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Development of a risk score to predict abnormal glycemic status among Thai dental patients

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Abstract

Purpose – To construct a risk score using both clinical and intra-oral variables and to determine a risk score to screen individuals according to their risk of hyperglycemia.

Design/methodology/approach – A cross-sectional study was carried out among 690 Thai dental patients who visited the Special Clinic, Faculty of Dentistry, Mahidol University and a mobile dental unit of His Majesty the King of Thailandss Dental Service Unit. Participants aged ≥25 years without a previous history of type 2 diabetes mellitus were included in the study. Participants diagnosed with severe anemia and polycythemia

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were excluded. Questionnaires were used to collect demographic data. Point-of-care HbA1c, body mass index (BMI), blood pressure and periodontal status were analyzed.

Findings – A total of 690 participants were included in the study. A risk scoring system including five variables was developed. It exhibited fair discrimination (area under the curve = 0.72, 95%CI 0.68–0.71). The risk score value of 9 was used as the cut-off point for increased risk of abnormal HbA1c. Subjects that had a total risk score of 9 or more had a high probability of having abnormal HbA1c and were identified for referral to physicians for further investigation and diagnosis.

Originality/value – A risk score to predict hyperglycemia using a dental parameter was developed for convenient evaluation in dental clinics.

Keywords Abnormal glycemic status, Dental patients, Risk score

Paper type Research paper

Introduction

Type 2 diabetes mellitus (DM) can result in several serious complications that shorten life expectancy. Its prevalence is rapidly increasing worldwide, and with no available cure, early detection and containment of the condition are essential. Many studies have proved that it is preventable by lifestyle modifications among high-risk individuals [1–3]. The primary prevention method would be to administer interventions to prevent the transition to prediabetes and/or type 2 DM [1].

Type 2 DM can worsen oral infection and vice versa. Periodontal disease, in particular, has a clear association with the development of type 2 DM, and type 2 DM can also exacerbate periodontal disease [4, 5]. In addition, complications from dental procedures such as infection and delayed wound healing can occur in patients with chronic undiagnosed hyperglycemia. Understanding the clinical manifestations, pathophysiology and management of orofacial infection related to type 2 DM is necessary for the dentist to provide patients presenting with these illnesses with the best possible care and to prevent these patients from developing any serious complications [6].

Clinical opportunistic screening is one mechanism for diagnosing a disease before symptoms occur. Several studies conducted worldwide have indicated that prediabetes and type 2 DM are related to various risk factors, i.e. age, waist circumference, body weight, race, hypertension, family history of DM and a sedentary lifestyle [7–9]. More importantly, oral health status has been associated with DM in several studies [10–13]. A strong relationship between uncontrolled type 2 DM and periodontitis has been discovered, suggesting the importance of DM screening among dental patients [13, 14]. A recent study conducted in Thailand has revealed a high prevalence (>30%) of hyperglycemia, defined as point-of-care (POC) $HbA_{1c} \geq 5.7\%$, among dental patients. Moreover, multiple logistic regression analysis showed that older patients, family history of DM, severe periodontitis, central obesity and BMI ≥ 23 kg/m^2 were significantly associated with hyperglycemia [15]. These data suggested that a risk score to predict abnormal glycemic status could be established to identify patients with undiagnosed type 2 DM who are at risk of developing hyperglycemia in a dental clinic.

A clinical prediction model based on clinical and nonclinical predictors of a particular disease has been developed to calculate the probability of the presence of the disease [16]. The methodology used for developing and validating the model was explained. The model constituted a useful method to present the predicted probability of a result which is practically convenient to use [17]. In addition, Sullivan *et al.* developed a system called the point system that simplified the complex statistical models for practitioners. The system assisted the practitioners to estimate the risks of having diseases, help in the decision-making process regarding interventions and persuade patients toward a healthy life [17].

