Use of dental practices for the identification of adults with undiagnosed type 2 Diabetes mellitus or non-diabetic hyperglycaemia

Yonel, Zehra; Cerullo, E. ; Kroeger, Annika; Gray, L. J.

DOI:
10.1111/dme.14324

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (Harvard):
Yonel, Z, Cerullo, E, Kroeger, A & Gray, LJ 2020, 'Use of dental practices for the identification of adults with undiagnosed type 2 Diabetes mellitus or non-diabetic hyperglycaemia: a systematic review', *Diabetic Medicine*, vol. 37, no. 9, pp. 1443-1453. https://doi.org/10.1111/dme.14324

DIABETICMedicine

DOI: 10.1111/dme.14324

Systematic Review Or Meta-Analysis

Use of dental practices for the identification of adults with undiagnosed type 2 diabetes mellitus or non-diabetic hyperglycaemia: a systematic review

Z. Yonel[1], E. Cerullo[2], A. T. Kröger[1] and L. J. Gray[2]

[1]University of Birmingham,Birmingham School of Dentistry, Birmingham and [2]Department of Health Sciences, University of Leicester, Leicester, UK

Accepted 13 May 2020

Abstract

Aim Type 2 diabetes is a growing global challenge. Evidence exists demonstrating the use of primary care (non-hospital based) dental practices to identify, through risk assessments, those who may be at increased risk of type 2 diabetes or who may already unknowingly have the condition. This review aimed to synthesize evidence associated with the use of primary care dental services for the identification of undiagnosed non-diabetic hyperglycaemia or type 2 diabetes in adults, with particular focus on the pick-up rate of new cases.

Method Electronic databases were searched for studies reporting the identification of non-diabetic hyperglycaemia/type 2 diabetes in primary care dental settings. Returned articles were screened and two independent reviewers completed the data-extraction process. A descriptive synthesis of the included articles was undertaken due to the heterogeneity of the literature returned.

Results Nine studies were identified, the majority of which utilized a two-stage risk-assessment process with risk score followed by a point-of-care capillary blood test. The main barriers cited were cost, lack of adequate insurance cover and people having previously been tested elsewhere. The pick-up rate of new cases of type 2 diabetes and non-diabetic hyperglycaemia varied greatly between studies, ranging from 1.7% to 24% for type 2 diabetes and from 23% to 45% for non-diabetic hyperglycaemia, where reported.

Conclusion This review demonstrates that although it appears there may be benefit in using the dental workforce to identify undiagnosed cases of non-diabetic hyperglycaemia and type 2 diabetes, further high-quality research in the field is required assessing both the clinical and cost effectiveness of such practice. (Prospero Registration ID: PROSPERO 2018 CRD42018098750).

Introduction

Type 2 diabetes is a growing public health concern; it currently accounts for 10% of the UK National Health Service (NHS) budget and this is estimated to rise to 17% by 2035 [1]. In addition to the 3.8 million people currently diagnosed with type 2 diabetes in the UK, it is predicted that almost 1 million UK residents have undiagnosed type 2 diabetes [2] and an additional 5 million people are thought to be at high risk of developing type 2 diabetes [3,4].

Impaired glucose regulation, often referred to as non-diabetic hyperglycaemia, describes the situation in which blood glucose levels are elevated, although not yet in the formal diabetic range. This is important, because individuals with non-diabetic hyperglycaemia are at increased risk of developing both type 2 diabetes and cardiovascular conditions [5]. Recent advances in diabetes care have led to the suggestion that earlier detection of type 2 diabetes may reduce the risk of complications associated with the condition, including cardiovascular complications and blindness [6,7]. There is also existing evidence suggesting that type 2 diabetes can be prevented or delayed in those considered high risk [8].

Type 2 diabetes is often symptom-free in its early stages and individuals may remain undiagnosed for many years, which has implications for both secondary prevention and management of the condition [2]. Although currently opposed to population-based screening for type 2 diabetes, the UK National Screening Committee note that there are benefits to the early identification of individuals at risk of

Correspondence to: Zehra Yonel. E-mail: z.yonel@bham.ac.uk

What's new?

- There is an established association between periodontitis and type 2 diabetes.
- Different populations exhibit different attendance patterns with different healthcare professionals.
- We found that primary care dental settings can be used to successfully identify previously undiagnosed cases of non-diabetic hyperglycaemia and type 2 diabetes.
- The potential early detection of non-diabetic hyperglycaemia/type 2 diabetes allows for instigation of either prevention strategies or earlier management, which may prove clinically and cost-effective.

developing the condition, as well as non-diabetic hyperglycaemia and those with undiagnosed type 2 diabetes [9]. Hence, the NHS have rolled out the National Diabetes Prevention Programme (DPP). The Healthier You: NHS DPP was developed to prevent or delay onset of type 2 diabetes in adults already identified as high risk, defined as having non-diabetic hyperglycaemia [10]. This is based on evidence from randomized controlled trials (RCTs) demonstrating that the onset of type 2 diabetes can be prevented or delayed through behavioural interventions in those with non-diabetic hyperglycaemia [6]. Hence, the consideration of novel and alternative mechanisms to identify those with non-diabetic hyperglycaemia and undiagnosed type 2 diabetes earlier, which may confer benefits [11]. These benefits include potential improvements in health outcomes, quality of life outcomes, and reductions in costs to the NHS.

Severe periodontitis (gum disease) affects 11% of adults globally, with increased prevalence seen for milder forms of periodontal disease, which evidence suggests affect 50% of adults and up to 60% of those aged > 65 years [12]. The association between type 2 diabetes and severe periodontitis is considered to be significant and independent [13]. Additionally, within the UK, it is mandated that dental professionals screen people for periodontal disease, providing information on dental risk factors for type 2 diabetes that general practitioners (GPs) are unable to assess. There is also evidence that glycaemic status impacts directly upon oral health [14]. Poor glycaemic control results in undesirable consequences within the periodontal tissues, which in the absence of intervention from dental care professionals, will ultimately result in tooth loss [13,15]. Moreover, there is an established association between periodontal disease and type 2 diabetes, whereby improvements in periodontal care have been shown to result in improved diabetes control [13,16]. This was recently revealed in an RCT demonstrating a reduction in HbA_{1c} at 12 months following treatment of periodontal disease [17].

Raising awareness of non-diabetic hyperglycaemia and type 2 diabetes status via dental teams in primary care dental settings may facilitate improved and targeted strategies for both prevention and management of the conditions, ensuring better oral health outcomes. Importantly, it may also enable a pathway to improved systemic health for these individuals, by allowing earlier detection and instigation of prevention and management strategies. This would enhance the potential role of dental teams in contributing to the mounting challenges associated with type 2 diabetes.

