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ORIGINAL ARTICLE

Tooth loss is associated with prevalent diabetes and incident diabetes in a longitudinal study of adults in Ireland

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Abstract

Aim: The aim of this study was to explore the relationship between periodontal status, tooth loss and diabetes among community-dwelling adults aged 50 years and over in Ireland.

Methods: From respondents who attended a health assessment in Wave 3 of the Irish Longitudinal Study on Ageing (TILDA), an opportunistic sample was selected for an oral health examination. The oral health examination criteria were used in previous Irish surveys and WHO recommendations. For diabetes, the self-reported and objectively measured data on diabetes for the same cohort from Wave 3 to Wave 5 of TILDA was used. Multinomial regression analysis was used to evaluate the relationship between diabetes and tooth loss and tooth loss and incident diabetes, controlling for other covariates.

Results: Out of the 3111 people who were offered an oral health assessment 2539 were examined. For the purposes of analysis, the adults below 50 years of age ($n=31$) and those with an incomplete oral health assessment ($n=4$) were omitted from the sample. The final sample consisted of 2504 people, giving a response rate of 80.5%. Among the study sample, 9.9% ($n=249$) were edentate; 35.7% ($n=895$) had 1–19 teeth and 54.4% ($n=1360$) had ≥20 teeth. From the sample of 2504 adults, 2358 had HbA1c results and 8.4% ($n=198$) of these had diabetes according to the TILDA criteria. Multinomial regression analysis showed that diabetes was associated with tooth loss. Diabetes at Wave 3 was associated with a higher rate of being edentate (PR 2.12, 95% CI 1.27–3.52) relative to having ≥20 teeth while controlling for the effect of age, gender, education level, area of residence, body mass index (BMI) and smoking. Furthermore, having 1–19 teeth at Wave 3 was associated with incident diabetes over a 4-year follow-up (OR 1.94, 1.00–3.75). There was no evidence of an association between diabetes and periodontal status as measured in this sample.

Conclusion: The results suggested that diabetes was associated with tooth loss and that this relationship may be bi-directional among community-dwelling adults aged 50 years and over in Ireland, but they do not support a relationship between diabetes and periodontal status in this sample.

KEYWORDS
ageing, diabetes mellitus, glycated haemoglobin, periodontal disease, prediabetes, tooth loss

1 | INTRODUCTION

It is estimated that oral diseases affect nearly 3.5 billion people worldwide and many share common risk factors with other major non-communicable diseases.[1-3] The relationship between oral health and systemic health conditions has been investigated for many years and the importance of this relationship has been endorsed by the World Health Organization (WHO).[3-6] Some oral health and systemic health conditions not only share common risk factors and risk indicators, but there are also pathophysiological connections between the oral cavity and the body systems in both healthy and diseased situations.[3,7,8] The inter-relationship between oral health and systemic disease needs further research to establish the nature of these relationships; in particular, whether they are associations or causative.[9-11] The relationship between oral health and systemic health conditions may be more apparent in older adults. Chronic diseases are more common as people age; apart from the pathophysiological links and common risk factors between chronic diseases and oral health status, the medicines used to manage different chronic diseases can lead to poor oral health, as hyposalivation is a side effect of many of them.

Tooth loss is a basic indicator of oral health and represents the cumulative effect of oral disease and dental treatment.[12] Studies have reported on the relationship between periodontal health, tooth loss and diabetes.[13-22] Globally, diabetes mellitus is a widespread disease with complications that lead to poor quality of life and reduced longevity. In 2014, the WHO reported that worldwide 422 million people suffered from diabetes and this figure is projected to increase to 439 million (affecting 10% of adults) by 2030.[23] The WHO has reported that diabetes is the 9th most common cause of death (an increase of 70% since 2000) and is responsible for the largest rise in male deaths, with an 80% increase since 2000.[23]

There are three possible mechanisms behind the link between periodontal disease and diabetes: (i) an interrelationship between periodontitis and diabetes caused by systemic inflammation and poor glycaemic control, which leads to increased tooth loss,[17,24,25,26] (ii) eating habits in a person with fewer teeth that can lead them to develop diabetes,[27-30] (iii) common risk factors exist for diabetes, periodontitis and tooth loss.[8,31,32]

However, it is not clear to what extent diabetes contributes to periodontal disease and subsequent tooth loss in a particular population and how much the prevention and control of diabetes (and periodontal disease) would reduce tooth loss. This may depend on a range of local factors, such as the prevalence of other dental diseases, access to dental treatment and the influence of other common risk factors (diet, smoking, oral hygiene). In this context, firstly, a cross-sectional study was conducted to evaluate the relationship between tooth loss, periodontal status and diabetes, after controlling for both general health and socio-economic factors, among community-dwelling adults aged 50 years and over in Ireland. Secondly, the study investigated the longitudinal associations of tooth loss and periodontal status with incident diabetes over a 4-year follow-up.

