
Standardized screening for periodontitis as an integral part of multidisciplinary management of adults with type 2 diabetes: An observational cross-sectional study of cohorts in the USA and UK.


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Standardized screening for periodontitis as an integral part of multidisciplinary management of adults with type 2 diabetes: an observational cross-sectional study of cohorts in the USA and UK

Andrew S Pumerantz,1,2 Susan M Bissett,3,4 Fanglong Dong,5 Cesar Ochoa,1 Rebecca R Wassall,3 Heidi Davila,1 Melanie Barbee,1 John Nguyen,1 Pamela Vila,2 Philip M Preshaw3,4

ABSTRACT

Objective To determine prevalence and factors predictive of periodontitis by using a standardized assessment model in adults with type 2 diabetes.

Research design and methods We performed an observational cross-sectional study to determine the burden of periodontitis in adults with type 2 diabetes attending urban, ambulatory referral centers in the USA and UK. Full-mouth probing was performed and periodontitis was diagnosed based on either a low (≥5 mm at ≥1 site) or high pocket probing-depth threshold (≥6 mm at ≥1 site). Results were stratified into a five-stage schema and integrated with other clinical variables into the novel Diabetes Cross-Disciplinary Index to function as a balanced health scorecard. Corresponding demographic and routinely collected health data were obtained and comparisons were made between patients with and without periodontitis. Multivariable logistic regression was performed to identify factors predictive of the presence or absence of periodontitis.

Results Between our two cohorts, 253 patients were screened. Caucasians comprised >90% and Hispanic Americans >75% of the UK and US cohorts, respectively. Males and females were equally distributed; mean age was 53.6±11 years; and 17 (6.7%) were edentulous. Of the 236 dentate patients, 128 (54.2%) had periodontitis by low threshold and 57 (24.2%) by high threshold. Just 17 (7.2%) were periodontally healthy. No significant differences in age, HbA1c, blood pressure, body mass index, low-density lipoprotein cholesterol, or smoking status (all p>0.05) were identified between those with or without periodontitis (regardless of threshold) and none was found to be a significant predictor of disease.

Conclusions Periodontitis is frequent in adults with type 2 diabetes and all should be screened. Periodontal health status can be visualized with other comorbidities and complications using a novel balanced scorecard that could facilitate patient–clinician communication, shared decision-making, and prioritization of individual healthcare needs.

INTRODUCTION

People with type 2 diabetes are at higher risk of developing a number of disabling and life-threatening comorbidities and complications, including periodontal disease, than people without diabetes.1 The type 2 diabetes pandemic and its consequences result from complex interactions of genetic and epigenetic systems within complex social structures that include many behavioral and environmental factors.2 3 The relationship between type 2 diabetes and periodontitis has been extensively investigated.4–7 Poor glucose control poses an increased risk of inflammation of the tissue surrounding the tooth (periodontium), which is a major cause of tooth loss, increased risk of cardiovascular disease, and death.1 4 7 8 Conversely, inflammation can exacerbate insulin resistance and poor glycemic control.3 Timely detection and management of comorbid periodontal disease in people with type 2 diabetes could optimize oral hygiene, prevent tooth loss, facilitate a healthy diet, and improve glucose control.1 7 9

Global prevalence of type 2 diabetes is increasing and three in four affected adults now live in low- and middle-income countries, which means that without effective screening and management strategies rates of oral and systemic health complications are likely to increase.3 Assessing the status of periodontal health is a standard recommendation for delivering integrated, ‘whole-person’ diabetes care10–12 in the USA and elsewhere, yet fewer than half of American adults with...
known diabetes have annual dental examinations.13 In the UK, despite 15 Healthcare Essentials that comprise the most recent guidelines for care for everyone with diabetes published by Diabetes UK, periodontal health is not included and there is no recommendation to seek oral health evaluation.14 Barriers to care integration include the lack of patient and provider awareness of the relationship between oral and general health15 as well as the lack of electronic record-linkage and data-sharing between medical and dental providers.16 Furthermore, variation between national guidelines based on single clinical findings into a balanced health scorecard, such as the Diabetes Cross-Disciplinary Index (DXDI), to aid in patient–clinician communication and multidisciplinary management of comorbid chronic diseases.

How might these results change the focus of research or clinical practice?

