Screening for prediabetes and type 2 diabetes in dental offices

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Abstract

Objectives: Most Americans see dentists at least once a year. Chair-side screening and referral may improve diagnosis of prediabetes and diabetes. In this study, we developed a multivariate model to screen for dysglycemia (prediabetes and diabetes defined as HbA1c ≥5.7 percent) using information readily available to dentists and assessed the prevalence of dysglycemia in general dental practices.
Methods: We recruited 1,033 adults ≥30 years of age without histories of diabetes from 13 general dental practices. A sample of 181 participants selected on the basis of random capillary glucose levels and periodontal status underwent definitive diagnostic testing with hemoglobin A1c. Logistic models were fit to identify risk factors for dysglycemia, and sample weights were applied to estimate the prevalence of dysglycemia in the population ≥30 years of age.
Results: Individuals at high risk for dysglycemia could be identified using a questionnaire that assessed sex, history of hypertension, history of dyslipidemia, history of lost teeth, and either self-reported body mass index ≥35 kg/m^2 (severe obesity) or random capillary glucose ≥110 mg/dl. We estimate that 30 percent of patients ≥30 years of age seen in these general dental practices had dysglycemia.
Conclusions: There is a substantial burden of dysglycemia in patients seen in general dental practices. Simple chair-side screening for dysglycemia that includes or does not include fingerstick random capillary glucose testing can be used to rapidly identify high-risk patients.
Practical implications: Further studies are needed to demonstrate the acceptability, feasibility, effectiveness, and cost-effectiveness of chair-side screening.

Introduction

Diabetes mellitus affects 25.8 million Americans or 8.3 percent of the population (1). Another 79 million Americans are estimated to have prediabetes (1), the vast majority of whom are undiagnosed. The US Preventive Services Task Force has recommended screening for type 2 diabetes in asymptomatic adults with sustained blood pressure >135/80 mmHg (2). The American Diabetes Association has recommended screening for diabetes every 3 years in persons ≥45 years of age and in those <45 years of age with body mass index (BMI) ≥25 kg/m^2 and one or more risk factors for diabetes (3).

Approximately 70 percent of Americans see dentists at least once a year for check-ups and cleanings (4). The concept of prevention is fundamental to dentistry, and many dental healthcare professionals have built relationships with their patients focused on prevention. The American Dental Association has recognized that its members may wish to take advantage of this relationship to monitor cardiovascular risk factors (5). There may also be an opportunity to screen for prediabetes and diabetes during routine dental checkups.

Screening for a disease is appropriate if the disease is serious; its natural history is understood; it is detectable in its preclinical stage; the screening test is inexpensive, safe, acceptable, and valid; early treatment of the disease is more

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effective than late treatment; and screening programs improve outcomes (6). Type 2 diabetes meets many of these criteria (7). Screening for diabetes also provides an opportunity to identify people with prediabetes who are at increased risk for both type 2 diabetes and cardiovascular disease. Randomized controlled clinical trials have conclusively demonstrated that lifestyle and medication interventions are effective in delaying or preventing the development of type 2 diabetes in high-risk individuals with prediabetes (8-12). The failure to translate proven-effective interventions for diabetes prevention into widespread clinical practice is due in large part to the difficulty in identifying high-risk individuals. To help address this problem, investigators have developed and validated multivariate risk factor models (13-18) and implemented them in a variety of settings including primary care.

In an analysis of data from the Third National Health and Nutrition Examination Survey (NHANES), Eklund *et al*. described prediabetes and diabetes among patients who reported that they had at least one dental visit during the past year (Eklund, unpublished observations). At least 10 percent of patients ≥50 years of age had diabetes and approximately 40 percent had impaired fasting glucose. Perhaps even more startling and troubling was the fact that one-third to one-half of those with diabetes and more than 90 percent of those with impaired fasting glucose reported that they had never been told by a doctor that they had diabetes or prediabetes. As a result, they remained undiagnosed and untreated. This may ultimately increase the risk of diabetes and its complications and comorbidities, negatively impact oral health, and preclude appropriate dental care.

The purpose of this study was to develop and validate a tool to screen for prediabetes and previously undiagnosed diabetes in dental practices using information readily available to dental practitioners and to assess the prevalence of prediabetes and previously undiagnosed diabetes in general dental practices. Because we wanted to develop a tool specifically for dental practitioners, we assessed essentially all of the risk factors previously associated with dysglycemia as well as symptoms and signs of periodontal disease not previously assessed as risk factors for dysglycemia and used multivariate analysis to develop a new screening tool.