2 | MATERIALS AND METHODS

An observational study was carried out, based on data from The Irish Longitudinal Study on Ageing (TILDA) Wave 3 to Wave 5. The methods used for TILDA data collection and details about the TILDA cohort have been reported previously.[33] In line with the WHO criteria, missing teeth were recorded as missing due to caries, except missing third molar teeth or where there was a clear indication and history of teeth missing due to trauma or orthodontic extractions.[34] CPITN on index teeth was used for the periodontal examination, the mouth was divided into sextants and the highest (worst) score on the index teeth (1.6/1.6, 1.1, 2.6/2.7, 3.6/3.7, 3.1 and 4.6/4.7) in each sextant was recorded as the sextant score. The scores were no disease (H), bleeding on examination (B), supra or subgingival calculus present (C), pocket depth up to 4–5 mm (P1), pocket depth > 6 mm (P2) and if no teeth were present in a sextant/unable to record (X).

In 2014–2015, from the TILDA Wave 3 cohort ($n = 6618$) who completed the Computer-Assisted Personal Interview (CAPI) and Self-Completed Questionnaire (SCQ), 4256 participants underwent a health assessment. Of those who completed the health assessment, 3111 respondents were invited to have an oral health assessment; 2539 (81.6%) agreed to the assessment. Respondents aged less than 50 years ($n = 31$) and those with incomplete assessments ($n = 4$) were omitted from the sample. The final oral health sample consisted of 2504 respondents aged 50 years and over.

The examination criteria used in this study were the same as those used in previous national Irish oral health surveys and similar to those recommended by the WHO.[34,35] Further details of methods used for oral health assessment study are reported elsewhere.[36]

Self-reported data from TILDA Waves 3–5, and clinically measured data from Wave 3 were used to determine the presence of diabetes. Table 1 shows the criteria for reporting a respondent as having diabetes. Diagnosed diabetes was defined using self-reported doctors' diagnoses and medication data. The American Diabetic Association provides a cut-off value of HbA1c ≥ 48 nmol/mol, as undiagnosed diabetes. Glycated haemoglobin (HbA1c) analysis was used to identify undiagnosed and pre-diabetes. HbA1c provides an individual estimate of glycaemic control over the previous 8–12 weeks and is an accepted method to diagnose diabetes and pre-diabetes.[37] Incident diabetes between Wave 3 and Wave 5 was estimated based

TABLE 1 TILDA criteria used to classify adults with diabetes.

Diabetes	Self-reported	Self-reported doctor diagnosed diabetes in TILDA Wave 3
		Taking diabetic medications (oral hypoglycaemic or insulin) Wave 3
	Undiagnosed diabetes	HbA1c ≥ 48 nmol/mol in Wave 3 and no self-reported diabetes or no use of diabetic medications (oral hypoglycaemic or insulin) in Wave 3
No diabetes		No self-reported diabetes in Wave 3, no record of taking diabetic medications and HbA1c <48 nmol/mol in Wave 3.
Pre-diabetes	Objectively measured	HbA1c ≥ 38 nmol/mol and <48 nmol in Wave 3 and no self-reported diabetes or no use of diabetic medications (oral hypoglycaemic or insulin)
Incident diabetes	Self-reported	Self-reported doctor diagnosed diabetes in TILDA Wave 4–Wave 5 and no previous diagnosis/or use of diabetic medication Wave 1–Wave 3

TABLE 2 Characteristics of the sample at Wave 3 by tooth number at Wave 3 (Base: Edentate and dentate sample, *n* = 2504).

	Edentate (*n* = 249)		1–19 teeth (*n* = 895)		≥20 teeth (*n* 1360)	
Characteristics	***N***	**%**	***N***	**%**	***N***	**%**
Diabetes						
No diabetes	198	9.2	745	34.5	1217	56.3
Diabetes negative	157	8.4	626	33.4	1089	58.2
Pre-diabetes	41	14.2	119	41.3	128	44.4
Any diabetes	34	17.2	86	43.4	78	39.4
Age group						
50–64	48	3.9	292	24.0	878	72.1
65–74	107	11.7	422	46.1	387	42.2
>=75	94	25.4	181	48.9	95	25.7
Gender						
Male	88	8.1	428	39.2	576	52.7
Female	156	11.5	446	33.0	751	55.5
Education						
Primary/none	97	20.3	228	47.7	153	32.0
Secondary	94	9.4	385	38.4	523	52.2
Third/higher	58	5.7	282	27.6	683	66.8
Area of residence						
Dublin city or county	47	6.9	224	32.9	409	60.1
Another town or city	64	9.7	230	34.8	367	55.5
A rural area	138	11.9	441	37.9	584	50.2
BMI						
Normal weight	49	9.1	155	28.9	332	61.9
Overweight	102	9.2	406	36.8	595	53.9
Obese	96	11.3	324	38.3	427	50.4
Smoker						
Never	105	8.7	386	32.1	713	59.2
Past	117	10.9	413	38.6	541	50.5
Current	27	11.8	96	41.9	106	46.3