► Integrating periodontal health status into standard comprehensive evaluations for all adults with type 2 diabetes can be effectively undertaken.
► Balanced health scorecards such as the DXDI that integrate oral and general health require additional field-testing to determine whether patient–provider communication could be optimized, patient-centered outcomes improved, and if diabetes care guidelines and policy decisions should be modified.

RESEARCH DESIGN AND METHODS

We undertook a registry-supported, observational cross-sectional cohort study of patients aged ≥18 years who were receiving care at two urban diabetes referral centers, the Western Diabetes Institute (WDI) at Western University of Health Sciences, Pomona, California, USA, and Newcastle upon Tyne Hospitals and Newcastle University (NCL), Newcastle upon Tyne, UK. Full-mouth periodontal assessment by dental care teams at their respective institutions was performed to screen for periodontitis. All patients gave written, informed consent prior to participating in the research, which was undertaken following receipt of appropriate ethical approvals.

Between September 2014 and June 2016, patients at WDI underwent periodontal screening as part of a multidisciplinary, ‘one-stop-shop’ evaluation within an urban, ambulatory, integrated practice unit setting, and additionally gave permission to have their past, present, and future health record information placed into the IRB-approved WDI Diabetes Research Registry. Following the evaluation, patient data were entered into the novel Diabetes Cross-Disciplinary Index (DXDI) (figure 1). DXDI plots the clinical status of 13 diabetes-relevant health domains as a ‘balanced scorecard’.32 Each domain is stratified into levels 1 (health/absence of disease) through 5 (advanced disease). The domains encompass essential components of a comprehensive diabetes evaluation, including glycemic, cholesterol and blood pressure control; the status of kidney health,
**Figure 1** The Diabetes Cross-Disciplinary Index (DXDI). The DXDI is a pictorial representation of diabetes-relevant health domains, including glycemic control (HbA1c), low-density lipoprotein cholesterol (LDLc) level, systolic blood pressure (SBP), and diastolic blood pressure (DBP); kidney health (urinary albumin-to-creatinine ratio (UACR) and estimated glomerular filtration rate (eGFR)); retinal health (dilated retinal scan), periodontal health (see below), foot health, functional independence; as well as body mass index (BMI), waist circumference (WC), depression (patient health questionnaire 9 (PHQ 9)), and smoking status. Each domain is stratified into levels 1 (ie, health or absence of disease) through 5 (ie, severe or advanced disease). Periodontal health status was stratified in the following manner: DXDI 1, periodontal health (PD ≤3 mm and BOP ≤15% of sites); DXDI 2, gingivitis/incipient periodontitis (PD ≤4 mm and/or BOP >15% of sites); DXDI 3, mild–moderate periodontitis (PD=5 mm at ≥1 site); DXDI 4, localized advanced periodontitis (PD ≥6 mm at ≥30% sites); and DXDI 5, generalized advanced periodontitis (PD ≥6 mm at >30% sites). CVD, cardiovascular disease; PVD, peripheral vascular disease.