Members of the public generally seek GP appointments when symptomatic, whereas people tend to visit their dentist on a regular (6–12 monthly) basis, often doing so even if they are dentally healthy, to prevent the onset of oral and dental diseases [18]. A study undertaken in the UK found 12% of people claiming to attend dental appointments at 6-monthly intervals also stated they had not had contact with their GP in the same 12-month period [19]. Furthermore, of the sample that identified as regular dental attenders, almost half claimed to have never had an NHS health check at their GP surgery [19]. As ~ 60% of the UK adult population are registered with a dentist [20], this places dental teams in a strong position to identify individuals for risk-based assessments, as they have access to people who would not necessarily attend their GP regularly when asymptomatic.

The National Institute for Health and Care Excellence (NICE) recommend that healthcare professionals, such as dentists, undertake a risk assessment for type 2 diabetes [21]. Data from Europe and the USA demonstrate non-diabetic hyperglycaemia and type 2 diabetes can be identified effectively in a dental setting [22–28]. Government policies exist that advocate the use of dental teams to provide preventative advice for risk factors related to systemic conditions and general health promotion [29,30]. Dental teams currently provide advice that includes reducing sugar consumption as well as broader dietary and smoking cessation advice, all of which are risk factors shared with type 2 diabetes. There may be an opportunity for collaborative working between dental teams and GPs to provide enhanced services for the prevention and earlier identification of non-diabetic hyperglycaemia, type 2 diabetes, and for developing an improved care pathway [31]. This aligns closely with the UK 'Making Every Contact Count' agenda to improve general health and well-being [32].

We recently undertook a review focusing on qualitative outcomes including assessing barriers and facilitators, as well as stakeholder opinions and perceptions of dental teams risk-assessing for type 2 diabetes [28]. The review article found strong support from stakeholders including dental teams, people with diabetes and physicians for risk-assessing for type 2 diabetes in dental settings. The studies contributing to the review, however, were undertaken in secondary care environments. In the UK, > 95% of dentistry is delivered in dental primary care settings. These are very different from secondary care dental services in terms of person profiles, care delivery pathways and financial drivers. Therefore, given the disparity in these healthcare settings, it would have

been inappropriate to pool data and as such, drawing conclusions based on both settings would not be meaningful.

This review therefore aimed to identify and synthesize all evidence relating specifically to the use of primary care dental services for the identification of non-diabetic hyperglycaemia and undiagnosed type 2 diabetes in adults.

The review had a particular focus on the identification rate of new cases of non-diabetic hyperglycaemia and type 2 diabetes, and aimed to answer the following additional questions, as per the previously published protocol [4]:

- What methodology was utilized within the dental practice for case-finding?
- What were the recruitment rates within the studies?
- What are the reported barriers to uptake of any such implemented services?

Methods

A pre-specified protocol (PROSPERO 2018 CRD42018098750) [33] was used to guide the study and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Table S3) for conducting and reporting systematic reviews and meta-analyses.

Search strategy

Electronic bibliographic databases including Web of Science, The Cochrane Library, MEDLINE Ovid and Clinicaltrials.gov were searched for eligible studies. Additional papers for inclusion were identified through searching the reference lists of all eligible full-text articles. The search strategy (see Table S1) included terms associated with the identification of non-diabetic hyperglycaemia and type 2 diabetes in primary care dental settings. Search terms were adapted for use with other bibliographic databases and restricted to papers in the English language. Searches were limited to articles published between 1950 and November 2019.

Because the majority of included studies were observational, the PICO method was not suitable due to the absence of a comparator arm. However, the 'Population, Intervention, Reference standard, Target condition' (PIRT) format was applied, where [P] is the stakeholder, such as adults aged > 18 years attending primary care dental services and healthcare professionals involved in the delivery of dental care; [I] is the screening method of choice; [R] is method of diagnosis for non-diabetic hyperglycaemia/type 2 diabetes; and [T] is non-diabetic hyperglycaemia or type 2 diabetes.

Risk of bias

This review was not limited solely to RCTs. The 'Study Quality Assessment Tools', validated and published by the National Institute of Health (NIH) [34], were used by two independent examiners to determine risk of bias associated with each of the included articles (Table S2). Disagreement was resolved by discussion; a third author was consulted if consensus could not be reached. If the NIH study quality assessment was deemed inappropriate or inconclusive for the included studies, the United States Preventative Task Force 'Criteria for Assessing Internal Validity of Individual Studies' was also used.

Data extraction and data management

The titles and abstracts of all returned articles were screened for eligibilityby two independent reviewers (Table S4). Reviewers undertook calibration exercises to ensure consistency in their acceptance criteria of articles for inclusion, and a third reviewer was available in case agreement could not be reached. Where screened articles were deemed to meet the inclusion criteria, a full-text review was undertaken and reasons for exclusion at this stage were recorded (Table S5). Electronic data extraction forms were developed and piloted, and then used for all data extraction [4].

Strategy for synthesis

If possible, quantitative synthesis and meta-analysis was planned, provided that studies included within the review were suitably homogenous. High levels of heterogeneity were expected. If this proved to be the case, a descriptive synthesis was planned. The synthesis was centred on the primary and secondary outcomes of the review. We expect cases of non-diabetic hyperglycaemia and undiagnosed type 2 diabetes to be well reported across the assumed small number of existing studies [4].

Results

Nine studies met the eligibility criteria [22,25–27,35–39] and were included in the systematic review (Table 1 and Fig. 1); all were observational in nature. Five studies were based in the USA [22,26,27,37,39] with one study in each of the UK [35], Germany [38], Sweden [25] and Japan [36]. Two of the included studies were based solely in one primary care dental practice [37,38]. A further two recruited participants from two dental practices [35,39]. The remaining studies involved three [25], 11 [22], 13 [26] and 28 [27] practices, with one study not reporting the number of dental practices used to recruit participants [36]. None of the studies included in this review provided information relating to the dental practices and how they were selected for inclusion, nor whether the practices were in areas of high prevalence for type 2 diabetes.

In total, the combined sample screened within the included studies was 6263 participants. Studies ranged in size from 49 to 1568 participants, and the median number was 716. The reported recruitment rates within studies varied from 41% to

Table 1 Abbreviated summary of eligible articles included in the systematic review (for full table see Table S4).