Note: 'No Diabetes' category includes those with pre-diabetes.

on self-reported newly diagnosed diabetes in Wave 4 and Wave 5, from those with no previously diagnosed diabetes based on the question 'Did a doctor diagnose you with diabetes or high blood sugar since your last interview?'

For the analysis, the number of teeth was divided into three categories (edentate, 1–19 teeth, 20 or more teeth). These categories were used because they included the worst case (edentate adults) and adults with 20 or more teeth, which is the recommended WHO

target for retention of teeth among older adults.[38-41] For periodontal status, the Community Periodontal Index of Treatment Need on index teeth was used.[36] Periodontal status was collected only for those who had teeth and was categorized as 0, No disease, healthy (CPITN score 0); 1, bleeding & calculus (CPITN score 1 and 2) and 2, shallow and deep pockets (CPITN score 3 and 4).

Diabetes was the independent variable. Directed acyclic graphs (DAG), shown in Figures S1–S4, were used to clarify the study questions, explicitly identify assumptions of temporality and determine a minimally sufficient set of covariates for the models, derived from the literature and the accepted evidence about the relationship between diabetes, tooth loss and periodontal health. Included as categorical variables were age group (single year), gender (male and female), education (three categories; primary or no education, secondary, and third-level or higher), area of residence (three categories; Dublin city or county, another town or city and rural area), BMI (three categories; normal 18.5–24.9, overweight 25.0–29.9 and obese ≥30.0) and smoker (three categories; never, former and current) (see Supplementary Data for detailed descriptions of the oral health assessment and definition of variables).

The analysis was completed in two stages based on the DAGs. First, the study estimated the cross-sectional association of diabetes at Wave 3 and number of teeth (Figure S1) and periodontal status (Figure S2) at Wave 3. As the dependent variable was categorical, multinomial regression analysis was used. Second, to investigate the bi-directionality of the relationship, the study estimated the association between the number of teeth at Wave 3 (Figure S3) and periodontal status (Figure S4) with incident diabetes between Wave 4 and 5. The study repeated the analyses with periodontal status as the outcome variable. STATA software (Stata 15.1 Stata Corp LLC) was used for data analysis.

3 | RESULTS

The respondents were categorized according to the number of teeth present; (i) edentate ($n=249$), (ii) 1–19 teeth ($n=895$) and (iii) ≥20 teeth ($n=1360$). Among the study sample with HbA1c results ($n=2358$), 8.4% ($n=198$) of the adults were determined to have diabetes according to the criteria defined in Table 1 and a further 12.2% had pre-diabetes.[42] The characteristics of the sample by number of teeth are reported in Table 2 and by categories of periodontal status in Table 3. Between Wave 4 and Wave 5, 2.5% ($n=50$) received a new diagnosis of diabetes.

Table 4 shows that adults with both pre-diabetes and diabetes at Wave 3 were at higher risk of being edentate ($p=.001$) and having 1–19 teeth ($p<.001$) relative to having ≥20 teeth. After controlling for covariates- age, gender, education, area of residence, BMI and smoking, adults with diabetes remained at higher risk of being edentate ($p=.004$) relative to having 20 or more teeth (Table 4).

Regression analysis in Table 5 shows that there was no evidence of an association of either pre-diabetes or diabetes at Wave 3 with periodontal disease status.

Table 6 shows incident diabetes over a 4-year period of follow-up, following dental assessment at Wave 3 in 2015. Having fewer than 20 teeth at Wave 3 was associated with a higher risk of an incident diagnosis of diabetes relative to having ≥20 teeth and this association remained following adjustment for covariates ($p=.050$). Periodontal status at Wave 3 was not associated with an incident diagnosis of diabetes during a 4-year follow-up to Wave 5.

4 | DISCUSSION

By including an oral health assessment in the main TILDA study, this project was able to access a large sample of TILDA respondents and their systemic health data, such as longitudinal data on diabetes and socio-economic and behavioural covariates. This study adds to the literature as a large nationally representative cohort of older adults that included an objective measure of tooth loss, periodontal disease and diabetes. Furthermore, it represents a cohort of older adults who only had access to basic dental care, for example, extractions, rather than preventive and restorative care which are accessible to younger adults nowadays.