<table>
<thead>
<tr>
<th>Domain</th>
<th>DXDI 1</th>
<th>DXDI 2</th>
<th>DXDI 3</th>
<th>DXDI 4</th>
<th>DXDI 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbA1c</td>
<td>&lt;7.0%</td>
<td>7.0-7.9</td>
<td>8.0-8.9</td>
<td>≥10.0</td>
<td>≥11.0</td>
</tr>
<tr>
<td>LDLc</td>
<td>&lt;100 mg/dl or &lt;15 mmol/l</td>
<td>100-130</td>
<td>130-160</td>
<td>160-190</td>
<td>≥200</td>
</tr>
<tr>
<td>SBP</td>
<td>&lt;130 mmHg</td>
<td>130-139</td>
<td>140-169</td>
<td>≥170</td>
<td>≥200</td>
</tr>
<tr>
<td>DBP</td>
<td>&lt;80 mmHg</td>
<td>80-89</td>
<td>90-99</td>
<td>≥110</td>
<td>≥120</td>
</tr>
<tr>
<td>BMI</td>
<td>&lt;25 kg/m²</td>
<td>25-29.9</td>
<td>30-34.9</td>
<td>≥35.0</td>
<td>≥35.0</td>
</tr>
<tr>
<td>WC</td>
<td>&lt;80 cm</td>
<td>80-89</td>
<td>90-99</td>
<td>≥100</td>
<td>≥100</td>
</tr>
<tr>
<td>UACR</td>
<td>&lt;30 mg/g</td>
<td>30-299</td>
<td>300-599</td>
<td>≥600</td>
<td>≥600</td>
</tr>
<tr>
<td>eGFR</td>
<td>&gt;60 ml/min/1.73 m²</td>
<td>30-59</td>
<td>20-29</td>
<td>≤20</td>
<td>≤20</td>
</tr>
<tr>
<td>Modified</td>
<td>Independent</td>
<td>Modified</td>
<td>Moderate</td>
<td>Severe</td>
<td>Severe</td>
</tr>
<tr>
<td>Status</td>
<td>No risk factors present</td>
<td>One risk factor present</td>
<td>2-3 risk factors present</td>
<td>4-5 risk factors present</td>
<td>6+ risk factors present</td>
</tr>
<tr>
<td>1</td>
<td>No DM, no CVD</td>
<td>DM, no CVD</td>
<td>DM, CVD</td>
<td>Severe DM, CVD</td>
<td>Severe DM, CVD</td>
</tr>
<tr>
<td>2</td>
<td>No DM, no CVD</td>
<td>DM, no CVD</td>
<td>DM, CVD</td>
<td>Severe DM, CVD</td>
<td>Severe DM, CVD</td>
</tr>
<tr>
<td>3</td>
<td>No DM, no CVD</td>
<td>DM, no CVD</td>
<td>DM, CVD</td>
<td>Severe DM, CVD</td>
<td>Severe DM, CVD</td>
</tr>
<tr>
<td>4</td>
<td>No DM, no CVD</td>
<td>DM, no CVD</td>
<td>DM, CVD</td>
<td>Severe DM, CVD</td>
<td>Severe DM, CVD</td>
</tr>
<tr>
<td>5</td>
<td>No DM, no CVD</td>
<td>DM, no CVD</td>
<td>DM, CVD</td>
<td>Severe DM, CVD</td>
<td>Severe DM, CVD</td>
</tr>
</tbody>
</table>

At the time of our study, there was no consensus on international standards for reporting periodontitis prevalence, extent, and severity. Therefore, periodontal assessment in dentate patients included the extent of full-mouth, pocket-probing depth (PD) measurements and bleeding on probing (BOP). Periodontal health status was stratified in the following manner: DXDI 1, periodontal health (PD ≤3 mm and bleeding on probing (BOP) ≤15% of sites); DXDI 2, gingivitis/incipient periodontitis (PD ≤4 mm and/or BOP >15% of sites); DXDI 3, mild–moderate periodontitis (PD=5 mm at ≥1 site); DXDI 4, localized advanced periodontitis (PD ≥6 mm at ≥30% sites); and DXDI 5, generalized advanced periodontitis (PD ≥6 mm at >30% sites). CVD, cardiovascular disease; PVD, peripheral vascular disease. Statistical analyses were conducted using SAS software for Windows V.9.3. Descriptive statistics were presented as means and SD for continuous variables, and frequencies and proportions for categorical variables. Independent
### Table 1: Comparisons of recorded parameters in the ‘periodontitis’ and ‘no periodontitis’ groups

<table>
<thead>
<tr>
<th></th>
<th>Low threshold for periodontitis (PD ≥5mm at ≥1 site)</th>
<th>High threshold for periodontitis (PD ≥6mm at ≥1 site)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Periodontitis n=128 (54.2%)</td>
<td>No periodontitis n=108 (46.8%)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>52.7±9.3</td>
<td>53.3±12.2</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>8.2±1.8</td>
<td>7.9±1.8</td>
</tr>
<tr>
<td>HbA1c (mmol/mol)</td>
<td>66.1±20.1</td>
<td>63.1±20.2</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>139.3±21.2</td>
<td>138.2±20.8</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>82.2±15.9</td>
<td>80.6±10.4</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>33.7±7.3</td>
<td>34.8±8.3</td>
</tr>
<tr>
<td>LDLc (mg/dL)</td>
<td>126.7±36.6</td>
<td>128.5±43.1</td>
</tr>
<tr>
<td>Current smoker, n (%)</td>
<td>12 (9.4%)</td>
<td>4 (3.7%)</td>
</tr>
<tr>
<td>Former smoker, n (%)</td>
<td>49 (38.3%)</td>
<td>32 (29.6%)</td>
</tr>
<tr>
<td>Never smoked, n (%)</td>
<td>67 (52.3%)</td>
<td>72 (66.7%)</td>
</tr>
</tbody>
</table>

Values expressed as means ± SD for continuous variables and n (%) for categorical variables. No significant differences were identified (all p>0.05) for comparisons between groups within low and high thresholds for defining periodontitis.