Numerous studies have developed simple risk scores to predict undiagnosed type 2 DM [18–21]. For instance, Griffin *et al.* developed a score based on patients' information available in a primary care setting to determine the risk of having undiagnosed type 2 DM [18]. Age, sex, BMI,

corticosteroid or blood pressure–lowering drug use, family history of DM and history of smoking contributed to the score. This model and risk score were subsequently evaluated in a cohort study in England and Wales for its capacity to detect undiagnosed hyperglycemia. It was found that a risk score using information regularly available in primary care could identify individuals with high HbA_{1c} with reasonable sensitivity and specificity [21].

Although simple risk scores to predict probable people with type 2 DM have been developed in primary care settings, none of these have been studied among Thai dental patients. Moreover, intra-oral parameters that might be affected by hyperglycemia had never been used for the establishment of a risk score to predict dental patients who are at risk of unknown hyperglycemia. Thus, the objective of this study was to develop a simple scoring system to characterize dental patients at risk of having hyperglycemia and to validate this scoring system in some randomly selected subjects.

Methodology

Study design

We conducted a cross-sectional analytical study amongst Thai dental patients who visited the Special Clinic of the Faculty of Dentistry, Mahidol University (SCMU), and His Majesty the King's Mobile Dental Service Unit (MDSU) between December 1, 2014 and July 31, 2015.

Inclusion and exclusion criteria

Participants aged ≥25 years with no previous history of hyperglycemia were recruited in the study. Participants with diagnosed type 2 DM, on glucose-lowering medication(s), systemic steroids and severe anemia and/or polycythemia were excluded from the study.

Sample size calculation

The sample size was calculated using the following formula; $n = z^2\, p\, (1-p)/d^2$ [22] where p was the expected prevalence of undiagnosed hyperglycemia in a group of Thais which was equal to 0.13 [23]. Thus, 690 participants constituted the total sample of the study. These 690 participants were further divided into 650 participants for the establishment of the risk score and 50 randomly selected participants for the validation of this risk score.

Data collection

A questionnaire was used to record the demographic data that included age, sex, level of education, marital status, family history of type 2 DM, smoking status and alcohol consumption of the participants. Relevant medical history such as hypertension, cardiovascular diseases, gout and dyslipidemia was also recorded, and the participants with one or more diseases were categorized as positive. The interviews and collection of relevant data from the participants were conducted by a single researcher.

The height and weight of the participants were measured and recorded. BMI was calculated as weight (kg) divided by height squared (m^2). The criterion of the World Health Organization was used to classify participants into normal (BMI < 23 kg/m^2), overweight (BMI: 23 to < 27.5 kg/m^2) and obese (BMI ≥ 27.5 kg/m^2) groups [24].

Blood pressure was measured in each patient following a standard procedure, and hypertension was defined as systolic blood pressure (SBP) ≥140 mmHg or diastolic blood pressure (DBP) ≥90 mmHg [25]. Known cases of hypertension revealed during history-taking were also labeled as hypertensive patients.

A single experienced dentist evaluated the periodontal health of all the participants. The reliability of the observations for the periodontal health made by the dentist was tested using the intra-class correlation coefficient (ICC), which was found to be 0.73. The parameters that would determine the periodontal health status were set and defined based on a previously published study [15]. Probing depth (PD) was defined as the distance from the gingival

margin to the base of the sulcus. Gingival recession was measured in six locations (mesiobuccal, mid-buccal, distobuccal, mesiolingual, mid-lingual and distolingual) for all teeth except the third molars. The clinical attachment level (CAL) was defined as the distance between the cementoenamel junction and the base of the periodontal sulcus and was computed from the measurements for the PD and gingival recession. The periodontal health status of the participants was then classified into three categories as (1) severe periodontitis (two or more interproximal sites with a CAL ≥6 mm and ≥1 interproximal site with PD ≥ 5 mm); (2) moderate periodontitis (two or more interproximal sites with CAL ≥4 mm or ≥2 interproximal sites with PD ≥ 5 mm) and (3) mild or no periodontitis (neither severe nor moderate periodontitis) [26].

Glycemic measurement

A POC HbA_{1c} measurement using a fingerstick blood sample and a benchtop analyzer (DCA Vantage Analyzer; Siemens Medical Solutions Diagnostics, Tarrytown, NY) was used to assess glycemic conditions of all participants. Patients with abnormal HbA_{1c} were defined as POC $HbA_{1c} \geq 5.7\%$ [27].