Methods

Following University of Michigan Institutional Review Board review and approval, we hired and trained research assistants and assigned them to general dental practices where they recruited all adults ≥30 years of age with no history of diabetes who were being seen for routine checkups and cleanings. Recruitment occurred between November 2009 and July 2011. Following written informed consent, patients completed questionnaires that assessed essentially all of the established risk factors for dysglycemia including age, sex, race/ethnicity, education, income, self-reported height and weight, self-reported physical activity, history of hypertension and hypertension treatment, history of dyslipidemia and lipid treatment, history of cigarette smoking, history of cardiovascular disease, history of gestational diabetes, family history of diabetes, medical insurance coverage, and access to medical care. The questionnaire also assessed symptoms and signs of periodontal disease including teeth that hurt, painful gums, teeth that became loose by themselves without injury, and teeth that were lost from the upper or lower jaw other than wisdom teeth or teeth extracted to get braces. For purposes of this analysis, answers to the question about lost teeth were dichotomized as none versus one or more teeth. Thereafter, the research assistant performed a random capillary glucose measurement from each participant's finger with a portable blood glucose testing system (FreeStyle Lite blood glucose meters and test strips, Abbott Diabetes Care Inc., Alameda, CA, USA). We have previously assessed the performance of random capillary glucose as a screening test and found a cutpoint of ≥110 mg/dl to be very sensitive in identifying people with previously undiagnosed diabetes regardless of age and time since last food or drink (19). The hygienist or dentist then performed a brief periodontal evaluation based on their usual office practice and indicated the absence or presence of periodontal disease and its severity. Periodontal status was initially classified into one of five categories (Appendix 1). For the purpose of this analysis, periodontal status was dichotomized as none or gingivitis only versus early/slight, moderate, or advanced/severe periodontitis.

Because we wished to rigorously evaluate the sensitivity and specificity of the newly developed screening tool, we performed definitive diagnostic tests on a systematic sample of the entire study population. All respondents at higher risk for previously undiagnosed diabetes (random capillary glucose ≥110 mg/dl) and a 50 percent random sample of those at lower risk for undiagnosed diabetes (random capillary glucose <110 mg/dl) and all patients with any degree of hygienist- or dentist-reported periodontitis were invited to the Michigan Clinical Research Unit for a hemoglobin A1c (HbA1c) measurement. HbA1c was measured using a Tosoh G7 HPLC Analyzer (Tosoh Biosciences Inc, South San Francisco, CA, USA).

HbA1c provides an integrated measure of average glycemia over the past 3 months (20) and has been endorsed by the International Expert Committee and the American Diabetes Association for the diagnosis of prediabetes and diabetes (21). The American Diabetes Association has defined normal as HbA1c <5.7 percent, prediabetes as HbA1c 5.7-6.4 percent, and diabetes as HbA1c ≥6.5 percent (3). We defined dysglycemia as prediabetes or diabetes (HbA1c ≥5.7 percent).

We compared the normal and dysglycemic groups using one-way analysis of variance when the measure was continuous or a chi-square test when the measure was discrete.

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Logistic regression models were then developed to identify risk factors for dysglycemia using a backwards elimination process. We chose to use this approach because all of the factors that we assessed were potential risk factors for dysglycemia. Initially, all variables were included in the model. Then, at each step, the variable that was least significant was eliminated until all the terms were significant. Using the final set of variables, we examined whether interactions with sex were significant. To compare the fit of the models, we reported the percent of the likelihood chi-square that was explained by adding variables to the null model.

To estimate the prevalence of dysglycemia in the entire screened population, we calculated the number of individuals in each 10 year age and sex group and multiplied the number by the prevalence of dysglycemia in the participants in that age and sex group who underwent definitive diagnostic testing (HbA1c). All analyses were performed using SAS 9.2 (SAS Institute, Cary, NC, USA).

Results

We recruited 1,033 adults ≥30 years of age without histories of diabetes from 13 general dental practices in southeastern Michigan. An additional 106 adults were approached in the dental practices but declined to participate. The reasons given for nonparticipation included lack of time, ineligibility due to diabetes, and unwillingness to provide a capillary blood sample. All participants provided written informed consent and completed questionnaires, had random capillary glucose tests performed by trained research staff using test strips and portable glucose meters approved for self-monitoring of blood glucose, and had brief oral examinations performed by the hygienist or dentist in the office. The mean age (±standard deviation) of participants was 52.8 ± 12.7 years, 43 percent were male, and 81 percent were white. The numbers of participants recruited from each practice ranged from 13 to 242 with a median of 47.