First author	Year	Reference	Risk of bias rating [34]	Country	Percent male	Mean age (years)	Number screened	Assessment method	Recruitment rates (%)	Identification of non-diabetic hyperglycaemia (%)	Identification of type 2 diabetes (%)	Reported barriers to uptake
Barasch	2013	27	Fair	USA	45	52.2	498	Pre-screen questionnaire followed by random capillary glucose	99	No	24	Of the 7 refusing participants, 6 did so because they had just been tested at home or in their physician's office
Engstrom	2013	25	Fair	Sweden	50	48.6	1568	Finger-prick random capillary glucose	Not reported	Not reported	10	Not reported
Genco	2014	22	Low	USA	39	56.5	1022	Pre-screen questionnaire followed by HbA_{1c}	41	23	12	Not reported
Herman	2015	26	Fair	USA	44	52.8	1033	Finger-prick random capillary glucose	91	32	1.7	Further studies are needed to demonstrate the acceptability, feasibility, effectiveness and cost-effectiveness of such screening
Harase	2015	36	Low	Japan	43	61	716	Pre-screen questionnaire followed by periodontal assessment Finger-prick random capillary glucose	79	Unclear	4	Not reported
Bossart	2016	37	High	USA	54	57.8	49	Pre-screen questionnaire followed by HbA_{1c}	88	32	2	Cost or lack of dental insurance may inhibit implementation
Bould	2017	35	Fair	UK	Unclear	Unclear	1035	Pre-screen questionnaire followed by HbA_{1c}	50	45	4.1	Participant reported barriers; 'the main reasons for refusal were, a recent blood glucose test, a recent health check-up such as the Well Man's Check arranged through the GP, dental pain and fear, and lack of interest in the research'.
Mirza	2018	39	Low	USA	44	49	226	Finger-prick and gingival crevicular random capillary glucose. In the event of abnormal glucose test results, an HbA_{1c} test was performed	Unclear	Unclear	11	Introducing these practices to dental clinics will require a concerted effort to educate and introduce a procedure that will require a cultural change. It is a challenging task, albeit one that has potential
Ziebolz	2019	38	Fair	Germany	44	56	116	Pre-screen questionnaire followed by venous blood sample for HbA_{1c} and an oral glucose tolerance test	88	Unclear	Unclear	Not reported

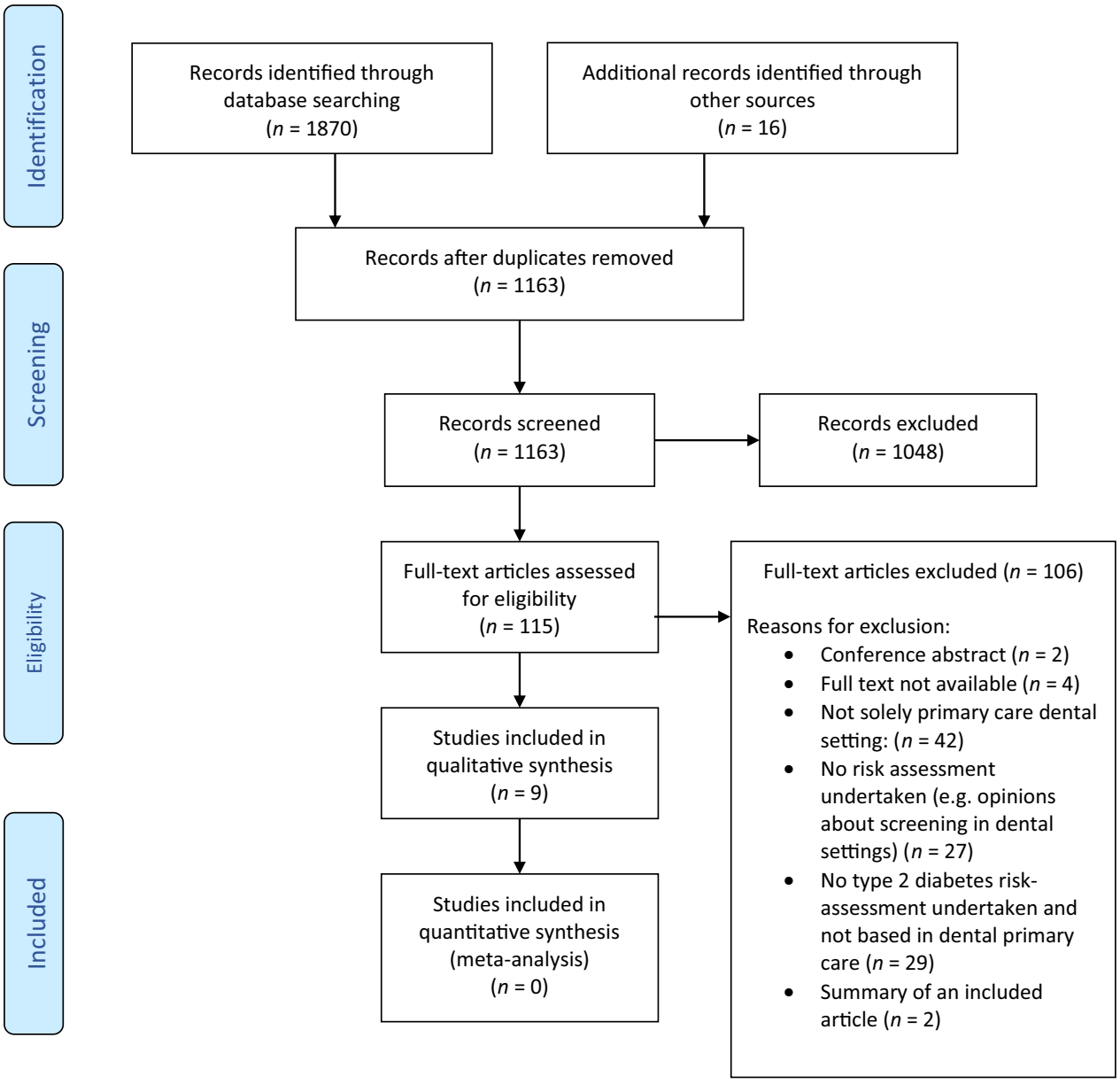

FIGURE 1 Prisma flow diagram of the search results.

98%, with one study not reporting the rate of recruitment. The study-level mean age was 54.2 years and the average proportion of men was 45%. In four studies, participant ethnicity was not reported [25,35,36,38]. In the remaining studies, ethnicity was reported to be predominantly 'White', ranging from 78% to 92% of the study population. The majority of studies failed to report the socio-economic background of participants; where this was reported, one study mentioned that 96% of participants had medical insurance, 78% had dental insurance and 86% had a university degree [37]. A further study reported that > 95% of participants had health insurance. In selecting participants for inclusion, all studies used either consecutive eligible persons attending the dental practice or a convenience sample.