PD, probing depth measurements.

### RESULTS

Across the two centers, a total of 253 patients with previously diagnosed type 2 diabetes (170 at WDI and 83 at NCL) underwent full-mouth periodontal assessment. Hispanic Americans comprised >75% of the WDI cohort, whereas white Caucasians comprised 94% of the NCL cohort. The combined study population contained roughly equal numbers of males and females (125 and 128, respectively) and the mean age was 53.6±11 years. A total of 146 (57.7%) reported never having smoked tobacco, and of the 107 who reported using tobacco at some point in their lives, 17 (15.9%) were currently smokers.

In total, 17 (6.7%) of the 253 screened were edentulous. Of the remaining 236 dentate patients, 128 (54.2%) were assigned a diagnosis of periodontitis based on the low threshold and 57 (24.2%) were diagnosed based on the higher threshold for periodontitis (table 1). No significant differences were identified between the ‘periodontitis’ and ‘no periodontitis’ groups (within thresholds) for age, smoking status, BMI, blood pressure, LDLc, or HbA1c (all p>0.05), and none of these factors was identified as a significant predictor for the presence of periodontitis in multivariable logistic regression.

Furthermore, there were no significant differences between periodontal DXDI classifications with respect to evaluable clinical variables that were common to both the WDI and NCL cohorts (table 2). Table 2 also identifies that of the 236 dentate patients in our combined cohort only 17 (7.2%) were periodontally healthy.

### CONCLUSIONS

The emerging global burden of comorbid type 2 diabetes and periodontal disease is likely to have significant impact on quality and longevity of life for hundreds of millions of people well into the 21st century. Given the geographically and demographically disproportionate burden of these complex, chronic diseases that are, in turn, challenged by anachronistic healthcare systems and conflicting clinical guidelines, patients are frequently not informed of their increased risk for periodontitis and the importance of its management to optimize oral and general health. As a result, many affected adults with type 2 diabetes fall short of achieving goals for preventive practices like dental examinations, which further obscures the true burden of multimorbidity on the population. Indeed, novel screening and management strategies are desperately needed and, to be truly impactful, must involve practical, replicable, and scalable solutions.

In our multicenter study, respectively representative of predominantly Hispanic American and white Caucasian British patients with type 2 diabetes, we observed epidemic rates of periodontitis whether using a low (54.2%) or high (24.2%) diagnostic threshold to define...
the presence of disease. However, we were unable to identify, through multivariable logistic regression, any clinical predictors of periodontitis. Therefore, we concur with published guidelines that recommend periodontal screening (as an essential part of comprehensive health evaluation and management) for all adults with type 2 diabetes. Our simplified approach to screening with full-mouth periodontal probing (and not requiring the use of radiographs) could be undertaken by either dentists or task-shifted to dental hygienists and therapists. Such an approach could facilitate the periodontal assessment of patients with diabetes in both resource-rich and resource-challenged locations, and is supported by the European Federation of Periodontology manifesto on periodontal prevention, early diagnosis and effective treatment of periodontal diseases and general health, which ‘calls for a division exists between the medical and dental professions, which has the potential to negatively impact access to the care that they need. Yet patients perceive that a division exists between the medical and dental professions, which has the potential to negatively impact on diabetes care. At one of our centers (WDI), bridges were built across multiple interprofessional divides. Periodontal data are integrated into the balanced health scorecard, DXDI (figure 1), to promote precision healthcare for people with diabetes. Periodontal health status is stratified in the following manner: 1, periodontal health (PD ≤3 mm and BOP ≤15% of sites); 2, gingivitis/incipient periodontitis (PD ≤4 mm and/or BOP >15% of sites); 3, mild–moderate periodontitis (PD=5 mm at ≥1 site); 4, localized advanced periodontitis (PD≥6 mm at ≤30% sites); and 5, generalized advanced periodontitis (PD≥6 mm at >30% sites).

