeth and periodontal health status (question 2) was not included in the prediction models of both ≥CPI 3 and CPI 4 (P >0.05). In addition, the question about awareness of "having gum disease" was only included in the prediction model for CPI 4, which indicated severe periodontitis. In the questions used to predict the prevalence of ≥CPI 3, the question of "noticed a tooth that does not look right" was relatively less significant in correlation with PD ≥4 mm than that of other selected questions (P = 0.18) (Table 4). It is likely that the individuals with disabilities have lower dental visits because of their physical ability and types of disorders. This is expected to result in lower awareness of their dental knowledge and oral health status than individuals without disabilities. Because the patients' guardians answered some of the questions, this also would reduce the sensitivity of the self-report questionnaires.

There has been a need in the periodontal field to develop non-invasive, low-cost, easy-to-use diagnostic tests. However, measuring PD and clinical attachment level using a periodontal probe and assessing gingival inflammation by various indices are still the most reliable methods for diagnosing periodontal disease. In medicine and dentistry, some efforts have been made to measure the presence, severity, and risk of developing diseases, such as chronic inflammatory disease, alcohol abuse and dependence, and masticatory dysfunction, by using objective or subjective evaluation methods.[33-35] These methods measure physical function, behavior, and mental problems by evaluating the physical or biologic factors or by using questions about behavior, habits, and awareness of disease. However, those studies have narrowly defined the association between objective and subjective measurement methods and the evaluations of the validity for whether each method individually represents the gold standard used in describing a disease or not. To overcome these problems, this study proposes that a prediction model combining objective and subjective measurement methods could compensate for these limitations and enhance the prediction performance of the presence of clinically measurable disease than each individual method of measurement. In the present study, the prediction model combining salivary hemoglobin level (objective method), self-report oral health questionnaire (subjective method), and age of participants displays similar specificity to each single method but improved sensitivity and accuracy with AUC values up to 0.8 for prediction of periodontitis as measured by CPI. In particular, these results demonstrate that the use of salivary hemoglobin and the age of participants could serve as a means of enhancing the validity of the prediction model when they were combined with a periodontal questionnaire.

The selected questions were different depending on the definition of periodontitis and participants used in respective studies, and the prediction validity of the selected questions displayed an increasing tendency when demographic variables were included in the prediction model.[11,12,36] This tendency is observed in the results of the combination prediction model of the present study. In particular, a question about the current smoking status was also included in prediction models of ≥CPI 3. Overall, the salivary hemoglobin level, self-report questionnaire, and the combination model displayed improved prediction validity for CPI 4 rather than ≥CPI 3, although the prevalence of disease was lower. This suggests that the three screening methods used in this study are more useful in predicting more severe periodontitis in a narrow sense.

The three prediction models used in this study reveal highly positive predictive values of >80% against a prevalence of ≥CPI 3. This may be attributed to the fact that the participants of this study had

disabilities with systemic disease and had a high prevalence of periodontitis of 75.9% with PD ≥4 mm. Therefore, this selection bias has to be considered when generalizing the present findings to a group without disabilities.

There could be variations in accuracy of responses to these questions to a certain extent depending on a patient's factors, such as literacy and awareness. Additional research that undertakes cognitive assessment of people with disabilities and their guardians is required.

This study has another limitation stemming from the low-to-moderate sensitivity of the self-report periodontal questionnaire, which is used as an alternative to the CPI. This could be resolved if the questions are expressed and modified with simple and understandable terms or answered with the assistance of professionals.[37] In addition, the development of additional questions, which denote the characteristics of periodontitis as measured by the CPI, is necessary for obtaining higher sensitivity.

CONCLUSIONS

This study attempts to assess whether the prevalence of periodontitis could be predicted by non-invasive measurement methods. The results of the present study reveal that the objective method of salivary hemoglobin level and subjective methods, such as a self-report questionnaire, could be used for predicting the presence of periodontitis as measured by CPI, and the combination method improved the validity of the predictive model for the disease.