All studies had a 'fair' risk of bias according to the NIH study quality assessment tool [34]. Using United States Preventative Task Force criteria to assess internal validity, one study was deemed to have a high risk of bias [37], whereas three studies were deemed to have a lower risk of bias than the others [22,36,39]. The remaining studies were deemed to be 'fair' (Table S2). The main factors contributing to increased risk of bias were related to inadequate reporting of how dental practices and participants were selected for inclusion in the study, poor follow-up to determine those who went on to receive confirmation of the risk assessment,

failure to demonstrate the reliability of the risk assessment process selected, failure to clearly report follow-up procedures and limited sample size.

Eight of the nine studies reported the pick-up rate of potential new cases of type 2 diabetes or those at risk of developing the condition. Two studies reported pick-up rate based on exceeding a threshold on a validated risk questionnaire screening tool. Six studies utilized point-of-care capillary blood test (POCT) samples to determine pick-up rates, with half reporting HbA_{1c} and half reporting random blood glucose levels. There was a large range, from 1.7% to 41%, in the reported pick-up rates of potential non-diabetic hyperglycaemia and type 2 diabetes. Three of these eight studies also followed up participants to determine the proportion of those who screened positive and went on to receive a formal diagnosis from a diabetologist or primary care physician.

Two studies used the validated finnish diabetes risk score (FINDRISC) questionnaire for identifying those at risk of type 2 diabetes. One study found that 47% (247) of participants fell into the slightly elevated risk category, 19% (101) were in the low-risk category and 33% (172) were seen as having a moderate, high or very high risk of developing diabetes [35]. In this study, the participants who were deemed at increased risk then went on to have a HbA_{1c} POCT. Of those who undertook the POCT, 45% (108) had a result of between 39 and 46 mmol/mol (5.7–6.4%) (i.e. non-diabetic hyperglycaemia), a further 4.1% (10) had a HbA_{1c} > 48 mmol/mol (6.5%) (i.e. possible type 2 diabetes). All participants at elevated risk according to the questionnaire were advised to see a primary care professional for formal follow-up and testing; only 60% did so, and the results of the follow-up are not reported [35]. In the other study using a similar methodology, 31% (29) of participants screened positive with the FINDRISC questionnaire, of whom 16 attended for formal follow-up with a diabetologist for HbA_{1c} and oral glucose tolerance test (OGTT) and nine (56%) showed 'conspicuous findings' [38].

Three studies utilized HbA_{1c} POCT, one of which reported that of the tested participants: 41% (416) had HbA_{1c} > 39 mmol/mol (5.7%) and were advised to follow up with a physician; 35% (146) of whom did follow-up and of these, 23% were found to be in the non-diabetic hyperglycaemia range and a further 12% in the type 2 diabetes range [27]. A further study with a similar sample size and methodology supported these findings, also reporting 23% of participants in the non-diabetic hyperglycaemia range and a further 12% in the type 2 diabetes range [22]. An additional study undertaking HbA_{1c} POCT, found that 32% of their sample had potential non-diabetic hyperglycaemia, and a further 2% potential type 2 diabetes [37], although this study had a considerably smaller sample size.

The remaining three studies that reported potential identification rates utilized random blood glucose levels to screen people for potential non-diabetic hyperglycaemia or type 2 diabetes. One of these studies found that 31% of their sample screened within the non-diabetic hyperglycaemia range and a further 1.7% were in the type 2 diabetes range; however, formal follow-up and diagnosis rates were not reported [26]. Another study found that 3.5% of previously undiagnosed participants had hyperglycaemia [36]. In support of this, the third study reported 10% (155) of participants screened positive with a finger-prick random blood glucose sample; of these, 89% attended for follow-up in primary care within 3 years of their screening assessment and of those, 5.8% (9) were diagnosed as having type 2 diabetes according to the World Health Organization criteria. Interestingly, in this study of those who did not screen positive, 80% (1137) also attended the primary healthcare centre within the 3-year follow-up period and 0.6% (8) were found to have type 2 diabetes [25].

Two of the nine studies used a one-stage screening process; in one of the studies this involved participants having their height and weight recorded and a fingerstick random blood glucose [25]. The other study involved all participants completing questionnaires regarding diabetes status and undergoing periodontal assessment and obtaining a finger-prick capillary blood sample (see Table 2).

The remaining studies utilized a sequential screening strategy, with the first stage of the screening process being a non-invasive test in all but one of the studies. This was done using a risk score or comparison against pre-selected risk factor cut-off points, such as age, ethnicity or BMI [22,26,27,35,37,38]. In five of these studies, the second stage of the risk-assessment process was a point-of-care fingerstick blood sample, with one study choosing to refer participants for venous blood sample HbA_{1c} and an OGTT [38]. One study used a sequential screening strategy, initially using a point-of-care fingerstick and gingival crevicular blood sample, followed by a venous HbA_{1c} test in the event of an abnormal point-of-care random blood glucose level [39]. Of the studies that utilized point-of-care fingerstick blood samples, three used HbA_{1c} devices as part of their risk assessment; the remaining studies utilized random blood glucose measurements, with one opting for an additional HbA_{1c} test if the random blood glucose level was elevated [39].

Six studies recorded participant BMI as part of the risk-assessment process. In five cases, this was self-reported by participants and in one case, participant BMI was recorded in the dental setting. BMI was not included as part of inclusion or exclusion criteria. In all studies where BMI was reported, mean BMI was in the overweight category.

Use of dental data as part of the risk assessment was reported in five studies. In all cases, the periodontal health of participants was recorded and one study also the recorded decayed/missing/filled teeth score [38]. Only one study stratified the results of the diabetes screening based on dental findings. This study found that the proportion of people with hyperglycaemia increased as periodontal disease severity

Table 2 Summary of identification rates.