A total of 354 participants with either random capillary glucose ≥110 mg/dl and/or periodontitis were invited to the Michigan Clinical Research Unit (MCRU) for definitive diagnostic testing and 100 (28 percent) participated. Similarly, 327 participants with random capillary glucose <110 mg/dl and no periodontitis were invited to the MCRU for testing and 81 (25 percent) participated. Participants who were invited for definitive diagnostic testing and attended were significantly older than those who were invited and did not attend. Participants with either elevated random capillary glucose and/or periodontitis who were invited and attended were 57.4 ± 11.7 years of age compared with 54.7 ± 13.9 years of age for those who were invited and did not attend ($p = 0.0015$). Participants with normal random capillary glucose and no periodontitis who were invited and attended were 54.1 ± 12.0 years of age compared with 50.5 ± 11.9 years of age for those who were invited and did not attend ($P = 0.0178$). Participants with either elevated random capillary glucose and/or periodontitis who were invited and attended were significantly more likely to have a history of dyslipidemia than those who were invited and did not attend ($P = 0.0020$) and were significantly more likely to have a history of lost teeth than those who were invited and did not attend ($P = 0.0174$). There were no differences between participants who were invited and attended and those who were invited and did not attend with respect to sex, race, BMI, random capillary glucose, history of hypertension, or history of cardiovascular disease. Of the 181 participants tested, three were diagnosed with diabetes based on HbA1c ≥6.5 percent, 57 were diagnosed with prediabetes based on HbA1c 5.7-6.4 percent, and 121 were diagnosed with normal glycemia (HbA1c <5.7 percent).

Table 1 presents the sociodemographic characteristics and the prevalence of risk factors by HbA1c category. Dysglycemia was associated with older age, higher BMI as calculated from self-reported height and weight, and history of hypertension, dyslipidemia, and myocardial infarction or stroke. Dysglycemia was associated with both higher random capillary glucose levels and random capillary glucose >110 mg/dl. History of loss of one or more teeth was associated with dysglycemia but clinical evidence of periodontitis was not. The vast majority of participants reported having insurance, having a primary care physician (PCP), and seeing their PCP at least once per year. Dysglycemia was not significantly associated with sex, race, income, education, physical activity, cigarette smoking, family history of diabetes, and report of painful teeth or loose teeth.

All of the variables in Table 1 were included in a logistic regression model in which age and BMI were incorporated as continuous variables. After backwards elimination, the final model included sex, history of hypertension, history of dyslipidemia, history of loss of one or more teeth, and random capillary glucose category (<110 versus ≥110 mg/dl). There was a significant interaction between history of hypertension and sex (Table 2). The variables in the model explained 24 percent of the likelihood chi-square. When the same model was fit using random capillary glucose as a continuous variable, the model explained less of the likelihood chi-square. When the model was fit without incorporating random capillary glucose as a categorical or continuous variable, it included sex, history of hypertension, history of dyslipidemia, history of loss of one or more teeth, and BMI category (<35 versus ≥35 kg/m^2 corresponding to severe obesity). This model explained 20 percent of the likelihood chi-square (Table 3). Appendix 2 includes the questions used to ascertain the variables that entered the final models.

We then identified rules to operationalize the models for clinical practice and chose cutpoints such that the specificity of the models would be approximately 80 percent (in order to

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Table 1 Sociodemographic Characteristics and Prevalence of Risk Factors by HbA1c Category*

	Dysglycemia† *n* = 60	Normal‡ *n* = 121	*P*-value
Age (years)	59.4 ± 9.4	54.3 ± 12.7	0.0027
Sex (male)	34 (56.7)	56 (46.3)	0.21
Race (nonwhite)	16 (26.7)	18 (15.0)	0.070
Income <$50,000	16 (31.4)	20 (18.7)	0.10
Education <college graduate	27 (45.0)	41 (34.5)	0.19
BMI (kg/m^2)	30.5 ± 7.4	28.2 ± 5.6	0.042
Inactive	23 (38.3)	48 (40.3)	0.87
Smoke cigarettes (yes)	7 (11.7)	8 (6.7)	0.27
Family history of diabetes (yes)	28 (47.5)	45 (37.8)	0.26
History of hypertension (yes)	34 (56.7)	32 (26.9)	0.0001
History of dyslipidemia (yes)	47 (78.3)	50 (42.0)	<0.0001
History of MI or stroke (yes)	11 (18.6)	9 (7.6)	0.04
Random capillary glucose level (mg/dl ± SD)	117 ± 20	104 ± 22	0.0002
Random capillary glucose ≥110 mg/dl	38 (63.3)	34 (28.1)	<0.0001
Painful teeth (yes)	8 (13.6)	10 (8.3)	0.30
Loose teeth (yes)	3 (5.0)	6 (5.0)	1.00
One or more lost teeth (yes)	37 (61.7)	48 (40.3)	0.01
Periodontitis (yes)	16 (26.7)	23 (19.0)	0.25
Have insurance (yes)	60 (100.0)	115 (95.8)	0.17
Have PCP (yes)	57 (96.6)	112 (94.1)	0.72
See PCP at least once per year (yes)	43 (87.8)	88 (91.7)	0.55

* Mean ± standard deviation or *n* (%).