The data showed that a reduced number of teeth was associated with the presence of diabetes; this relationship remained after controlling for demographics and health behaviours. These findings are consistent with other research, which also found a relationship between diabetes and tooth loss.[16,17,18,43,44] Similar findings were seen in a cross-sectional evaluation of the relationship between self-reported data on tooth loss and self-reported diabetes, among adults aged 54 years and over in the complete TILDA Wave 3 sample ($n=6425$).[20] Both self-reported and objectively measured missing teeth in the TILDA samples included tooth loss for any reason. It would be preferable if tooth loss due to periodontal disease only could be identified to fully understand any relationship with diabetes.

Many investigators have described a relationship between periodontal disease and diabetes.[11,13,24,25,26,45,46] A recent meta-analysis suggests that severe periodontitis may have a strong influence on incident diabetes,[47] but this study did not find such a relationship, which could possibly be due to the method by which periodontal status was assessed. The use of CPITN on index teeth is not designed to comprehensively record the presence and severity of periodontal disease. A full periodontal charting (bleeding on probing, measurement of loss of attachment and tooth mobility) of all remaining teeth would be a better assessment of periodontal disease. This CPITN index was used in Wave 3 because it is a simple and reliable way to assess broad treatment needs, and because of the limitations of time for the oral health assessments. There is evidence to show that glycaemic control plays an important role in the relationship between diabetes and the severity of periodontal disease. It is not known whether the sample in this study had good glycaemic control, to the extent that it might have limited the impact of diabetes on tooth loss. Alternatively, as periodontal disease is a precursor to tooth loss, and the study only measured periodontal disease in

TABLE 3 Characteristics of the sample at Wave 3 by periodontal status at Wave 3 (Base dentate, $n=2197$ and edentate excluded, $n=58$).

	Healthy (CPITN score 0) ($n=131$)		Bleeding and calculus (CPITN score 1 and 2) ($n=793$)		Shallow and deep pockets (CPITN score 3 and 4) ($n=1273$)	
Characteristics	***N***	**%**	***n***	**%**	***N***	**%**
Diabetes						
No diabetes	103	5.6	662	36.0	1076	58.4
Diabetes negative	92	5.7	582	36.2	932	58.0
Pre-diabetes	11	4.7	80	34.0	144	61.3
Any diabetes	13	8.4	53	34.4	88	57.1
Age group						
50–64	61	5.3	379	32.7	719	62.0
65–74	47	6.0	301	38.5	434	55.5
>=75	23	9.0	113	44.1	120	46.9
Gender						
Male	43	4.5	308	32.0	611	63.5
Female	84	7.1	461	38.9	639	54.0
Education						
Primary/none	19	5.2	140	38.4	206	56.4
Secondary	52	5.9	309	34.8	526	59.3
Third/higher	60	6.3	344	36.4	541	57.2
Area of residence						
Dublin City or county	53	8.6	277	44.9	287	46.5
Another town or city	26	4.5	196	33.7	359	61.8
A rural area	52	5.2	320	32.0	627	62.8
BMI						
Normal weight	33	6.8	195	40.5	254	52.7
Overweight	61	6.3	344	35.5	565	58.2
Obese	37	5.1	249	34.2	443	60.8
Smoker						
Never	63	5.8	425	39.2	596	55.0
Past	60	6.6	318	34.7	538	58.7
Current	8	4.1	50	25.4	139	70.6

Note: 'No Diabetes' category includes those with pre-diabetes.

those with teeth, a cohort with less tooth loss may be necessary to evaluate this association. Another reason for not finding any relationship between periodontal disease and diabetes could be the availability of only self-reported data on diabetes from TILDA wave 4 and wave 5, which was used for the evaluation of this relationship. Self-reporting of diabetes might have underestimated the diabetes incidence because adults with poor health literacy may not be aware of the symptoms or risks of diabetes. However, in the TILDA cohort underdiagnosis of diabetes was found to be low (0.9%) and was associated with area of residence and medical cost cover.[42] Among the adults who were classified as diabetic ($n=536$), 10 respondents had Type 1 diabetes, while the remaining respondents had Type 2 diabetes. For this reason, it was not possible to evaluate the relationship of Type 1 and Type 2 diabetes separately with oral health. Our findings support the bi-directional relationship between tooth loss and incident diabetes, and the study found that having fewer than 20 teeth was associated with an incident diagnosis of diabetes over a 4-year follow-up, supporting findings from other studies.[48-50]

In this study, the oldest age group was at higher risk of tooth loss for any reason, but diabetes was a risk indicator for tooth loss following adjustment for age. The clinical significance of this relationship needs further investigation because, as reported by Haworth and colleagues, the reasons for tooth loss in older adults are difficult to determine.[51] TILDA is a longitudinal study which provides an opportunity to follow these people over time. Important aspects of such a follow-up might be whether the people with diabetes continue to lose teeth and whether they receive regular dental care and the effect of that care.