Author	Year	Reference	Sample size	Method	Results
Barasch	2014	27	1022	Participants reported data (demographic, medical and physical). A periodontal examination and HbA_{1c} were performed by the investigators. Those with $HbA_{1c} \geq 39$ mmol/mol (5.7%) were referred to their physician for further workup and diagnosis	Of those tested, 41% ($n = 416$) had an $HbA_{1c} > 39$ mmol/mol (5.7%). Of these, 35% ($n = 146$) followed up with a physician and of those: 23% had non-diabetic hyperglycaemia and 12% had type 2 diabetes
Bossart	2016	37	50	Point-of-care diabetes screenings performed by a dental hygienist for people with periodontitis, using a diabetes risk questionnaire, periodontal findings and a HbA_{1c} analyser	32% potential non-diabetic hyperglycaemia and 2% potential type 2 diabetes
Bould	2017	35	520	Participants completed a demographics and FINDRISC questionnaire. Those with a FINDRISC score of ≥ 10 were offered an HbA_{1c} finger-prick test to explore their risk further	$n = 247$ (47%) slightly elevated risk category, $n = 101$ (19%) low-risk category, $n = 172$ (33%) moderate, high or very high risk of developing diabetes 10 participants (4.13% of those who took the HbA_{1c} test) had a result of 48 mmol/mol (≥ 6.5%). 108 participants (45% of those who took the test) had a result of between 39 and 46 mmol/mol (5.7% and ≥ 6.4%) Of the 258 participants advised to visit their GP for formal diabetes testing, 155 (60%) did so
Engstrom	2013	25	1558	Non-fasting blood glucose measured with a portable blood glucose meter. Participants with a blood glucose of 40 mmol/mol (5.8%) were referred to their primary healthcare centre for follow-up	Of the 155 (10%) participants who screened positive, 139 (90%) went to their primary healthcare centre within the 3-year follow-up period. $n = 9$ had type 2 diabetes (48 mmol/mol; ≥ 6.5%). Of the 1413 participants who screened negative, 1137 (81%) came to the primary healthcare centre and $n = 8$ (0.6%) had type 2 diabetes. Screening sensitivity was 53%, specificity 91% and positive predictive value 5.8%.
Genco	2014	22	1022	The Diabetes Risk Test questions and the A1CNow+ test	23% = potential non-diabetic hyperglycaemia; 12% = potential type 2 diabetes
Harase	2015	(36)	716	A questionnaire regarding history of diabetes mellitus was completed by all participants The periodontal condition was assessed (periodontal pocket depth and clinical attachment loss) Samples of finger capillary blood were obtained from all participants	The incidences of hyperglycaemia in the type 2 diabetes and non- type 2 diabetes groups were 32% and 3.5%, respectively ($P < 0.0001$) Proportion of participants with hyperglycaemia: 5 of 187 (2.6%) in the mild periodontitis group; 25 of 286 (8.7%) in the moderate periodontitis group, and 13 of 55 (23%) in the severe periodontitis group ($P < 0.0001$).
Herman	2015	(26)	1033	Questionnaire assessing established risk factors for dysglycaemia. Thereafter, random blood glucose using a POCT system.	32% = potential non-diabetic hyperglycaemia 1.7% = potential type 2 diabetes
Mirza	2018	39	226	After obtaining consent, POC and gingival crevicular (GC)C blood were collected, and random blood glucose levels from those samples were tested using an Accu-Chek® glucometer. In the event of abnormal glucose test results, we followed ADA guidance and performed an HbA_{1c} test simultaneously on POC and GC blood samples.	Not reported
Ziebolz	2019	38	102	FINDRISC Questionnaire was used for diabetes screening and positive results were referred to diabetologist for blood glucose and HbA_{1c}	29 previously undiagnosed participants had an elevated risk score. Only 16 of these 29 followed up with the diabetologist. Nine of the 16 were reported to have 'conspicuous' blood glucose findings

ADA, American Diabetes Association; POC, point of care; POCT, point-of-care capillary blood test.

increased, with hyperglycaemia in 2.6% (5 of 187) of participants in the mild periodontitis group, 8.7% (25 of 286) in the moderate periodontitis group, and 23% (13 of 55) in the severe periodontitis group.

Barriers to recruitment were generally not well reported in the studies. When barriers were mentioned, they were often in relation to recruitment and included people refusing participation due to having recently been tested by a

physician, costs relating to testing and lack of dental insurance. Facilitators to recruitment were not discussed in any of the included studies. A further limitation to the studies was reported follow-up of participants post screening. Three of the included articles [22,25,37] reported follow-up, with one following up a sub-sample of their population [26]. Although the studies did not address rates of follow-up as a potential barrier to the implementation of risk assessment services, all studies that reported on follow-up showed the rates to be poor.

Discussion

This systematic review found that there is a limited number of high-quality studies assessing diabetes risk assessment in a primary dental care setting. This review highlighted that primary care dental settings could potentially be beneficial sites at which to undertake targeted risk assessment for non-diabetic hyperglycaemia and type 2 diabetes. This conclusion is based on the available studies, which demonstrated that risk assessments could identify individuals with non-diabetic hyperglycaemia, undiagnosed type 2 diabetes or risk of developing type 2 diabetes to good effect. However, more research based on large-scale robust studies with appropriate follow-up is required to determine the barriers and facilitators to such risk assessments in primary dental care settings, as these appear to be under-reported within the literature in relation to primary care. Research is also needed to determine a gold standard method of risk assessment, and to determine how many of those identified via the risk-assessment processes translate into true cases of disease, and hence the clinical and cost-effectiveness of the process.

The majority of studies utilized a two-stage risk-assessment process with risk score followed by POCT. However, there was heterogeneity in terms of both the risk score and POCT chosen, with the majority of studies using random blood glucose testing and others using HbA_{1c}. The merit of utilizing a two-stage rather than one stage risk-assessment process was not discussed in the studies in terms of time, cost effectiveness or improvements in the identification rate for non-diabetic hyperglycaemia/type 2 diabetes. However, the two studies that used questionnaire-based risk assessment alone reported pick-up rates in the region of 50%, which is far higher than studies utilizing additional POCT. The benefits of a non-invasive and low-cost questionnaire need to be weighed against the high rate of false positives, the potential for increased unnecessary referrals to primary care physicians, and the associated cost of unnecessary follow-up procedures.

There was large variation in the studies that reported detection rate of type 2 diabetes, ranging from 1.7% [26] to 24% [27] of the study sample. Despite this large variation, both studies were based in the USA and reported a mean age of 52 years, with 44% and 45% of participants identifying as male, and 81% and 80% of participants reported as 'White'; the studies were based in New York and Birmingham, Alabama [26] and Michigan [27], respectively. Thus, the studies appear to be well matched for age, sex and ethnicity. A further potential cause of the difference could be the risk-assessment method used and the accuracy of the risk-assessment process. It is recognized that different POCT devices have different levels of accuracy. Interestingly, both studies used a risk score followed by a random blood glucose measurement; furthermore, both reported using the same POCT device (FreeStyle Lite blood glucose meters and test strips; Abbott Diabetes Care Inc., Alameda, CA, USA). Hence, differences in POCT devices should not account for the large variation. A further possible explanation is that the authors used different thresholds for diagnosing an individual's risk of type 2 diabetes.