† Dysglycemia defined as HbA1c ≥5.7%.

‡ Normal defined as HbA1c <5.7%.

reduce the number of false positive screening tests). Using the risk factors in the model in Table 2 that included random capillary glucose category, the risk of dysglycemia was high if the subject was male (with or without hypertension) or female with hypertension and had two of the following three risk factors: a history of dyslipidemia, a history of loss of one or more teeth, and capillary glucose ≥110 mg/dl. The risk of dysglycemia was also high if the subject was female without hypertension, and had a history of dyslipidemia, a history of loss of one or more teeth, and random capillary glucose ≥110 mg/dl.

Using the risk factors in the model in Table 3 that did not include random capillary glucose category, a male (with or without hypertension) or a female with hypertension was at high risk for dysglycemia if he or she had two of the following three risk factors: a history of dyslipidemia, a history of loss of one or more teeth, and BMI ≥ 35 kg/m^2 (corresponding to severe obesity). A female without hypertension was at high

Table 2 Factors Independently Associated with Prediabetes or Previously Undiagnosed Diabetes When Random Capillary Glucose Is Included

Parameter	Coefficient ± standard error	Odds ratio (95% CI)	*P*-value
Intercept	–0.70 ± 0.20		0.0006
Male with history of hypertension	0.15 ± 0.32	1.2 (0.44-3.11)	0.64
Male without history of hypertension	–0.00 ± 0.31	–	0.99
Female with history of hypertension	0.77 ± 0.37	5.4 (1.7-17.2)	0.035
Female without history of hypertension (reference group)	–0.92 ± 0.34	–	0.007
History of dyslipidemia	0.67 ± 0.21	3.8 (1.7-8.5)	0.0012
History of lost teeth	0.50 ± 0.19	2.7 (1.3-5.8)	0.0098
Random glucose ≥110 mg/dl	0.66 ± 0.19	3.8 (1.8-7.9)	0.0005

We used a cutpoint of –0.087 as calculated from the logistic regression model (corresponding to a probability of 0.45) to achieve a specificity of 80% and sensitivity of 60%.

The *P*-value for the sex by history of hypertension variable is 0.034 with 3 degrees of freedom.

The odds ratio for hypertension compares those with hypertension to those without hypertension within the same sex.

When a parameter is not listed in the table (e.g., random glucose <110 mg/dl), the coefficient is the negative of the coefficient that is given when it is present.

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Table 3 Factors Independently Associated with Prediabetes or Previously Undiagnosed Diabetes When Random Capillary Glucose Is Excluded

Parameter	Estimate ± standard error	Odds ratio (95% CI)	*P*-value
Intercept	–0.53 + 0.23		0.0238
Male with history of hypertension	0.31 + 0.31	1.4 (0.5-3.4)	0.32
Male without history of hypertension	0.01 + 0.30	–	0.97
Female with history of hypertension	0.60 + 0.37	4.5 (1.4-14.2)	0.11
Female without history of hypertension (reference group)	–0.92 + 0.33	–	0.0056
History of dyslipidemia	0.83 + 0.21	5.3 (2.3-12.1)	<.0001
History of lost teeth	0.47 + 0.19	2.5 (1.2-5.3)	0.012
BMI ≥ 35 kg/m^2	0.47 + 0.25	2.6 (0.9-7.0)	0.064

We used a cutpoint of -0.087 as calculated from the logistic regression model (corresponding to a probability of 0.45) to achieve a specificity of 80% and sensitivity of 50%.

The *P*-value for the sex by history of hypertension variable is 0.039 with 3 degrees of freedom.

The odds ratio for hypertension compares those with hypertension to those without hypertension within the same sex.

When a parameter is not listed in the table (e.g., BMI < 35 kg/m^2), its coefficient is the negative of the coefficient that is given when it is present.

risk if she had a history of dyslipidemia, a history of loss of one or more teeth, and BMI ≥ 35 kg/m^2 (corresponding to severe obesity). Areas under the receiver operator characteristic curves were 0.83 and 0.79 (Fig. 1a and b). When specificity was 80 percent, the sensitivity to identify dysglycemia was approximately 60 percent for the first model and 50 percent for the second.

Applying the observed rates of dysglycemia to the 10-year age and sex groups, we estimated that 13 (1.3 percent) of the 1,033 screened subjects ≥30 years of age would have previously undiagnosed diabetes, 297 (28.7 percent) would have prediabetes, and 723 (70.0 percent) would have normal glycemia (Table 4). Specifically targeting older age groups such as those ≥45 years of age would improve the yield of screening.