Risk score development

The data from 690 participants were randomly split into two datasets as follows: the training dataset for the development of a risk score ($n = 640$) and the test dataset for the validation of the risk score ($n = 50$) [28].

In the training dataset, we first used bivariate analysis to assess the association of each potential risk factor with abnormal HbA_{1c}. A chi-square test was used to determine categorical variables. Initial candidate independent variables were those with $p < 0.25$. Then, multivariable logistic regression with backward stepwise selection was performed to choose variables in the final model. The significant levels of variables to add to and remove from the model were $p < 0.05$ and $p < 0.1$, respectively. Subsequently, to predict the presence of abnormal HbA_{1c} in each individual, the score-based predictive model was developed from the logistic regression equation using the regression coefficient–based scoring method [17]. To generate a simple integer-based point score for each predictor variable, scores were developed by dividing beta coefficients by the absolute value of the smallest coefficient in the model and rounding up to the nearest integer. The total score for each patient was calculated by summing each component together.

Next, the receiver operating characteristic (ROC) curve analysis and the area under the ROC curve (AUC) and its corresponding 95% confidence interval were computed. The cut-off point of risk score that discriminated between a low-risk category and a high-risk category was verified. The cut-off points were selected for those scores optimizing the sensitivity–specificity relationship, and the Youden index was used in the interpretation and evaluation of a score which defined the maximum potential effectiveness of the risk score [29].

Testing the risk score

The risk score was validated internally using the test dataset ($n = 50$). Each participant's score was calculated according to the scoring scheme. The AUC of the validation was compared to the AUC of the training dataset. The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the scoring system were also calculated to evaluate the predictive accuracy.

Statistical analysis

All statistical analyses were performed using STATA (STATA Statistical Software, Version 14.0; College Station, TX).

Ethical consideration

The research protocol was approved by the Institutional Review Board, Faculty of Medicine, Chulalongkorn University (reference number: 255/2014), the Committee on Human Rights and Human Experimentation, Faculty of Dentistry and Faculty of Pharmacy, Mahidol University (MU-DT/PY-IRB 2014/057.2611) and the Ethics Committee of Maharat Nakhon Ratchasima Hospital.

Results

Establishment of the scoring system

A total of 640 participants were included for risk score development, 408 from SCMU and 232 from HMDSU. The bivariate analysis indicated that participants with abnormal HbA_{1c} were significantly more likely to be ≥ 46 years (81.9 vs 63.3%, $p < 0.001$), have a medical condition (44.2 vs 34.8%, $p = 0.021$), have a family history of type 2 DM (43.5 vs 31.8%, $p = 0.004$), present with hypertension (21.9 vs 14.0%, $p = 0.012$), have a BMI ≥ 27.5 (41.7 vs 20.3%, $p < 0.001$) and have severe periodontitis (17.6 vs 11.3%, $p = 0.014$) (Table 1).

Multivariate analysis indicated that age 46–55 years (OR = 3.03; 95%CI:1.58–5.82), age 56–65 years (OR = 4.65; 95%CI:2.40–9.02), age 66 to 89 years (OR = 5.27; 95%CI:2.49–11.15), secondary education (OR = 1.75; 95%CI:1.04–2.96), family history of DM (OR = 1.63; 95% CI:1.13–2.35), BMI 23 to < 27.5 kg/m^2 (OR = 1.87; 95%CI:1.19–2.95), BMI ≥ 27.5 kg/m^2 (OR = 5.00; 95%CI:3.05–8.19) and severe periodontitis (OR = 1.88; 95%CI:1.0—3.27) were significantly associated with the risk of abnormal $HbA_{1c.}$

According to the regression coefficient obtained from the multivariate regression model, the smallest β-coefficient of this model was 0.28 [17]. The risk score value (last column in Table 2) was then calculated by dividing the β-coefficient of each variable by 0.28 which is the smallest β-coefficient of this model. Subsequently, the number derived from the division was rounded up to the nearest integer. Therefore, if the β-coefficient was between 0.28–0.41, the score would be 1; for a β-coefficient between 0.49–0.63, the score would be 2; for a β-coefficient equaled 1.11, the score would be 4; for a β-coefficient equaled 1.54, the score would be 5 and for a β-coefficient between 1.61–1.66, the score would be 6 (Table 2).