Controlling for socio-demographic factors in this study does not rule out other factors affecting tooth loss, such as lack of

TABLE 4 Multinomial regression analysis of diabetes and pre-diabetes at Wave 3 associated with the number of teeth in Wave 3 (Base-edentate and dentate, $n = 1958$).

Relationship of diabetes with number of teeth (Reference value no diabetes)	Diabetes status associated with edentulism ($n = 232$) and 1–19 teeth ($n = 831$) compared to (base) 20 or more teeth ($n = 1295$)			
	Edentate		1–19 teeth	
	PR (95% CI)	*p* value	PR (95% CI)	*p* Value
Model 1				
Pre-diabetes	2.22 (1.51–3.27)	<.001	1.62 (1.24–2.11)	<.001
Diabetes	3.02 (1.95–4.78)	<.001	1.92 (1.39–2.65)	<.001
Model 2 controlling for demographics				
Diabetes				
Pre-diabetes	1.49 (0.96–2.32)	.077	1.32 (0.99–1.76)	.065
Diabetes	2.37 (1.44–3.91)	.001	1.48 (1.04–2.10)	.030
Model 3 controlling for demographics and behaviours				
Diabetes				
Pre-diabetes	1.40 (0.89–2.20)	.142	1.25 (0.92–1.68)	.151
Diabetes	2.12 (1.27–3.52)	.004	1.36 (0.93–1.95)	.096

Note: Number of teeth is a dependent variable, and pre-diabetes, diabetes, demographic and behavioural factors are independent variables. Model 1 univariate; Model 2 adjusted for demographics: age, sex, educational attainment, area of residence; Model 3 adjusted for demographics and health behaviours: smoking status and BMI.

Abbreviation: PR, prevalence ratio.

TABLE 5 Multinomial regression analysis of diabetes and pre-diabetes associated with periodontal status (Base-dentate, $n = 2121$) at Wave 3.

Relationship of diabetes with periodontal status (Reference value no diabetes)	Diabetes status associated with bleeding and calculus ($n = 793$) and shallow and deep pockets ($n = 1273$) compared to healthy periodontium ($n = 131$) as the base.			
	Bleeding and calculus		Shallow and deep pockets	
	PR (95% CI)	*p* value	PR (95% CI)	*p* value
Model 1				
Pre-diabetes	0.75 (0.39–1.43)	.380	0.88 (0.66–1.18)	.398
Diabetes	1.42 (0.76–2.62)	.270	0.95 (0.67–1.35)	.787
Model 2 controlling for demographics				
Diabetes				
Pre-diabetes	0.73 (0.38–1.40)	.342	0.85 (0.63–1.14)	.280
Diabetes	1.64 (0.87–3.10)	.128	0.96 (0.67–1.39)	.849
Model 3 controlling for demographics and behaviours				
Diabetes				
Pre-diabetes	0.79 (0.41–1.54)	.491	0.90 (0.67–1.22)	.509
Diabetes	1.83 (0.95–3.65)	.069	1.03 (0.71–1.50)	.868

Note: Periodontal status is the dependent variable, and pre-diabetes, diabetes, demographic and behavioural factors are independent variables. Model 1 univariate; Model 2 adjusted for demographics: age, sex, educational attainment, area of residence; Model 3 adjusted for demographics and health behaviours: smoking status and BMI.

Abbreviation: PR, prevalence ratio.

access to dental care, and lack of knowledge of oral health care in the early part of the respondents' lives. There has been an increased awareness of oral health among all sociodemographic groups in Ireland, and dental care has become more accessible and affordable over the lifetime of people in this study. Data from the first Irish national survey of adult oral health (1989–1990) reported that tooth loss was higher among adults with low incomes who were entitled to state-funded dental care, which was limited to episodic care including extractions, removable dentures and simple restorations for caries, but very little periodontal care.[52] At that time, a much higher level of edentulousness in females was also reported, which indicates that socioeconomic or access to care issues were factors.[52] However, this gender discrepancy has reduced over time in Ireland.[36]

TABLE 6 Logistic regression analysis of number of teeth at Wave 3 (Base-edentate and dentate, $n = 2504$) and periodontal status at Wave 3, associated with incident diabetes from Wave 4 to Wave 5.

