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# Association between diabetes and edentulism and their joint effects on health status in 40 low and middle-income countries

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## ABSTRACT

**Introduction** Previous studies on the diabetes–edentulism relationship have yielded conflicting results. Therefore, the goal of this study was to investigate the association between diabetes and edentulism, and their joint effects on health status in adults from 40 low and middle-income countries (LMICs).

**Research design and methods** Data from the World Health Survey were used for this cross-sectional study (2002–2004). Forty countries (18 low-income and 22 middle-income countries) were included. Edentulism and diabetes were assessed using yes-no questions based on self-report. Health status was assessed in seven different domains (self-care, pain/discomfort, cognition, interpersonal activities, sleep/energy, affect, and perceived stress). The association between diabetes (exposure) and edentulism (outcome) was analyzed using multivariable logistic regression models, while their joint effects on health status were assessed using multivariable linear regression models.

**Results** There were 175 814 adults aged ≥18 years included in this study (mean (SD) age 38.4 (16.0) years; 49.3% men). Overall, the prevalence of edentulism was 6.0% and diabetes was 2.9%. There was a positive and significant association between diabetes and edentulism in the overall sample (OR=1.40, 95% CI 1.18 to 1.66), in low-income countries (OR=1.78, 95% CI 1.21 to 2.62) and in middle-income countries (OR=1.24, 95% CI 1.04 to 1.47). In addition, people with comorbid diabetes and edentulism had worse health status in the domains of cognition, sleep/energy, and perceived stress, compared with those with diabetes only.

**Conclusions** Diabetes was positively associated with edentulism in this sample of more than 175 000 individuals living in LMICs. Providing oral care to individuals with diabetes may potentially lead to a reduction in their risk of edentulism.

## INTRODUCTION

Edentulism is a chronic condition defined as the permanent loss of all natural teeth.<sup>1</sup> The prevalence of edentulism is high in the world, and reaches 12% among older adults living in low and middle-income countries (LMICs).<sup>2</sup> Edentulism is associated with poor self-rated health,<sup>3</sup> psychiatric diseases<sup>4</sup> and low quality of life,<sup>5</sup> and these associations may be more pronounced in LMICs, where access to

## Significance of this study

### What is already known about this subject?

► Studies that have investigated the association between diabetes and edentulism have yielded conflicting findings.

### What are the new findings?

► There was a positive and significant association between diabetes and edentulism in a large sample of adults from low and middle-income countries. Among those with diabetes, having comorbid edentulism was associated with significant declines in health status in the domains of cognition, sleep/energy and perceived stress.

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

► These results highlight the importance of measures (eg, promotion of regular tooth brushing, use of fluoride toothpaste, decreased tobacco consumption) aiming at the prevention of edentulism among people with diabetes.

healthcare services is limited.<sup>6</sup> In this context, research aiming at better understanding the epidemiology and risk factors of edentulism in these countries is urgently needed.

In the last decades, numerous studies have focused on the association between diabetes and edentulism, and these studies have reported conflicting findings.<sup>2 7–11</sup> For example, a cross-sectional study including 2508 participants from the USA showed that diabetes was significantly associated with edentulism after adjusting for several socio-demographic and behavioral factors.<sup>8</sup> In contrast, another study of 35 334 older adults from six LMICs found no significant relationship between diabetes and edentulism.<sup>2</sup> Diabetes may increase risk for edentulism via the direct oral manifestations of diabetes (eg, xerostomia, dental caries and gingival

inflammation)<sup>12</sup> and also by several mediating factors (eg, depression,<sup>13 14</sup> cognitive impairment<sup>15 16</sup> and pain<sup>17 18</sup>). However, it is unclear whether diabetes is associated with edentulism. Given the contradicting results on this association from previous studies, it is possible that the association between diabetes and edentulism is context specific, and more multicountry data are thus needed to identify potential between-country differences on the association between diabetes and edentulism. Finally, to the best of the authors' knowledge, no study has yet compared the health of people with both diabetes and edentulism and the health of those with diabetes only. Diabetes and edentulism may have joint deleterious effects on several health domains such as pain, sleep and perceived stress, and analyzing these effects is necessary to understand the health outcome of this comorbidity.