The point score of each variable is presented in Table 3. The final scoring system ranges from 0 to 18 with a higher score reflecting a greater risk of having abnormal HbA_{1c}. The maximum score of 18 was the sum of the highest possible points from each predictor variable, whereas the minimum score of 0 was the sum of references. The scoring system exhibited fair discrimination (AUC = 0.72, 95%CI 0.68–0.76) (Figure 1). According to the Youden index, the risk score value of 9 was selected as a cut-off point for an increased risk of abnormal HbA_{1c}, with an approximate sensitivity of 0.65 and specificity of 0.70. Subjects that had a total point-score of 9 or more had a higher probability of having abnormal HbA_{1c}.

As an illustration, we took a 66-year-old male patient, who visited our clinic for the first time to estimate the risk of having abnormal HbA_{1c}. The other relevant parameters in the patient for estimating the risk were – a secondary level of education, a family history of DM, a BMI of 25 kg/m^2 and severe periodontitis. According to Table 3, his risk score would be equal to 14 [6 (age 66–89) + 2 (secondary education) + 2 (family history of type 2 DM) + 2 (BMI 23 to < 27.5 kg/m^2) + 2 (severe periodontitis)] and should be considered a high-risk case for abnormal HbA_{1c}.

Internal validation

Using a simple random sampling technique, a group of 50 participants was selected, and their data were used in the validation phase. The demographic data of this group are presented in Table 1. The point scores of each patient were calculated according to the scoring scheme (Table 3). The AUC of the validation phase was 0.63 (95%CI 0.47–0.78) which indicated that the point score exhibited fair discrimination. For cut point risk score of ≥9, the prevalence of

Characteristic	Study population (n = 640) Total n (%)	Normal HbA_{1c} (n = 424) n (%)	Abnormal HbA_{1c} (n = 216) n (%)	p-value	Validation population (n = 50) Normal HbA_{1c} (n = 36) n (%)	Abnormal HbA_{1c} (n = 14) n (%)	p-value
Age (years)				<0.001			0.111
25–35	101 (15.8)	84 (19.8)	17 (7.9)		3 (8.3)	1 (7.1)	
36–45	94 (14.7)	72 (17.0)	22 (10.2)		12 (33.3)	1 (7.1)	
46–55	189 (29.5)	122 (28.8)	67 (31.0)		14 (38.9)	5 (35.7)	
56–65	173 (27.0)	97 (22.9)	76 (35.2)		5 (13.9)	3 (21.4)	
66–89	83 (13.0)	49 (11.6)	34 (15.7)		2 (5.6)	4 (28.6)	
Sex				0.052			0.675
Male	101 (23.8)	37 (17.1)	138 (21.6)		4 (11.1)	1 (7.1)	
Female	323 (76.2)	179 (82.9)	502 (78.4)		32 (88.9)	13 (92.9)	
Education level				0.187			0.598
None-primary education	181 (28.3)	116 (27.4)	65 (30.1)		10 (27.8)	4 (28.6)	
Secondary education	123 (19.2)	75 (17.7)	48 (22.2)		6 (16.7)	4 (28.6)	
Higher education	336 (52.5)	233 (55.0)	103 (47.7)		20 (55.6)	6 (42.9)	
Marital status				0.283			0.283
Single	194 (30.3)	145 (34.2)	49 (22.7)		14 (38.9)	4 (28.6)	
Married	381 (59.5)	242 (57.1)	139 (64.4)		21 (58.3)	8 (57.1)	
Separated	65 (10.2)	37 (8.7)	28 (13.0)		1 (2.8)	2 (14.3)	
Smoking status**				0.322			0.809
Never smoked	586 (91.7)	386 (91.3)	200 (92.6)		32 (88.9)	13 (92.9)	
Former smoker	21 (3.3)	17 (4.0)	4 (1.9)		1 (2.8)	0 (0.0)	
Current smoker	32 (5.0)	20 (4.7)	12 (5.6)		3 (8.3)	1 (7.1)	
Current alcohol consumer				0.131			0.384
No	525 (82.2)	341 (80.6)	184 (85.2)		30 (83.3)	13 (92.9)	
Yes	114 (17.8)	82 (19.4)	32 (14.8)		6 (16.7)	1 (7.1)	
History of medical illness				0.021			0.106
No	395 (62.0)	275 (65.2)	120 (55.8)		22 (61.1)	5 (35.7)	
Yes	242 (38.0)	147 (34.8)	95 (44.2)		14 (38.9)	9 (64.3)	
Family history of DM)				0.004			0.41
No	411 (64.2)	289 (68.2)	122 (56.5)		25 (69.4)	8 (57.1)	
Yes	229 (35.8)	135 (31.8)	94 (43.5)		11 (30.6)	6 (42.9)	
History of hypertension**				0.012			0.018
No	531 (83.4)	363 (86.0)	168 (78.1)		33 (91.7)	9 (64.3)	
Yes	106 (16.6)	59 (14.0)	47 (21.9)		3 (8.3)	5 (35.7)	
BMI (kg/m^2)				<.001			
<23	196 (30.6)	158 (37.3)	38 (17.6)		11 (30.6)	3 (21.4)	0.575
23 to < 27.5	268 (41.9)	180 (42.5)	88 (40.7)		15 (41.7)	5 (35.7)	
≥27.5	176 (27.5)	86 (20.3)	90 (41.7)		10 (27.8)	6 (42.9)	
Periodontal status				0.014			0.413
No or mild periodontitis	279 (43.6)	200 (47.2)	79 (36.6)		18 (50.0)	8 (57.1)	