	Association with an incident diagnosis of diabetes Wave 4 to Wave 5					
	Model 1 unadjusted		Model 2 adjusted for demographics		Model 3 adjusted for demographics and health behaviours	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Number of teeth (Reference ≥20 teeth)						
Edentate	1.87 (0.74–4.70)	.183	2.90 (1.05–8.02)	.040	2.48 (0.88–7.05)	.087
1–19 teeth	1.83 (1.00–3.33)	.048	2.21 (1.15–4.26)	.018	1.94 (1.00–3.75)	.050
Periodontal status (Reference value healthy periodontium)						
Bleeding and calculus	0.58 (0.19–1.78)	.339	0.52 (0.17–1.62)	.258	0.51 (0.16–1.60)	.245
Shallow and deep pockets	0.56 (0.19–1.64)	.286	0.45 (0.15–1.38)	.163	0.40 (0.13–1.24)	.114

Note: Diabetes incidence at Wave 4 and Wave 5 is a dependent variable, and number of teeth, periodontal status, demographic and behavioural factors at Wave 3 are independent variables. Model 1 univariate; Model 2 adjusted for demographics: age, sex, educational attainment and area of residence; Model 3 adjusted for demographics and health behaviours: smoking status and BMI.

Abbreviation: OR, odds ratio.

In Ireland, a new national oral health policy (*Smile agus Sláinte*) was launched in 2019 which focuses on oral health care over the life course, rather than providing items of episodic care.[53] This approach will be expected to improve periodontal health and retention of natural teeth. Monitoring the oral health status of the oldest age groups in populations is essential for planning and delivering oral health programmes, though a dental assessment can be a challenge for some older people with impairment, loss of cognitive function and poorer general health. A limitation of this study was that it did not include adults living in institutional care, who are more likely to have significant systemic or cognitive decline. There is a need to develop simplified oral health assessments that can allow a range of healthcare workers to collect key basic data on oral health status in all older adults.

A further limitation of this study was that only one oral health assessment was carried out so a cross-lagged panel model to determine bi-directional associations between tooth loss and diabetes was not possible. To mitigate this limitation, and to attempt to investigate the potential bi-directionality of the relationships, we completed a second analysis and estimated the association of tooth loss at Wave 3 with incident diagnoses of diabetes between Wave 4 and 5.

5 | CONCLUSIONS

This study found that diabetes was associated with being edentate and having fewer than 20 teeth among adults aged 50 years and over in Ireland, but no association was found with periodontal status, possibly due to the high number of extractions in this population. Furthermore, having fewer than 20 teeth was associated with a higher incident diagnosis of diabetes over 4 years. The analysis controlled for age and socio-economic status, and all respondents were ambulant and not in residential care. In the TILDA study, there is an opportunity to monitor tooth loss on a longitudinal basis which may give an indication of the value of tooth loss as a simple indicator of oral health.

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CONFLICT OF INTEREST STATEMENT

No competing interests were disclosed.

DATA AVAILABILITY STATEMENT

The oral health data presented in this report was collected during Wave 3 of TILDA. Wave 3 data are available from the Irish Social Science Data Archive (ISSDA): ISSDA: Data set 1. *The Irish Longitudinal Study on Ageing (TILDA) Wave 3, 2014–2015*. Study number: 0053-04. www.ucd.ie/issda/data/tilda/wave3 [54].

ACCESSING THE DATA

To access the data, please complete an ISSDA Data Request Form for Research Purposes sign it and send it to ISSDA by email (issda@ucd.ie).

For teaching purposes, please complete the ISSDA Data Request Form for Teaching Purposes and follow the procedures, as above. Teaching requests are approved on a once-off module/workshop

basis. Subsequent occurrences of the module/workshop require a new teaching request form.

Data will be disseminated on receipt of a fully completed, signed form. Requests to access the OHA data should be made directly to TILDA (tilda@tcd.ie).