Table 2  Evaluable clinical variables common to both Western Diabetes Institute and Newcastle University cohorts according to periodontal Diabetes Cross-Disciplinary Index (DXDI) classification

<table>
<thead>
<tr>
<th>Clinical care/Education/Nutrition</th>
<th>Periodontal DXDI 1 (n=17)</th>
<th>Periodontal DXDI 2 (n=91)</th>
<th>Periodontal DXDI 3 (n=71)</th>
<th>Periodontal DXDI 4 (n=57)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>57.7±15.5</td>
<td>52.4±11.3</td>
<td>52.8±10.2</td>
<td>52.5±8.3</td>
<td>0.300</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>7.7±1.7</td>
<td>8.0±1.9</td>
<td>8.3±1.9</td>
<td>8.2±2.0</td>
<td>0.531</td>
</tr>
<tr>
<td>HbA1c (mmol/mol)</td>
<td>60.2±18.5</td>
<td>63.7±20.5</td>
<td>67.2±20.2</td>
<td>65.7±19.9</td>
<td>0.519</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>144.1±16.7</td>
<td>137.2±21.3</td>
<td>138.2±21.2</td>
<td>140.7±21.3</td>
<td>0.560</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>81.4±11.9</td>
<td>80.5±10.2</td>
<td>81.5±15.8</td>
<td>83.2±16.1</td>
<td>0.714</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>35.0±8.1</td>
<td>34.8±8.4</td>
<td>33.1±8.2</td>
<td>34.4±6.0</td>
<td>0.542</td>
</tr>
<tr>
<td>Low-density lipoprotein cholesterol (mg/dL)</td>
<td>139.2±38.2</td>
<td>125.1±44.7</td>
<td>128.2±37.9</td>
<td>125.7±36.5</td>
<td>0.841</td>
</tr>
<tr>
<td>Current smoker</td>
<td>0 (0%)</td>
<td>4 (4.4%)</td>
<td>7 (9.9%)</td>
<td>5 (8.8%)</td>
<td>0.142</td>
</tr>
<tr>
<td>Former smoker</td>
<td>3 (17.7%)</td>
<td>29 (31.9%)</td>
<td>24 (33.8%)</td>
<td>25 (43.9%)</td>
<td></td>
</tr>
<tr>
<td>Never smoked</td>
<td>14 (82.4%)</td>
<td>58 (63.7%)</td>
<td>40 (56.3%)</td>
<td>27 (47.4%)</td>
<td></td>
</tr>
</tbody>
</table>

None was classified as periodontal DXDI 5 in either cohort. Values expressed as means ± SD for continuous variables and n (%) for categorical variables. Periodontal health status stratification: DXDI 1, periodontal health (PD ≤3 mm and BOP ≤15% of sites); DXDI 2, gingivitis/incipient periodontitis (PD ≤4 mm and/or BOP >15% of sites); DXDI 3, mild-moderate periodontitis (PD=5 mm at ≥1 site); DXDI 4, localized advanced periodontitis (PD≥6 mm at ≤30% sites); DXDI 5, generalized advanced periodontitis (PD≥6 mm at >30% sites).

BOP, bleeding on probing; PD, probing depth.

Many patients express a desire that all their care providers offer consistent health messaging and facilitate access to the care that they need. Yet patients perceive that a division exists between the medical and dental professions, which has the potential to negatively impact on diabetes care. At one of our centers (WDI), bridges were built across multiple interprofessional divides. Periodontal data are integrated into the balanced health scorecard, DXDI (figure 1), to promote precision healthcare for people with diabetes. Periodontal health status is stratified in the following manner: 1, periodontal health (PD ≤3 mm and BOP ≤15% of sites); 2, gingivitis/incipient periodontitis (PD ≤4 mm and/or BOP >15% of sites); 3, mild–moderate periodontitis (PD=5 mm at ≥1 site); 4, localized advanced periodontitis (PD≥6 mm at ≤30% sites); and 5, generalized advanced periodontitis (PD≥6 mm at >30% sites). Other DXDI domains incorporate validated staging criteria for their respective aspects of health and disease. For example, the DXDI domain for kidney health reflects contemporary approaches to chronic kidney disease staging. Adiposity was derived...
from established BMI and waist circumference ranges.\textsuperscript{38}

The diabetic foot staging, originally based on the University of Texas classification system,\textsuperscript{39} was further modified to conform with subsequent work published by the Scottish Diabetes Foot Action Group.\textsuperscript{40} Retinopathy staging was based on international clinical severity scales\textsuperscript{41,42} and functional status was adapted from the validated Functional Independence Measure.\textsuperscript{42}