(*continued*)

Table 1.
Clinical characteristics according to HbA_{1c} levels in the study and validation population*

Characteristic	Study population (n = 640) Total n (%)	Normal HbA_{1c} (n = 424) n (%)	Abnormal HbA_{1c} (n = 216) n (%)	p-value	Validation population (n = 50) Normal HbA_{1c} (n = 36) n (%)	Abnormal HbA_{1c} (n = 14) n (%)	p-value
Moderate periodontitis	275 (43.0)	176 (41.5)	99 (45.8)		14 (38.9)	3 (21.4)	
Severe periodontitis	86 (13.4)	48 (11.3)	38 (17.6)		4 (11.1)	3 (21.4)	

Note(s): *Data are stratified into groups of normal HbA_{1c} (<5.7) and abnormal HbA_{1c} (≥5.7). Values are presented as absolute number (n), percentage of a stratified subgroup (normal and abnormal) and p-values. Statistically significant at $p < 0.05$); **Each variable might have different numbers of participants due to missing data

Table 1.

Factor	Adjusted OR	95% CI	p-value	β-coefficient	Score*
Age in years					
25–35	1.00	Reference			0
36–45	1.51	0.72–3.17	0.279	0.410	1
46–55	3.03	1.58–5.82	0.001	1.109	4
56–65	4.65	2.40–9.02	<0.001	1.537	5
66–89	5.27	2.49–11.15	<0.001	1.661	6
Education level					
None/primary education	1.00	Reference			
Secondary education	1.75	1.04–2.96	0.035	0.562	2
Higher education	1.47	0.94–2.29	0.09	0.383	1
Family history of DM					
No	1.00	Reference			
Yes	1.63	1.13–2.35	0.01	0.487	2
BMI (kg/m^2)					
<23	1.00	Reference			
23 to < 27.5	1.87	1.19–2.95	0.007	0.625	2
≥27.5	5.00	3.05–8.19	<0.001	1.609	6
Periodontal status					
No or mild periodontitis	1.00	Reference			
Moderate periodontitis	1.32	0.90–1.95	0.154	0.281	1
Severe periodontitis	1.88	1.08–3.27	0.025	0.631	2

Note(s): *The score values were estimated based on the β-coefficient of the logistic regression model

Table 2.
Predictors for abnormal HbA_{1c} among Thai dental patients (n = 640)

hyperglycemia was 28%, the sensitivity was 0.64 (95%CI 0.35–0.87), the specificity was 0.61 (95%CI 0.44–0.77), the PPV (the probability of having hyperglycemia if risk score ≥ 9) was 0.39 (95%CI 0.20–0.62) and the NPV (the probability of not having hyperglycemia if risk score was <9) was 0.82 (95%CI 0.62–0.94).