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REFERENCES

1. James SL, Abate D, Abate KH, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the global burden of disease study 2017. *The Lancet*. 2018;392(10159):1789-1858.
2. Benzian H, Bergman M, Cohen L, Hobdell M, Mackay J. The UN High-level Meeting on Prevention and Control of Non-communicable Diseases and its significance for oral health worldwide. *J Public Health Dent*. 2012;72(2):91-93.
3. World Health Organisation. Executive Board EB148/CONF./3-148th session 19 January 2021- Agenda item 6- Oral Health. 2021. https://extranet.who.int/nonstateactorsstatements/meetingoutline/7
4. Petersen PE, Yamamoto T. Improving the oral health of older people: the approach of the WHO Global Oral Health Programme. *Community Dent Oral Epidemiol*. 2005;33(2):81-92.
5. Sanz M, Ceriello A, Buysschaert M, et al. Scientific evidence on the links between periodontal diseases and diabetes: consensus report and guidelines of the joint workshop on periodontal diseases and diabetes by the international diabetes federation and the European Federation of Periodontology. *Diabetes Res Clin Pract*. 2018;137:231-241.
6. Sanz M, Marco del Castillo A, Jepsen S, et al. Periodontitis and cardiovascular diseases: consensus report. *J Clin Periodontol*. 2020;47(3):268-288.
7. Chapple IL. The impact of oral disease upon systemic health—symposium overview. *J Dent*. 2009;37(8):S568-S571.
8. Sheiham A, Watt RG. The common risk factor approach: a rational basis for promoting oral health. *Community Dent Oral Epidemiol: Commentary*. 2000;28(6):399-406.
9. Seymour G. Good oral health is essential for good general health: the oral–systemic connection. *Clin Microbiol Infect*. 2007;13(s4):1-2.
10. Otomo-Corgel J, Pucher JJ, Rethman MP, Reynolds MA. State of the science: chronic periodontitis and systemic health. *J Evid Based Dent Pract*. 2012;12(3):20-28.
11. Winning L, Linden GJ. Periodontitis and systemic disease: association or causality? *Curr Oral Health Rep*. 2017;4(1):1-7.
12. Thorstensson H, Johansson B. Why do some people lose teeth across their lifespan whereas others retain a functional dentition into very old age? *Gerodontology*. 2010;27(1):19-25.
13. Papapanou PN. Periodontal diseases: epidemiology. *Ann Periodontol*. 1996;1(1):1-36.
14. Mealey BL, Oates TW. AAP-commissioned review. *J Periodontol*. 2006;77:1289-1303.
15. Lalla E, Papapanou PN. Diabetes mellitus and periodontitis: a tale of two common interrelated diseases. *Nat Rev Endocrinol*. 2011;7(12):738-748.
16. Kapp JM, Boren SA, Yun S, LeMaster J. Diabetes and tooth loss in a national sample of dentate adults reporting annual dental visits. *Prev Chronic Dis*. 2007. Available from: http://www.cdc.gov/pcd/issues/2007/jul/06_0134.htm
17. Taylor GW, Manz MC, Borgnakke WS. Diabetes, periodontal diseases, dental caries, and tooth loss: a review of the literature. *Compend Contin Educ Dent*. 2004;25(3):179-184. quiz 192.
18. Demmer RT, Jacobs DR, Desvarieux M. Periodontal disease and incident type 2 diabetes: results from the first National Health and nutrition examination survey and its epidemiologic follow-up study. *Diabetes Care*. 2008;31(7):1373-1379.
19. Patino MN, Loyola RJ, Medina SC, Pontigo LA, Reyes MJ, Ortega RJ. Caries, periodontal disease and tooth loss in patients with diabetes mellitus types 1 and 2. *Acta Odontol Latinoam*. 2008;21(2):127-133.
20. Sheehan A, McGarrigle a C, O'Connell B. *Oral Health and Wellbeing of Older Irish Adults*. Irish Longitudinal Study Ageing (TILDA); 2017.
21. Borgnakke WS. IDF diabetes atlas: diabetes and oral health–a two-way relationship of clinical importance. *Diabetes Res Clin Pract*. 2019;157:107839.
22. Patel MH, Kumar JV, Moss ME. Diabetes and tooth loss: an analysis of data from the National Health and nutrition examination survey, 2003–2004. *J Am Dent Assoc*. 2013;144(5):478-485.
23. World Health Organisation, F.S. *The top 10 causes of death*. World Health Organization; 2020. Accessed April 2020. https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death
24. 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:S106-S112.
25. Taylor JJ, Preshaw PM, Lalla E. A review of the evidence for pathogenic mechanisms that may link periodontitis and diabetes. *J Clin Periodontol*. 2013;40:S113-S134.
26. Taylor GW, Burt BA, Becker MP, et al. Non-insulin dependent diabetes mellitus and alveolar bone loss progression over 2 years. *J Periodontol*. 1998;69(1):76-83.
27. Sheiham A, Steele JG, Marcenes W, et al. The relationship among dental status, nutrient intake, and nutritional status in older people. *J Dent Res*. 2001;80(2):408-413.
28. Gilbert GH, Meng X, Duncan RP, Shelton BJ. Incidence of tooth loss and prosthodontic dental care: effect on chewing difficulty onset, a component of oral health–related quality of life. *J Am Geriatr Soc*. 2004;52(6):880-885.
29. Joshipura KJ, Willett WC, Douglass CW. The impact of edentulousness on food and nutrient intake. *J Am Dent Assoc*. 1996;127(4):459-467.
30. Woelber JP, Bremer K, Vach K, et al. An oral health optimized diet can reduce gingival and periodontal inflammation in humans-a randomized controlled pilot study. *BMC Oral Health*. 2017;17(1):1-8.
31. Genco RJ, Genco FD. Common risk factors in the management of periodontal and associated systemic diseases: the dental setting and interprofessional collaboration. *J Evid Based Dent Pract*. 2014;14:4-16.
32. de Araújo Nobre M, Maló P. Prevalence of periodontitis, dental caries, and peri-implant pathology and their relation with systemic status and smoking habits: results of an open-cohort study with 22009 patients in a private rehabilitation center. *J Dent*. 2017;67:36-42.
33. Kenny RA. An introduction to the irish longitudinal study on ageing. *J Am Geriatr Soc*. 2013;61(s2):S263-S264.
34. World Health Organization. *Oral Health Survey Basic Methods*. 5th ed. World Health Organization; 2013.
35. Whelton H. *Oral Health of Irish Adults 2000–2002: Final Report-April 2007*. Department of Health and Children; 2007.
36. Naseer A, McLoughlin J, Donoghue OA, Kenny RA, O'Connell B. Dental health status of community-dwelling adults aged 50 years and over in Ireland. A cross-sectional analysis of the Wave 3 TILDA cohort. *HRB Open Res*. 2018;1:26. doi:10.12688/hrbopenres.12891.3