Discussion

In this study, we have demonstrated the predictive value of simple self-reported risk factors and random capillary glucose levels in screening for dysglycemia. Risk can be easily assessed with the one-page instrument provided in Appendix 2 with or without assessment of random capillary glucose. We have also demonstrated a high prevalence of dysglycemia among patients receiving screening and prophylaxis in general dental practices despite the fact that most report having health insurance, having PCPs, and seeing their PCP at least once per year.

Borrell *et al*. analyzed data from NHANES-3 to estimate the predicted probability of having undiagnosed diabetes

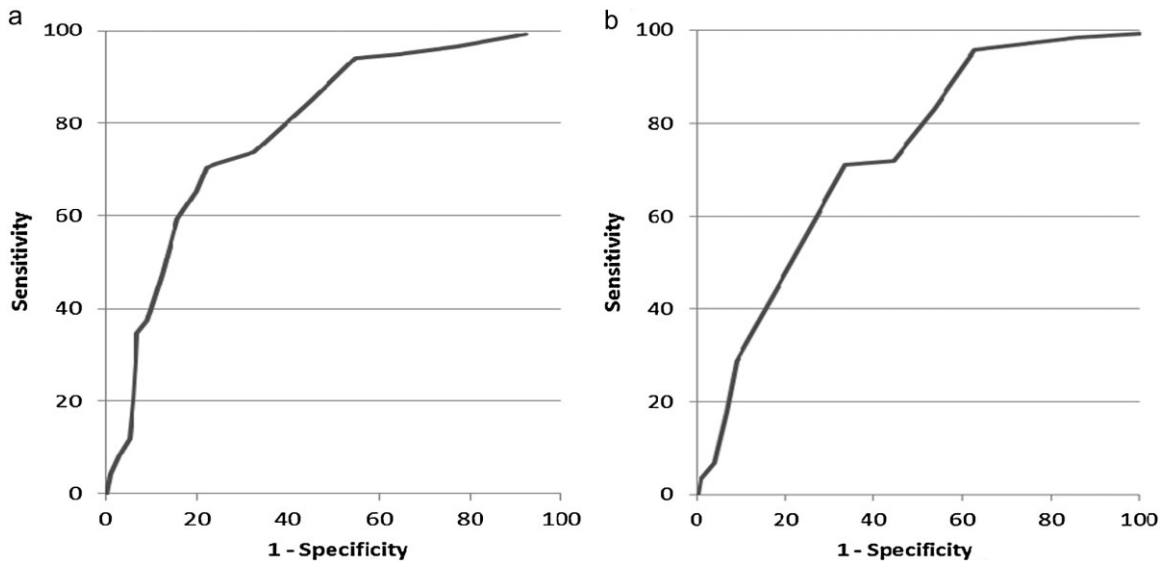

Figure 1 Receiver operator characteristic curves. a. Performance of model 2A that includes random capillary glucose category in predicting dysglycemia [area under the curve (AUC) = 0.83]. b. Performance of model 2B that excludes random capillary glucose category in predicting dysglycemia (AUC = 0.79).

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Table 4 Estimated Prevalence (Weighted Percentages) of Previously Undiagnosed Diabetes, Prediabetes, and Normal Glucose Tolerance in the Population Screened in General Dental Practices by Sex and Age

	Diabetes	Prediabetes	Normal
Women			
30-39 years	0.0%	20.0%	80.0%
40-59 years	2.0%	13.9%	84.1%
60+ years	2.6%	43.4%	54.1%
Total	1.8%	23.5%	74.8%
Men			
30-39 years	0.0%	15.4%	84.6%
40-59 years	0.0%	43.4%	56.6%
60+ years	1.9%	36.1%	61.9%
Total	0.6%	35.8%	63.6%
Total			
30-39 years	0.0%	18.0%	82.0%
40-59 years	1.2%	25.9%	72.9%
60+ years	2.3%	40.0%	57.7%
Total	1.3%	28.7%	70.0%

(22). They demonstrated that self-reported information obtained from a standard health history, coupled with findings from a periodontal examination in the dental office that included probing depth measurements and assessment of clinical attachment levels resulted in predicted probabilities of undiagnosed diabetes between 27 percent and 53 percent. Further analyses from NHANES 2003-2004 demonstrated that 93 percent of individuals with periodontal disease and 63 percent of those without periodontitis met ADA Guidelines for diabetes screening (23), highlighting the importance of periodontal disease and its sequelae as risk factors for dysglycemia.

Barasch *et al*. explored the utility of random plasma glucose levels for screening for prediabetes or previously undiagnosed diabetes in community dental practices. Of 418 subjects who qualified for testing in 28 dental practices, 18 percent had diabetes or prediabetes (24,25). A follow-up survey found that blood glucose testing was well-received by both practitioners and patients (25). Lalla *et al*. further explored the feasibility of screening adult patients who presented for care at a dental clinic and had never been told they had prediabetes or diabetes. The presence of ≥4 missing teeth or ≥26 percent of teeth with deep pockets correctly identified 73 percent of true cases (26).