Discussion

The objective of this study was to develop a risk score to predict the possibility of having abnormal levels of HbA_{1c} in dental patients using noninvasive factors that are easy to measure in a dental clinic. Several risk scores for diabetes have been developed to serve as a

Variable	Category	Score
Age (years)		
	25–5	0
	36–45	1
	46–55	4
	56–65	5
	66–89	6
Education level		
	None/primary education	0
	Secondary education	2
	Higher education	1
Family history of DM		
	No	0
	Yes	2
BMI (kg/m^2)		
	<23	0
	23 to < 27.5	2
	≥27.5	6
Periodontal status		
	No or mild periodontitis	0
	Moderate periodontitis	1
	Severe periodontitis	2
Minimum score		0
Maximum score		18
Cut-off point		9

Table 3. Abnormal HbA_{1c} scoring system for dental patients ($n = 640$)

screening tool to identify high-risk subjects in any population [19] and Thais [7] in a primary care setting. Based on our knowledge, this study is the first of its kind that developed a scoring system to estimate the risk of abnormal HbA_{1c} using dental parameters among Thai dental patients. The multivariable analysis showed that increasing age, education level, family history of DM, high BMI and poor periodontal status were the variables in the risk score to predict abnormal HbA_{1c}. In comparison with a previous study conducted among the Thai population [7], our scoring system comprised five components with at least three including age, BMI and family history of DM that are similar to those previously reported, and the score was easily computed; therefore, its simplicity would promote the use of this model in a dental clinic.

Practical risk scores have been developed by many groups of researchers [18, 21]. Griffin and colleagues, in 2000, developed a simple risk score to detect patients with undiagnosed type 2 DM in general practice. A population-based sample of 1,077 participants, aged 40–64 years from a single Cambridgeshire general practice were assessed for glucose tolerance test. Age, gender, body mass index, use of steroid and antihypertensive medication, family history of type 2 DM and smoking history were used in the establishment of the risk score. It was found that in the test population which harbored 72% specificity, the sensitivity was 77%, a likelyhood ratio was 2.76 and the AUC was 0.80 [18]. A subsequent study that followed Griffin's study was conducted in the European Prospective Investigation of Cancer-Norfolk cohort (EPIC-Norfolk cohort) to validate the use of the previous risk score. For a specificity of 0.78, the risk score predicted an HbA_{1c} of ≥7.0 in subjects aged 39–78 years, with a sensitivity of 0.51 (95% CI 0.40–0.62). The AUC for $HbA_{1c} \geq 6.0$, 6.5 and 7.0% were 0.66 (95%CI 0.64–0.68), 0.72 (95%CI 0.68–0.75) and 0.74 (95%CI 0.69–0.79), respectively. From this study, it was