None of the studies in this review included the opinions of stakeholders relating to the risk-assessment process for type 2 diabetes in primary care dental settings. Work looking at the opinions of stakeholders, including people with diabetes, dental hygienists, dentists and physicians, regarding their attitudes to risk assessment for type 2 diabetes in dental settings has been undertaken in both the USA and UK [28,40–45]. Although these studies did not meet the eligibility criteria for this review, the overall opinion from each of the groups asked was generally positive in relation to using dental settings as potential sites for the early detection of non-diabetic hyperglycaemia and type 2 diabetes.

The studies included in the review cited cost, lack of adequate insurance cover and people having been previously tested elsewhere as the main reasons for a refusal to participate. The studies did not report widely on the barriers and facilitators of undertaking risk assessments within primary dental care. The reported barriers and facilitators to dental teams' risk-assessing for non-diabetic hyperglycaemia and type 2 diabetes have been discussed more widely in the literature, although mostly outside primary care settings [28].

A study undertaken in North America aimed to determine the perceptions of minority ethnic adults aged 50 years or more towards screening for type 2 diabetes and hypertension, as part of their routine dental assessment [43]. Several barriers to screening were identified, including a mistrust of their dental providers. Facilitators were also identified, including the acceptability of the chairside screening process and an understanding of the relationship between oral and systemic health [43].

Time and cost are often considered the most significant barriers to implementing new services. Studies in the USA and Europe have assessed time and costs relating to screening for type 2 diabetes in dental settings [46]. One study suggested the direct costs associated with undertaking a HbA_{1c} test as part of a risk-assessment process was US $9, excluding follow-up medical diagnosis. It also found the mean time for undertaking both risk assessment and participant education to be 14 min (SD 6.2) [37]. However, this

systematic review has identified a lack of consensus in the literature relating to which risk-assessment method and device to select. Given the variety of strategies reported in the literature, the time and costs associated with each process are likely to vary greatly. A further study undertaken in the USA found that three-quarters of those asked would be willing to contribute up to $20, with two-thirds willing to contribute up to $30 toward testing [42]. Whether this is viable within the UK healthcare system would need to be explored.

Following risk assessment for type 2 diabetes being undertaken within the dental setting, it is vital that there is clear communication and established care pathways with the person's GP to ensure appropriate onward management. However, a further barrier identified within the literature was poor follow-up with a physician post risk assessment [27,35,37]. Thus, although many studies stated that individuals and dental teams found risk-assessment methods feasible, acceptable and appropriate, in reality, poor follow-up by GPs mean that it is yet to be determined whether risk assessments in dental settings identified new cases of previously undiagnosed disease.

Historically, screening for type 2 diabetes has been controversial, due to limited evidence that early identification impacted sufficiently upon health outcomes and a lack of certainty regarding management of high-risk individuals. Evidence shows that population-based screening may be ineffective [9,11,47], consequently, the National Screening Committee do not currently recommend screening for type 2 diabetes in the UK. Although the evidence for population-based screening is controversial, emerging evidence supports a targeted approach to case finding [48–50].

In 2015, the US Preventative Service Taskforce recommended targeted case-finding for type 2 diabetes in overweight people aged > 40 years. This is because evidence suggests this approach is cost-effective and improves outcomes. A systematic review of clinical trials showed that screening contributes to delayed disease progression [49], and a meta-analysis has demonstrated that diabetes prevention programmes result in reductions in weight and in progression from non-diabetic hyperglycaemia to type 2 diabetes, compared with usual care [6]. In 2013, the National Screening Committee also acknowledged that advances in diabetes care may now enable benefit from early identification [9].

With ~ 60% of the UK population registered with a dentist [20], dental teams may be in an ideal position to target people for risk assessment of non-diabetic hyperglycaemia and type 2 diabetes, because they regularly interact with a population who would not necessarily attend their GP whilst asymptomatic [19,51,52].

NICE recommends a care pathway [21] that includes contributions from dental teams to identify individuals at high risk of type 2 diabetes. This pathway describes a process whereby dental teams utilized a risk-based questionnaire such as the Leicester Risk Assessment Score. However, the feasibility of undertaking targeted risk-based detection of type 2 diabetes in UK dental settings is still in its early development. This review highlights the requirement for further investigation to determine the feasibility and effectiveness of such a model in primary care dental settings. Furthermore, although much has been published relating to the use of dental settings in the identification of type 2 diabetes, most of this research is based within a secondary care environment [28]. To our knowledge, the evidence base relating to diabetes risk assessment in dental primary care is yet to be synthesized.

A recent article assessing perceptions of stakeholders in secondary care dental settings and dental university clinics demonstrated strong support for hospital-based dental professionals undertaking risk-assessment for type 2 diabetes. The results of which suggested that most hospital-based dental care professionals would be willing to undertake the required risk assessments to identify people with type 2 diabetes [28]. However, secondary and primary care dental services are very different, with different person profiles, care delivery pathways and financial drivers. In the UK, > 95% of dental care is delivered in a primary care setting and thus it was deemed important to establish whether cases of non-diabetic hyperglycaemia and undiagnosed type 2 diabetes could be identified in this environment.

The main strengths of this systematic review were a robust search, review and analysis method to provide assessment of the existing literature, which conformed to the protocol registered previously on PROSPERO [33] and published in the peer-reviewed literature for transparency and clarity of process [4]. The main weakness of this review was due in part to the heterogeneity of the available literature as a result of which, meta-analysis and summary statistics could not be calculated and presented, and we were limited to a descriptive analysis of findings.

The systematic review is based on the available literature, which is only nine studies, of limited quality and variable sample size. This limits the generalizability of results from this review. Furthermore, follow-up of participants beyond the risk-assessment process to determine whether they went on to receive formal non-diabetic hyperglycaemia or type 2 diabetes diagnosis was not widely reported. Where follow-up was reported, the numbers of people visiting their physician were poor. Additionally, different measures of an individual's risk were used, and even when the same measure was used, such as random blood glucose levels, different ranges and thresholds were utilized within the literature. This makes direct comparison between studies challenging.

This systematic review builds upon existing evidence in secondary care settings and highlights that the primary care dental setting may be a viable location to detect non-diabetic hyperglycaemia and undiagnosed type 2 diabetes. In addition, it also demonstrates that further research is required assessing the acceptability, feasibility, effectiveness and cost-effectiveness of such methods. Future larger scale studies

need to be conducted, with suitable follow-up to determine the rate of participants going on to receive a formal diagnosis of non-diabetic hyperglycaemia or type 2 diabetes and receive suitable intervention.