Genco *et al*. recently reported a field trial of screening for prediabetes and diabetes in dental practices. They screened 1,022 dental patients ≥45 years of age in 11 general and periodontal specialty dental offices and in a dental clinic within a community health center. Participants had no history of diabetes and had not been tested for diabetes in the previous 12 months. Screening was performed with the American Diabetes Association Diabetes Risk Test and a point-of-care capillary hemoglobin A1c test. Nearly 41 percent of participants had dysglycemia defined by HbA1c ≥5.7 percent. In general, the ADA Diabetes Risk Test performed poorly in predicting patients at high risk, and periodontal disease status, as assessed at the dental sites, added little to the HbA1c measurement used for screening (27).

In 2010, Greenberg *et al*. reported on attitudes toward, acceptance of, and perceived barriers to chair-side screening for medical conditions among practicing dentists (28). Seventy-seven percent thought it was very important or somewhat important for dentists to perform chair-side screening for diabetes. Most (85 percent) were very willing to refer a patient for consultation with a physician. Only 55 percent were very willing to conduct chair-side screening themselves and only 29 percent were very willing to gather blood via finger stick. Previous studies from the northeastern United States (29-31) and New Zealand (32) have indicated that almost one-third of dentists are unwilling to screen for diabetes using finger-stick tests and fewer than 3 percent have ever done so. Strauss *et al*. have suggested that measurement of gingival crevicular blood may be a more acceptable approach to diabetes screening in periodontal patients (33). Nevertheless, it is clear that although dental practitioners are receptive to performing preventive activities outside the traditional scope of dental practice, barriers remain to their widespread implementation.

The fact that 70 percent of Americans visit their dentists at least once per year (4) and that 20-50 percent may have undiagnosed dysglycemia (Eklund, unpublished data; 24) highlights the importance of the dental office as a place to screen and refer patients for diagnosis and subsequent medical care of this common and costly systemic disease. Early detection, prevention, and treatment may not only improve health and reduce medical costs, but enhance dentists ability to prevent and treat periodontal disease. Identifying and removing barriers to screening for dysglycemia in dentists' offices is critical to widespread implementation. Establishing policies that support reimbursement for screening may facilitate greater acceptance by dental practitioners. Cost-effectiveness analyses and assessment of return on investment may also assist in building a case for policies that facilitate screening in dental offices.

We have demonstrated that an estimated 30 percent of nondiabetic adults ≥30 years of age seen in general dental practices have dysglycemia and that high-risk adults can be identified using a questionnaire that assesses sex, history of hypertension, history of dyslipidemia, history of lost teeth, and random capillary glucose or self-reported BMI ≥ 35 kg/m^2. The results of our study must be interpreted with caution because of the low response rate among participants who were invited for definitive diagnostic testing and the possibility that those who came for testing were not representative of the population of patients seen in general dental practices. Fortunately, post hoc analyses demonstrated only

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minor differences between participants who were invited for definitive diagnostic testing and attended and those who did not attend. Although our estimate of the prevalence of dysglycemia may be high due to the greater likelihood of follow-up among higher risk patients, we suspect that the impact is small. In addition, the fact that patients at higher risk for dysglycemia are more likely to report for definitive diagnostic testing suggests that if implemented in routine clinical practice, follow-up may be better among higher risk patients, thus improving the yield of screening.

This study demonstrates the potential utility of chair-side screening and referral for definitive diagnostic testing and treatment. Further studies are needed to demonstrate the acceptability, feasibility, effectiveness, and cost-effectiveness of such screening.