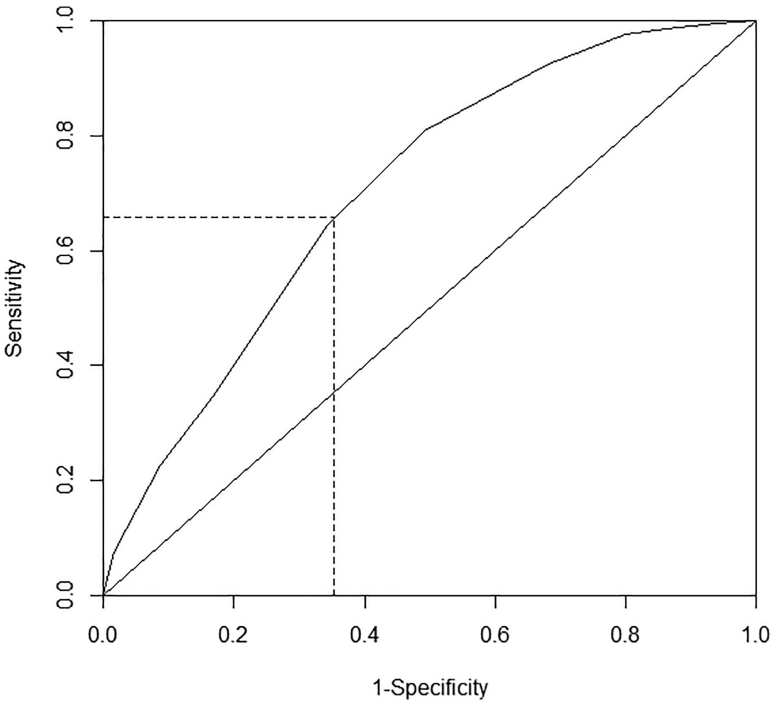

Figure 1.
ROC curve showing the performance of the risk score for cut point ≥9 in predicting hyperglycemia among dental patients

concluded that Griffin's risk score could be used to identify people with an elevated HbA_{1c} in general practice settings [21].

Aekplakorn and colleagues, in 2006, also developed a simple diabetes risk score in a Thai cohort of 2,677 individuals and validated in different 2,420 participants [7]. A total of 361 individuals developed type 2 DM in the exploratory cohort during the follow-up period. The significant predictive variables in the simple model were age, BMI, waist circumference, hypertension and history of DM in parents or siblings. A cut-off score of 6 of 17 produced the optimal sum of sensitivity (0.77) and specificity (0.60). The AUC was 0.74. Comparing these data to our study, when the periodontal status was incorporated into the risk score development and then validated in some of the information in the same data set if the value of 9 was selected as a cut-off point for an increased risk of abnormal HbA_{1c}, the sensitivity was 0.65 and the specificity was 0.70. The scoring system exhibited fair discrimination (AUC = 0.72, 95%CI 0.68–0.76). When the risk score was validated in 50 randomly selected individuals in the same data set, the AUC of the validation phase was 0.63 (95%CI 0.47–0.78) which indicated that the point-score exhibited fair discrimination. For the cut point risk score of ≥9, the prevalence of hyperglycemia was 28%, the sensitivity was 0.64 (95%CI 0.35–0.87) and the specificity was 0.61 (95%CI 0.44–0.77). Although our risk score exhibited fair discrimination, further study is needed to evaluate the use of this risk score in predicting patients at risk of having hyperglycemia in dental settings in a different group of the population.

Regarding the limitations of this study, the sample size in the testing (n = 640) and the validation groups (n = 50) was small when compared to a previous study in the Thai population which included 2,677 cases for testing cohort and 2,420 cases for the cohort validation [7]. When the number of observations is small, careful interpretation of results is essential. Hence, a study with a large cohort of dental patients will further validate our

findings. Despite having some limitations, this study has its strengths. Firstly, there was diversity in the study population. The participants who enrolled for the study at SCMU were mostly urban dwellers, whereas those at HMDSU were primarily residing in suburban areas such as Sukhothai, Nakhon Ratchasima, Ratchaburi and Khon Kaen provinces. This meant the results of our study could be generalized to other dental patients in the Thai population. Secondly, this is the first report on the development of risk score for screening of abnormal HbA_{1c} in dental patients that could be effortlessly used in dental clinics. Further studies using the screening test design on a certain population to test reliability, validity and efficacy of the model should be conducted. The scoring system obtained could be used as a screening tool for individuals when seeking dental treatment. Finally, the correlation between patients' oral and general health remains a novel trend in dentistry. Opportunistic screening for noncommunicable diseases (NCDs) has recently emerged as a new means toward this goal [30]. Identifying undiagnosed hyperglycemia in dental clinics would fit this trend. However, identifying and removing barriers to screening for hyperglycemia in a dental clinic is critical to widespread implementation. Establishing policies that support reimbursement for screening may facilitate greater acceptance by physicians, dentists and patients.

Conclusion

A risk scoring system was developed from five characteristics of dental patients including age, education level, family history of DM, BMI and periodontal status. This risk score system is simple and noninvasive and could contribute to the early detection of hyperglycemia through case finding or targeted screening in dental patients at risk.

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