Funding sources

None.

Competing interests

None declared.

Acknowledgements

No financial or material support were provided. There are no acknowledgements to be made.

References

1 Hex N, Bartlett C, Wright D, Taylor M, Varley D. Estimating the current and future costs of type 1 and type 2 diabetes in the UK, including direct health costs and indirect societal and productivity costs. *Diabet Med* 2012; **29**: 855–862.
2 Diabetes UK. *Early Identification of People With, and at High Risk of Type 2 Diabetes and Interventions for Those at High Risk*; 2015. Available at https://www.diabetes.org.uk/professionals/position-statements-reports/type-2-diabetes-prevention-early-identification Last accessed 21 May 2017.
3 National Cardiovascular Intelligence Network. *NHS Diabetes Prevention Programme (NHS DPP) Non-Diabetic Hyperglycaemia*. Public Health England: London, 2015. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/456149/Non_diabetic_hyperglycaemia.pdf Last accessed 12 December 2019.
4 Yonel Z, Sharma P, Gray LJ. Use of dental practices for the identification of adults with undiagnosed type 2 diabetes mellitus or nondiabetic hyperglycemia: protocol for a systematic review. *JMIR Res Protoc* 2018; **7**: e11843.
5 Public Health England. *NHS Diabetes Prevention Programme (NHS DPP) short report 2018-2019*. Public Health England: London, 2019. Online Report. Available at https://www.gov.uk/government/publications/nhs-diabetes-prevention-programme-non-diabetic-hyperglycaemia Last accessed 6 January 2020.
6 Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA *et al*. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 2002; **7346**: 393–403.
7 Hopper I, Billah B, Skiba M, Krum H. Prevention of diabetes and reduction in major cardiovascular events in studies of subjects with prediabetes: meta-analysis of randomised controlled clinical trials. *Eur J Cardiovasc Prev Rehabil* 2011; **18**: 813–823.
8 Ashra NB, Spong R, Carter P, Davies MJ, Dunkley A, Gillies C *et al*. *A Systematic Review and Meta-Analysis Assessing the Effectiveness of Pragmatic Lifestyle Interventions for the Prevention of Type 2 Diabetes Mellitus in Routine Practice*. Public Health England: London, 2015. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733053/PHE_Evidence_Review_of_diabetes_prevention_programmes-_FINAL.pdf Last accessed 26 May 2020.
9 Waugh NR, Shyangdan D, Taylor-Phillips S, Suri G, Hall B. Screening for type 2 diabetes: a short report for the National Screening Committee. *Health Technol Assess* **17**: 1–90.
10 Barron E, Clark R, Hewings R, Smith J, Valabhji J. Progress of the Healthier You: NHS diabetes prevention programme: referrals, uptake and participant characteristics. *Diabet Med* 2018; **35**: 513–518.
11 Simmons RK, Echouffo-Tcheugui JB, Sharp SJ, Sargeant LA, Williams KM, Prevost AT *et al*. Screening for type 2 diabetes and population mortality over 10 years (ADDITION-Cambridge): a cluster-randomised controlled trial. *Lancet* 2012; **380**: 1741–1748.
12 Kassebaum NJ, Bernabe E, Dahiya M, Bhandari B, Murray CJ, Marcenes W. Global burden of severe periodontitis in 1990–2010: a systematic review and meta-regression. *J Dent Res* 2014; **93**: 1045–153.
13 Chapple IL, Genco R. Diabetes and periodontal diseases: consensus report of the Joint EFP/AAP Workshop on Periodontitis and Systemic Diseases. *J Clin Periodontol* 2013; **40**(Suppl 14): S106–S112.
14 Sanz M, Ceriello A, Buysschaert M, Chapple IL, Demmer RT, Graziani F *et al*. Scientific evidence on the links between periodontal diseases and diabetes: consensus report and guidelines of the joint workshop on periodontal diseases and by the International Diabetes Federation and the European Federation of Periodontology. *Diabetes Res Clin Pract* 2018; **137**: 231–241.
15 The Research, Science and Therapy Committee of The American Academy of Periodontology. Position Paper: diabetes and periodontal diseases. *J Periodontol* 2000; **71**: 664–678.
16 Casanova L, Hughes FJ, Preshaw PM. Diabetes and periodontal disease: a two-way relationship. *Br Dent J* 2014; **217**: 433–437.
17 D'Aiuto F, Gkranias N, Bhowruth D, Khan T, Orlandi M, Suvan J *et al*. Systemic effects of periodontitis treatment in patients with type 2 diabetes: a 12 month, single-centre, investigator-masked, randomised trial. *Lancet Diabetes Endocrinol* 2018; **6**: 954–965.
18 Estrich C, Araujo MWB, Lipman R. Prediabetes and diabetes screening in dental care settings: NHANES 2013 to 2016. *JDR Clin Trans Res* 2019; **4**: 76–85.
19 Yonel Z, Sharma P, Yahyouche A, Jalal Z, Dietrich T, Chapple IL. Patients' attendance patterns to different healthcare settings and perceptions of stakeholders regarding screening for chronic, non-communicable diseases in high street dental practices and community pharmacy: a cross-sectional study. *BMJ Open* 2018; **8**: e024503.
20 White DA, Tsakos G, Pitts NB, Fuller E, Douglas GVA, Murray JJ *et al*. Adult Dental Health Survey 2009: common oral health conditions and their impact on the population. *Br Dent J* 2012; **213**: 567–572.
21 National Instititute for Health and Care Excellence. *Type 2 Diabetes: Prevention in People at High Risk*, 2017. Public Health Guidance 38. Available at https://www.nice.org.uk/guidance/ph38/chapter/recommendations#recommendation-3-risk-identification-stage-1 Last accessed X X 201X.
22 Genco RJ, Schifferle RE, Dunford RG, Falkner KL, Hsu WC, Balukjian J. Screening for diabetes mellitus in dental practices: a field trial. *J Am Dent Assoc* 2014; **145**: 57–64.
23 Lalla E, Cheng B, Kunzel C, Burkett S, Ferraro A, Lamster IB. Six-month outcomes in dental patients identified with hyperglycaemia: a randomized clinical trial. *J Clin Periodontol* 2015; **42**: 228–235.
24 Lalla E, Cheng B, Kunzel C, Burkett S, Lamster IB. Dental findings and identification of undiagnosed hyperglycemia. *J Dent Res* 2013; **92**: 888–892.
25 Engstrom S, Berne C, Gahnberg L, Svardsudd K. Effectiveness of screening for diabetes mellitus in dental health care. *Diabet Med* 2013; **30**: 239–245.