Facilitating appropriate dental referrals for those found to have periodontitis through standardized screening is just a start. Diabetes self-management education and support emphasizes the interrelationship of proper nutrition, oral health self-care, and regular physical activity. For example, at WDI the hygienist and dietitian-nutritionist can identify barriers and collaborate with the patient to devise an individualized meal plan that accounts for their oral health status, including the presence of any loose teeth and objective evidence of periodontitis as well as any complaints of sore gums and painful chewing. The hygienist, nutritionist, and physical therapist, often on the same follow-up appointment day, can work in concert with each patient to combine activities and behavioral management strategies.

However, there are several limitations of this study that warrant consideration when interpreting the results. While all attempts were made to standardize periodontal assessments with simplified and reproducible, quantitative criteria, the lack of universally agreed upon standards for diagnosing the presence, extent, and severity of periodontitis raises the possibility that its true prevalence was either overestimated or underestimated in our study. Second, while we were able to control for thoroughness and reliability of periodontal screening data at both WDI and NCL, the need to retrieve historical chart data for other corresponding clinical variables for the patient group at NCL could have affected our multivariable analysis, therefore limiting our ability to identify factors that were significantly associated with the presence of periodontitis. Finally, our study was not designed to assess the utility and impact of DXDI. Although anecdotal feedback from clinicians and patients suggested that DXDI could aid patient–clinician communication and engagement over time, this remains to be proven.

Therefore, more research is now required to investigate several remaining open questions. First, the impact of DXDI on the health outcomes of patients with type 2 diabetes and its associated comorbidities and complications remains to be defined. It seems intuitive that the ranking and visualization of multiple diabetes-relevant health domains would enable team-based discussion around the sequencing and prioritization of care for each patient.\textsuperscript{35} Yet, it would be important to know if DXDI helps providers from multiple disciplines to communicate consistent messaging to patients and improve their access to oral healthcare.\textsuperscript{15} Furthermore, while DXDI provides a composite view of the complexity and severity of diabetes and multimorbidity in our particular study population, its applicability to other ethnic, racial, and cultural groups would require additional field-testing and pilot-testing to determine whether it optimizes communication and facilitates the delivery of improved patient-centered outcomes. With that in mind, a modified version of DXDI was incorporated in 2015 into the Scottish Care Information Diabetes Collaboration (SCI-Diabetes) platform, in which the complete diabetes record can be viewed by any National Health Service healthcare professional involved in a patient’s care.\textsuperscript{43} It should also be noted that, at the time of this writing, data on periodontal health are not accessible through the SCI-Diabetes platform. Second, though our simplified approach to periodontal assessment was designed to enable effective multidisciplinary screening and use of the DXDI in real-world clinical settings across the globe (without requiring detailed measurements of periodontal attachment loss or the use of dental radiographic equipment that is not always readily available),\textsuperscript{2,44} validation of both through large-scale field studies is needed to help determine whether its sensitivity and specificity within diverse populations are clinically and epidemiologically acceptable. Indeed, issues of interoperator and technical skill variability may pose limits on the widespread applicability of our simplified approach even as it serves to mitigate cost and access barriers. Further study is warranted to assess those potential limitations. Third, determining the real burden of periodontitis\textsuperscript{51} and other comorbid chronic diseases, such as chronic obstructive pulmonary disease and heart failure, in people with type 2 diabetes, raises the possibility that new domains could be further added to DXDI to assist in the management of patients with multimorbidity.\textsuperscript{18,20,35,44,45} In turn, the interrelationships and complexities that impact health outcomes might be better understood and serve to inform guidelines and policy decisions around optimal allocation of scarce resources.\textsuperscript{2,17,30} How periodontitis impacts diverse populations in different geographical contexts and how treatment affects the complex natural history of diabetes and its complications remain to be determined.
Competing interests PMP reports grants from Dunhill Medical Trust, UK, and the UK Department of Health during the conduct of the study. ASP is the inventor of DXI.

Patient consent Obtained.

Ethics approval Institutional Review Board of Western University of Health Sciences Protocol #13/IRB/017; UK Research Ethics Service Sunderland Ethics Committee #06/Q0904/8. All data analyzed and reported in this study are anonymized as per IRB protocol.

Provenance and peer review Not commissioned; externally peer reviewed.

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