Therefore, the primary aim of this cross-sectional study was to investigate the association between diabetes and edentulism in a sample of more than 175 800 adults living in 40 LMICs. The secondary goal was to analyze the dual effects of diabetes and edentulism on health status compared with diabetes alone. It was hypothesized that diabetes would be positively and significantly associated with edentulism, and that individuals affected by both diabetes and edentulism would have a worse health status than their counterparts with diabetes only. Given that diabetes is a highly prevalent disorder in LMICs, while its prevalence is increasing drastically due to changes in lifestyles in this setting,<sup>19</sup> assessing the diabetes–edentulism relationship in these countries is a public health priority.

## METHODS

### The survey

The World Health Survey (WHS) was a cross-sectional survey conducted in 70 countries between 2002 and 2004. Single-stage and multistage random cluster samplings were undertaken in 10 and 60 countries, respectively. More details on the WHS are accessible at <https://apps.who.int/healthinfo/systems/surveydata/index.php/catalog/whs/about>. To summarize, the eligible sample included all people aged  $\geq 18$  years who had a valid home address at the time of the survey. One individual per household was selected using Kish tables, and the probability to be selected was equal between all members of the same household. To ensure comparability between countries, questionnaires were translated using standard procedures. Data were collected by trained staff during face-to-face and telephone interviews. The overall response rate in the WHS was 98.5%. Based on the United Nations Statistical Division's population distribution, sampling weights were created to adjust for non-response. Informed consent was obtained from each participant.

Data were publicly available for 69 countries. Among these 69 countries, there was a lack of sampling information for 10 countries, and these countries were therefore excluded. Furthermore, given that this study focused on LMICs, 10 high-income countries were further excluded from the analysis. Eight LMICs with more than 25% of missing data on

edentulism or diabetes were also excluded. Finally, there were no data on diabetes in Turkey, and this country was also omitted from the study. Thus, the final sample consisted of 40 LMICs including 175 814 individuals. Based on the classification of the World Bank at the time of the survey in 2003, there were 18 low-income ( $n=93\,423$ ) and 22 middle-income countries ( $n=82\,391$ ). A list of all countries included in this study with their respective sample size is available in online supplemental table 1. Data were nationally representative for all countries except China, Comoros, India, Ivory Coast, and Russia.

### Edentulism and diabetes

Edentulism was assessed by the question 'Have you lost all your natural teeth?' Participants answering 'yes' were considered to have edentulism. In addition, those who answered 'yes' to the question 'Have you ever been diagnosed with diabetes (high blood sugar)?' were considered to have diabetes.

### Health status

Seven domains were used to assess health status: (a) self-care; (b) pain/discomfort; (c) cognition; (d) interpersonal activities; (e) sleep/energy; (f) affect; and (g) perceived stress. These seven domains, which correspond to common health outcome measures (eg, the Short Form 12,<sup>20</sup> the Health Utilities Index Mark 3<sup>21</sup> and the EuroQol-5D<sup>22</sup>), have been used as proxies of health status in several WHS studies.<sup>23 24</sup> Each of the seven domains included two questions assessing past-month health function. Each item was scored on a five-point scale, and this score ranged from 'none' to 'extreme/cannot do'. One exception was perceived stress, as perceived stress was assessed using two questions from the Perceived Stress Scale with a five-point scale ranging from 'never' to 'very often'. All questions are displayed in online supplemental table 2. A factor analysis with polychoric correlations was further used for each of the seven health status domains to obtain a factor score ranging from 0 to 100, with higher values corresponding to decreased health function.<sup>24 25</sup> There were no data on affect in Morocco, and there were no data on perceived stress in Brazil, Hungary and Zimbabwe.

### Control variables

Previous literature was used to select control variables,<sup>26</sup> and these included age, sex, wealth, highest level of education achieved (ie, no formal education, primary, secondary, and tertiary), current smoking, and heavy alcohol consumption. Country-wise wealth quintiles were obtained using a principal component analysis including between 15 and 20 assets. Finally, participants were considered to be lifetime alcohol abstainers if they answered 'no' to the question 'Have you ever consumed a drink that contains alcohol (such as beer, wine, etc)?' Those replying 'yes' to this question were further asked to quantify the amount of standard drinks of any alcohol beverage consumed on each day of the past week. Women and men reporting a consumption of at least four and five drinks in at least 2 days during the last week were considered to be heavy drinkers.<sup>27 28</sup>