26 Herman WH, Taylor GW, Jacobson JJ, Burke R, Brown MB. Screening for prediabetes and type 2 diabetes in dental offices. *J Public Health Dent* 2015; **75**: 175–182.
27 Barasch A, Gilbert GH, Spurlock N, Funkhouser E, Persson LL, Safford MM *et al*. Random plasma glucose values measured in community dental practices: findings from the Dental Practice-Based Research Network. *Clin Oral Investig* 2013; **17**: 1383–1388.
28 Yonel Z, Batt J, Jane R, Cerullo E, Gray LJ, Dietrich T *et al*. The role of the oral healthcare team in identification of type 2 diabetes mellitus: a systematic review. *Curr Oral Health Rep* 2020; **7**: 87–97.
29 Taylor G. Modernising NHS dentistry implementing the plan. *Community Dent Health* 2000; **17**: 207–209.
30 Department of Health. *NHS Dentistry: Options For Change*. London: The Stationery Office, 2002. Available at https://publications.parliament.uk/pa/cm200708/cmselect/cmhealth/289/28905.htm#n41 Last accessed 19 December 2019.
31 Roland M. *The Future of Primary Care: Creating Teams for Tomorrow*. Leeds: Health Education England, 2015. Available at https://www.hee.nhs.uk/our-work/primary-care-workforce-commission Last accessed 11 February 2020.
32 Public Health England. *Making Every Contact Count*. London: NHS England, 2016. Available at https://www.gov.uk/government/publications/making-every-contact-count-mecc-practical-resources Last accessed 11 February 2020.
33 Yonel Z, Sharma P, Gray LJ. The use of dental practices for the identification of adults with undiagnosed type 2 diabetes mellitus or non-diabetic hyperglycaemia (prediabetes); a systematic review. PROSPERO 2018 CRD42018098750 Available at https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42018098750 Last accessed 15 March 2019.
34 Study Quality Assessment Tools. Available at https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools Last accessed 6 September 2018.
35 Bould K, Scott SE, Dunne S, Asimakopoulou K. Uptake of screening for type 2 diabetes risk in general dental practice; an exploratory study. *Br Dent J* 2017; **222**: 293–296.
36 Harase T, Nishida W, Hamakawa T, Hino S, Shigematsu K, Kobayashi S *et al*. Clinical implication of blood glucose monitoring in general dental offices: the Ehime Dental Diabetes Study. *BMJ Open Diabetes Res Care* 2015; **3**: e000151.
37 Bossart M, Calley KH, Gurenlian JR, Mason B, Ferguson RE, Peterson T. A pilot study of an HbA1c chairside screening protocol for diabetes in patients with chronic periodontitis: the dental hygienist's role. *Int J Dent Hyg* 2016; **14**: 98–107.
38 Ziebolz D, Bauwe I, Schmidt J, Kottmann T, Rinke S, Schmalz G. Diabetes screening in dental practice using the Find-Risk questionnaire – a practice-based pilot study. *Oral Health Prev Dent* 2019; **17**: 147–156.
39 Mirza W, Saleem MS, Patel G, Chacko P, Reddy S, Schaefer R *et al*. Early Screening strategies for diabetes mellitus by leveraging dental visits using optimal screening tools available onsite. *Cureus* 2018; **10**: e3641.
40 Esmeili T, Ellison J, Walsh MM. Dentists' attitudes and practices related to diabetes in the dental setting. *J Public Health Dent* 2010; **70**: 108–114.
41 Greenberg BL, Kantor ML, Bednarsh H. American dental hygienists' attitudes towards chairside medical screening in a dental setting. *Int J Dent Hyg* 2017; **15**: e61–e68.
42 Greenberg BL, Kantor ML, Jiang SYS, Glick M. Patients' attitudes toward screening for medical conditions in a dental setting. *J Public Health Dent* 2012; **72**: 28–35.
43 Greenblatt AP, Estrada I, Schrimshaw EW, Metcalf SS, Kunzel C, Northridge ME. Acceptability of chairside screening for racial/ethnic minority older adults: a qualitative study. *JDR Clin Trans Res* 2017; **2**: 343–352.
44 Creanor S, Millward BA, Demaine A, Price L, Smith W, Brown N *et al*. Patients' attitudes towards screening for diabetes and other medical conditions in the dental setting. *Br Dent J* 2014; **216**: E2.
45 Scambler S, Asimakopoulou K. Summary of: Patients' attitudes towards screening for diabetes and other medical conditions in the dental setting. *Br Dent J* 2014; **216**: 34–35.
46 Neidell M, Lamster IB, Shearer B. Cost-effectiveness of diabetes screening initiated through a dental visit. *Community Dent Oral Epidemiol* 2017; **45**: 275–80.
47 Royle PRL, Andrew M, Waugh N. *Updating the Scottish Needs Assessment Programme Report on Type 2 Diabetes: Screening and Prevention Part B: Research review for Scottish Public Health Network – Screening for and Prevention of Type 2 Diabetes*. Available at https://www.scotphn.net/projects/type-2-diabetes-needs-assessment-2/type-2-diabetes-needs-assessment/ Last accessed 17 December 2019.
48 Penn L, Rodrigues A, Haste A, Marques MM, Budig K, Sainsbury K *et al*. NHS Diabetes Prevention Programme in England: formative evaluation of the programme in early phase implementation. *BMJ Open* 2018; **8**: e019467.
49 Roberts S, Barry E, Craig D, Airoldi M, Bevan G, Greenhalgh T. Preventing type 2 diabetes: systematic review of studies of cost-effectiveness of lifestyle programmes and metformin, with and without screening, for pre-diabetes. *BMJ Open* 2017; **7**: e017184.
50 Bray GA, Culbert IW, Champagne CM, Dawson L, Eberhardt B, Greenway FL *et al*. The Diabetes Prevention Program – design and methods for a clinical trial in the prevention of type 2 diabetes. *Diabetes Care* 1999; **22**: 623–634.
51 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**: 156–162.
52 Rosedale MT, Strauss SM, Kaur N, Knight C, Malaspina D. Follow-up with primary care providers for elevated glycated haemoglobin identified at the dental visit. *Int J Dent Hyg* 2017; **15**: e52–e60.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Search strategy.
Table S2. Risk of bias assessment.
Table S3. Prisma checklist.
Table S4. Summary of eligible articles included in the systematic review.
Table S5. Rejected articles and reasons for rejection.