37. American Diabetes Association, 2. Classification and diagnosis of diabetes: standards of medical Care in Diabetes—2020. *Diabetes Care*. 2020;43(suppl 1):S14-S31.
38. Armellini D, Von Fraunhofer JA. The shortened dental arch: a review of the literature. *J Prosthet Dent*. 2004;92(6):531-535.
39. World Health Organisation. *Recent Advances in Oral Health: Report of a WHO Expert Committee*. World Health Organization; 1992:16-17.
40. Witter DJ, De Haan AF, Käyser AF, Van Rossum GM. A 6-year follow-up study of oral function in shortened dental arches. Part II: Craniomandibular dysfunction and oral comfort. *J Oral Rehabil*. 1994;21(4):353-366.
41. Marcenes W, Steele JG, Sheiham A, Walls AWG. The relationship between dental status, food selection, nutrient intake, nutritional status, and body mass index in older people. *Cad Saude Publica*. 2003;19:809-815.
42. Leahy S, O'Halloran AM, O'Leary N, et al. Prevalence and correlates of diagnosed and undiagnosed type 2 diabetes mellitus and prediabetes in older adults: findings from the Irish longitudinal study on ageing (TILDA). *Diabetes Res Clin Pract*. 2015;110(3):241-249.
43. Kaur G, Holtfreter B, Rathmann WG, et al. Association between type 1 and type 2 diabetes with periodontal disease and tooth loss. *J Clin Periodontol*. 2009;36(9):765-774.
44. Jimenez M, Hu FB, Marino M, Li Y, Joshipura KJ. Type 2 diabetes mellitus and 20 year incidence of periodontitis and tooth loss. *Diabetes Res Clin Pract*. 2012;98(3):494-500.
45. Nelson RG, Shlossman M, Budding LM, et al. Periodontal disease and NIDDM in Pima Indians. *Diabetes Care*. 1990;13(8):836-840.
46. Winning L, Patterson CC, Neville CE, Kee F, Linden GJ. Periodontitis and incident type 2 diabetes: a prospective cohort study. *J Clin Periodontol*. 2017;44(3):266-274.
47. Wu CZ, Yuan YH, Liu HH, et al. Epidemiologic relationship between periodontitis and type 2 diabetes mellitus. *BMC Oral Health*. 2020;20(1):204.
48. Raju K, Taylor GW, Tahir P, Hyde S. Association of tooth loss with morbidity and mortality by diabetes status in older adults: a systematic review. *BMC Endocr Disord*. 2021;21(1):1-16.
49. Stöhr J, Barbaresko J, Neuenschwander M, Schlesinger S. Bidirectional association between periodontal disease and diabetes mellitus: a systematic review and meta-analysis of cohort studies. *Sci Rep*. 2021;11(1):1-9.
50. Preshaw PM, Alba AL, Herrera D, et al. Periodontitis and diabetes: a two-way relationship. *Diabetologia*. 2012;55(1):21-31.
51. Haworth S, Shungin D, Kwak SY, et al. Tooth loss is a complex measure of oral disease: determinants and methodological considerations. *Community Dent Oral Epidemiol*. 2018;46:555-562.
52. O'Mullane D, Whelton H. *Oral Health of Irish Adults 1989–1990: A Survey Conducted by the Oral Health Services Research Centre, University College Cork*. Stationery Office; 1992.
53. Department of Health Ireland. National Oral Health Policy, Department of Health., Editor. 2019.
54. The Irish Logitudinal Study on Ageing. The Irish Longitudinal study on Ageing (TILDA) Wave 3, 2014–2015. [dataset]. Version 3.1. Irish Social Science Data Archive. SN:0053–04 2018. https://www.ucd.ie/issda/t4media/0053-04_TILDA_Wave3_CAPI_Questionnaire.pdf

SUPPORTING INFORMATION

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

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