References

1. CDC. 2011 National Diabetes Fact Sheet. Diagnosed and undiagnosed diabetes in the United States, all ages, 2010. [cited 2013 Sep 10]. Available from: http://www.cdc.gov/diabetes/pubs/estimates11.htm
2. U.S. Preventive Services Task Force. Screening for type 2 diabetes mellitus in adults: U.S. Preventive Services Task Force Recommendation Statement. *Ann Intern Med*. 2008;**148**:846-54.
3. American Diabetes Association. Standards of medical care in diabetes – 2014. *Diabetes Care*. 2014;**37**(Suppl 1):S14-8.
4. Americas Health Rankings. United Health Foundation. 2012. [ctied 2013 Sep 11]. Available from: http://www.americashealthrankings.org/ALL/dental/2012
5. American Dental Association. Oral Health Topics. 2012. [ctied 2013 Sep 11]. Available from: http://www.ada.org/en/member-center/oral-health-topics/oral-systematic-health
6. Engelgau MM, Aubert RE, Thompson TJ, Herman WH. Screening for NIDDM in nonpregnant adults: a review of principles, screening tests, and recommendations. *Diabetes Care*. 1995;**18**:1606-17.
7. Engelgau MM, Venkat Narayan KM, Herman WH. Screening for type 2 diabetes. *Diabetes Care*. 2000;**23**:1563-80.
8. Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;**346**:393-403.
9. Ramachandran A, Snehalatha C, Mary S, Mukesh B, Bhaskar AD, Vijay V. The Indian Diabetes Prevention Programme shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1). *Diabetologia*. 2006;**49**:289-97.
10. Li G, Zhang P, Wang J, Gregg EW, Yang W, Gong Q, Li H, Li H, Jiang Y, An Y, Shuai Y, Zhang B, Zhang J, Thompson TJ, Gerzoff RB, Roglic G, Hu Y, Bennett PH. The long-term effect of lifestyle interventions to prevent diabetes in the China Da Qing Diabetes Prevention Study: A 20-year follow-up study. *Lancet*. 2008;**371**(9626):1783-9.
11. Chiasson JL, Josse RG, Gomis R, Hanefeld M, Karasik A, Laakso M, for The STOP-NIDDM Trial Research Group. Acarbose for prevention of type 2 diabetes mellitus: The STOP-NIDDM randomized trial. *Lancet*. 2002;**359**(9323):2072-7.
12. DeFronzo RA, Tripathy D, Schwenke DC, Banerji M, Bray GA, Buchanan TA, Clement SC, Henry RR, Hodis HN, Kitabchi AE, Mack WJ, Mudaliar S, Ratner RE, Williams K, Stentz FB, Musi N, Reaven PD, Act NOW Study. Pioglitazone for diabetes prevention in impaired glucose tolerance. *N Engl J Med*. 2011;**364**:1104-15.
13. Baan CA, Ruige JB, Stolk RP, Witteman JCM, Dekker JM, Heine RJ, Feskens EJM. Performance of a predictive model to identify undiagnosed diabetes in a health care setting. *Diabetes Care*. 1999;**22**:213-9.
14. Griffin SJ, Little PS, Hales CN, Kinmonth AL, Wareham NJ. Diabetes risk score: towards earlier detection of type 2 diabetes in general practice. *Diabetes Metab Res Rev*. 2000;**16**:164-71.
15. Tabaei BP, Herman WH. A multivariate logistic regression equation to screen for diabetes: development and validation. *Diabetes Care*. 2002;**25**:1999-2003.
16. Glumer C, Carstensen B, Sandbaek A, Lauritzen T, Jorgensen T, Borch-Johnsen K. A Danish diabetes risk score for targeted screening: The Inter99 Study. *Diabetes Care*. 2004;**27**:727-33.
17. Ramachandran A, Snehalatha C, Vijay V, Wareham NJ, Colagiuri S. Derivation and validation of diabetes risk score for urban Asian Indians. *Diabetes Res Clin Pract*. 2005;**70**(1):63-70.
18. McEwen LN, Adams SR, Schmittdiel JA, Ferrara A, Selby JV, Herman WH. Screening for impaired fasting glucose and diabetes using available health plan data. *J Diabetes Complications*. 2013;**27**:580-7.
19. Engelgau MM, Thompson TJ, Smith PJ, Herman WH, Aubert RE, Gunter E, Wetterhall SF, Sous ES, Ali MA. Screening for diabetes mellitus in adults: the utility of random capillary blood glucose measurements. *Diabetes Care*. 1995;**18**:463-6.
20. Nathan DM, Kuenen J, Borg R, Zheng H, Schoenfeld D, Heine RJ, for the A1c-Derived Average Glucose (ADAG) Study Group. Translating the A1c assay into estimated average glucose values. *Diabetes Care*. 2008;**31**:1473-8.
21. International Expert Committee. International Expert Committee report on the role of the A1C assay in the diagnosis of diabetes. *Diabetes Care*. 2009;**32**:1327-34.
22. Borrell LN, Kunzel C, Lanster I, Lalla E. Diabetes in the dental office: using NHANES III to estimate the probability of undiagnosed disease. *J Periodont Res*. 2007;**42**:559-65.
23. Strauss SM, Russell S, Wheeler A, Norman R, Borrell LN, Rindskopf D. The dental office visit as a potential opportunity for diabetes screening: an analysis using NHANES 2003-2004 data. *J Public Health Dent*. 2010;**70**:156-62.
24. Barasch A, Gilbert GH, Spurlock N, Funkhouser E, Persson LL, Safford MM, for The DPBRN Collaborative Group.