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REFERENCES

1. Lloyd-Sherlock P. Population ageing in developed and developing regions: Implications for health policy. *Soc Sci Med* 2000;51:887-895.
2. Waldman HB, Perlman SP. Ensuring oral health for older individuals with intellectual and developmental disabilities. *J Clin Nurs* 2012;21:909-913.
3. de Jongh A, van Houtem C, van der Schoof M, Resida G, Broers D. Oral health status, treatment needs, and obstacles to dental care among noninstitutionalized children with severe mental disabilities in The Netherlands. *Spec Care Dentist* 2008;28:111-115.
4. Anders PL, Davis EL. Oral health of patients with intellectual disabilities: A systematic review. *Spec Care Dentist* 2010;30:110-117.
5. Morgan JP, Minihan PM, Stark PC, et al. The oral health status of 4,732 adults with intellectual and developmental disabilities. *J Am Dent Assoc* 2012;143:838-846.
6. Armitage GC; Research, Science and Therapy Committee of the American Academy of Periodontology. Diagnosis of periodontal diseases. *J Periodontol* 2003; 74:1237-1247.
7. Corbet EF, Ho DK, Lai SM. Radiographs in periodontal disease diagnosis and management. *Aust Dent J* 2009; 54(Suppl. 1):S27-S43.
8. World Health Organization. Oral health surveys: Basic methods. Geneva: World Health Organization; 1997.
9. Griffiths GS, Wilton JM, Curtis MA, et al. Detection of high-risk groups and individuals for periodontal diseases. Clinical assessment of the periodontium. *J Clin Periodontol* 1988;15:403-410.
10. Eke PI, Genco RJ. CDC Periodontal Disease Surveillance Project: Background, objectives, and progress report. *J Periodontol* 2007;78(Suppl. 7):1366-1371.
11. Eke PI, Dye B. Assessment of self-report measures for predicting population prevalence of periodontitis. *J Periodontol* 2009;80:1371-1379.
12. Eke PI, Dye BA, Wei L, et al. Self-reported measures for surveillance of periodontitis. *J Dent Res* 2013;92:1041-1047.
13. Socransky SS, Haffajee AD, Goodson JM, Lindhe J. New concepts of destructive periodontal disease. *J Clin Periodontol* 1984;11:21-32.
14. Okada H, Murakami S. Cytokine expression in periodontal health and disease. *Crit Rev Oral Biol Med* 1998;9:248-266.
15. Danesh J, Wheeler JG, Hirschfield GM, et al. C-reactive protein and other circulating markers of inflammation in the prediction of coronary heart disease. *N Engl J Med* 2004;350:1387-1397.
16. Takami Y, Nakagaki H, Morita I, et al. Blood test values and community periodontal index scores in medical checkup recipients. *J Periodontol* 2003;74: 1778-1784.
17. D'Aiuto F, Ready D, Tonetti MS. Periodontal disease and C-reactive protein-associated cardiovascular risk. *J Periodontal Res* 2004;39:236-241.
18. Miller CS, King CP Jr., Langub MC, Kryscio RJ, Thomas MV. Salivary biomarkers of existing periodontal disease: A cross-sectional study. *J Am Dent Assoc* 2006; 137:322-329.
19. Teles RP, Likhari V, Socransky SS, Haffajee AD. Salivary cytokine levels in subjects with chronic periodontitis and in periodontally healthy individuals: A cross-sectional study. *J Periodontal Res* 2009;44:411-417.
20. Miller CS, Foley JD, Bailey AL, et al. Current developments in salivary diagnostics. *Biomarkers Med* 2010;4:171-189.
21. Fonteles CS, Dos Santos CF, da Silva Alves KS, de Miranda Mota AC, Damasceno JX, Fonteles MC. Comparative proteomic analysis of human whole saliva of children with protein-energy undernutrition. *Nutrition* 2012;28:744-748.
22. Giannobile WV, Beikler T, Kinney JS, Ramseier CA, Morelli T, Wong DT. Saliva as a diagnostic tool for periodontal disease: Current state and future directions. *Periodontol 2000* 2009;50:52-64.
23. Nomura Y, Tamaki Y, Eto A, et al. Screening for periodontal diseases using salivary lactate dehydrogenase, hemoglobin level, and statistical modeling. *J Dent Sci* 2012;7:379-383.

24. Polson AM, Caton JG. Current status of bleeding in the diagnosis of periodontal diseases. *J Periodontol* 1985; 56(Suppl. 11):1-3.
25. Flahault A, Cadilhac M, Thomas G. Sample size calculation should be performed for design accuracy in diagnostic test studies. *J Clin Epidemiol* 2005;58:859-862.
26. Korean Act on Welfare of Persons with Disabilities (Jangaein bokji-pup: Act No. 10426, Jan. 4, 2011).
27. Duane B. Further evidence that periodontal bone loss increases with smoking and age. *Evid Based Dent* 2014;15:72-73.
28. Shepherd S. Alcohol consumption a risk factor for periodontal disease. *Evid Based Dent* 2011;12:76.
29. Burnham KP, Anderson DR, Burnham KP. Model selection and multimodel inference: A practical information-theoretic approach. New York: Springer; 2002.
30. Tsuchida S, Satoh M, Umemura H, et al. Proteomic analysis of gingival crevicular fluid for discovery of novel periodontal disease markers. *Proteomics* 2012; 12:2190-2202.
31. Gilbert AD, Nuttall NM. Self-reporting of periodontal health status. *Br Dent J* 1999;186:241-244.
32. Blicher B, Joshipura K, Eke P. Validation of self-reported periodontal disease: A systematic review. *J Dent Res* 2005;84:881-890.
33. Pincus T, Callahan LF, Brooks RH, Fuchs HA, Olsen NJ, Kaye JJ. Self-report questionnaire scores in rheumatoid arthritis compared with traditional physical, radiographic, and laboratory measures. *Ann Intern Med* 1989;110:259-266.
34. Aertgeerts B, Buntinx F, Ansoms S, Fevery J. Screening properties of questionnaires and laboratory tests for the detection of alcohol abuse or dependence in a general practice population. *Br J Gen Pract* 2001;51:206-217.
35. Ahn HJ, Lee YS, Jeong SH, Kang SM, Byun YS, Kim BI. Objective and subjective assessment of masticatory function for patients with temporomandibular disorder in Korea. *J Oral Rehabil* 2011;38:475-481.
36. Slade GD. Interim analysis of validity of periodontitis screening questions in the Australian population. *J Periodontol* 2007;78(Suppl. 7):1463-1470.
37. Buhlin K, Gustafsson A, Andersson K, Håkansson J, Klinge B. Validity and limitations of self-reported periodontal health. *Community Dent Oral Epidemiol* 2002; 30:431-437.

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