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Random plasma glucose values measured in community dental practices: findings from The Dental Practice-Based Research Network. *Clin Oral Investig*. 2013;**17**:1383-8.
25. Barasch A, Safford MM, Qvist V, Palmore R, Gesko D, Gilbert GH, Dental Practice-Based Research Network Collaborative Group. Random blood glucose testing in dental practice: a community-based feasibility study from The Dental Practice-Based Research Network. *J Am Dent Assoc*. 2012;**143**: 262-9.
26. Lalla E, Kunzel C, Burkett S, Cheng B, Lamster IB. Identification of unrecognized diabetes and pre-diabetes in a dental setting. *J Dent Res*. 2011;**90**:855-60. Erratum in: J Dent Res 2012;91:715.
27. Genco RJ, Schifferle RE, Dunford RG, Falkner KL, Hsu WC, Balukjian J. Screening for diabetes mellitus in dental practices. A field trial. *JADA*. 2014;**145**(1):57-64.
28. Greenberg BL, Glick M, Frantsve-Hawley J, Kantor ML. Dentists' attitudes toward chairside screening for medical conditions. *J Am Dent Assoc*. 2010;**141**(1):52-62.
29. Kunzel C, Lalla E, Albert DA, Yin H, Lamster IB. On the primary care frontlines: the role of the general practitioner in smoking-cessation activities and diabetes management. *J Am Dent Assoc*. 2005;**136**:1144-53; quiz 1167-1167.
30. Kunzel C, Lalla E, Lamster IB. Management of the patient who smokes and the diabetic patient in the dental office. *J Periodontol*. 2006;**77**:331-40.
31. Kunzel C, Lalla E, Lamster I. Dentists' management of the diabetic patient: contrasting generalists and specialists. *Am J Public Health*. 2007;**97**:725-30.
32. Forbes K, Thomson WM, Kunzel C, Lalla E, Lamster IB. Management of patients with diabetes by general dentists in New Zealand. *J Periodontol*. 2008;**79**:1401-8.
33. Strauss SM, Tuthill J, Singh G, Rindskopf D, Maggiore JA, Schoor R, Brodsky A, Einhorn A, Hochstein A, Russell S, Rosedale M. A novel intraoral diabetes screening approach in periodontal patients: results of a pilot study. *J Periodontol*. 2012;**83**:699-706.

Appendix 1. Guide to general periodontal assessment (American Dental Association/American Academy of Periodontology Classification)

1. Healthy: absence of gingivitis or periodontitis

2. Gingivitis: "Inflammation of the gingiva characterized clinically by changes in color, gingival form, position, surface appearance, and presence of blooding and/or exudate."

- **a.** No radiographic evidence of bone loss
- **b.** Probing depths may range up to 5 mm (with gingival swelling)

3. Early/Slight Periodontitis: "Progression of the gingival inflammation into the deeper periodontal structures and alveolar bone crest, with slight loss of connective tissue attachment and alveolar bone."

- **a.** Radiographic bone loss typically 0-15% of root length
- **b.** Often demonstrates probing depths of 3-6 mm
- **c.** Clinical Attachment Loss 1-2 mm

4. Moderate Periodontitis: "A more advances stage of the condition, with increased destruction of the periodontal structures and noticeable loss of bone support, possibly accompanied by an increase in tooth mobility. There may be furcation involvement in multi-rooted teeth."

- **a.** Radiographic bone loss typically 15-30% of root length
- **b.** Often demonstrates probing depths of 4-8 mm
- **c.** Clinical Attachment Loss 3-4 mm

5. Advanced/Severe Periodontitis: "Further progression of periodontitis with major loss of alveolar bone support usually accompanied by increased tooth mobility. Furcation involvement in multi-rooted teeth is likely."

- **a.** Radiographic bone loss >30% of root length
- **b.** Often demonstrates probing depths >6 mm
- **c.** Clinical Attachment Loss ≥5 mm

Appendix 2. Questions used to ascertain the variables that entered the final models

1. Today's date: _ _/ _ _/ 20_ _
Month Day Year

2. Current time: _ _: _ _ AM PM (Circle one)

3. What is your date of birth? _ _/ _ _/ 19_ _
Month Day Year

4. What is your sex?
0 ☐ Male
1 ☐ Female

5. Have you ever been told by a physician that you have high blood pressure or
hypertension?
0 ☐ No
1 ☐ Yes
8 ☐ Not sure

6. Have you ever been told by a physician that you have high cholesterol or high lipid levels?
0 ☐ No
1 ☐ Yes
8 ☐ Not sure

7. Other than wisdom teeth or teeth pulled to get braces, have you lost any other
teeth from your upper or lower jaw?
0 ☐ No
1 ☐ Yes

8. How tall are you without your shoes? _ _feet _ _inches

9. How much do you weigh without clothes? _ _ _Pounds
Calculated BMI: _ _. _kg/m^2
Optional:

10. Random capillary glucose level: _ _ _mg/dl

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