### Statistical analysis

Statistical analyses were performed with Stata V.14.1 (StataCorp, College Station, Texas). Sample characteristics were described using percentages except for age and health status (mean and SD). Multivariable logistic regression analysis was conducted to assess the association between diabetes (exposure) and edentulism (outcome). Analyses were conducted for the overall sample and also for country-income stratified samples (ie, low-income countries and middle-income countries). Next, based on the presence or absence of diabetes and edentulism, a four-category variable was created (ie, no diabetes and no edentulism (n=148 393), edentulism without diabetes (n=9746), diabetes without edentulism (n=3701), and diabetes with edentulism (n=919)) to assess whether diabetes with edentulism is associated with a larger decrement in health status as compared with diabetes alone. Multivariable linear regression analysis was conducted with this four-category variable as the exposure and the health status variables as the outcomes. Furthermore, in order to assess whether the difference between diabetes alone and comorbid diabetes/edentulism is statistically significant, the same analysis was conducted but changing the reference category to diabetes alone. All regression analyses were adjusted for age, sex, wealth, education, smoking, heavy drinking, and country. Adjustment for country was done by including dummy variables in the models as in previous WHS publications.<sup>23 29</sup> Complete case analysis was done. The sample weighting and the complex study design were taken into account in all analyses. Results from the logistic and linear regressions are

presented as ORs and b-coefficients, respectively, with 95% CIs. The level of statistical significance was set at  $p < 0.05$ .

### RESULTS

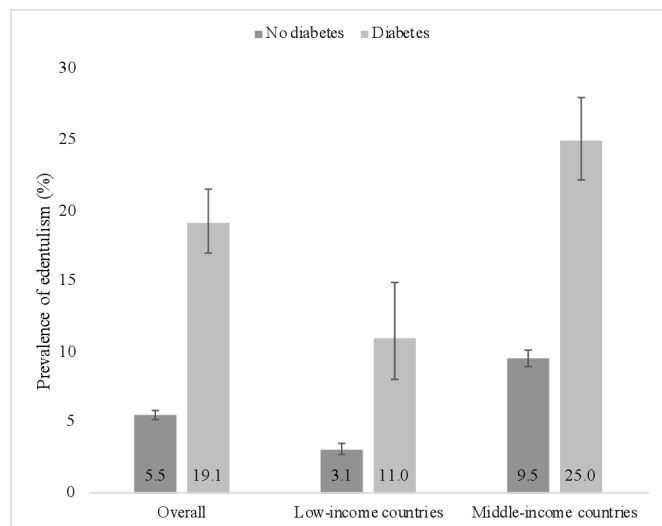
The analytical sample consisted of 175814 individuals with a mean (SD) age of 38.4 (16.0) years and 49.3% were men (table 1). Overall, the prevalence of edentulism and diabetes was 6.0% and 2.9%, respectively. The prevalence of edentulism was higher among those with diabetes than in those without diabetes overall (19.1% vs 5.5%), in low-income countries (11.0% vs 3.1%) and in middle-income countries (25.0% vs 9.5%) (figure 1). The results of the multivariable logistic regression using the overall sample showed that diabetes was associated with 1.40 (95% CI 1.18 to 1.66) times higher odds for edentulism (table 2). The association was stronger in low-income countries than in middle-income countries (OR=1.78, 95% CI 1.21 to 2.62 vs 1.24, 95% CI 1.04 to 1.47). Compared with those without diabetes and edentulism, diabetes alone and comorbid diabetes/edentulism were associated with significantly worse health status in all domains (table 3). As for edentulism alone, this was significantly associated with worse health status in the domains of self-care, pain/discomfort, cognition, and sleep/energy. Among those with diabetes, having comorbid edentulism was associated with significant declines in health status in the domains of cognition, sleep/energy and perceived stress (table 4).

**Table 1** Sample characteristics

Characteristic		Overall	Low-income countries	Middle-income countries
Edentulism	Yes	6.0	3.4	10.3
Diabetes	Yes	2.9	2.0	4.5
Age (years)	Mean (SD)	38.4 (16.0)	36.8 (15.3)	41.1 (16.8)
Sex	Male	49.3	50.6	47.2
Education	No formal	28.1	40.2	8.0
	Primary	32.2	33.1	30.5
	Secondary	29.9	20.6	45.3
	Tertiary	9.9	6.1	16.2
Smoking	Yes	26.7	26.9	26.5
Heavy drinking	Yes	4.9	2.2	9.2
Self-care	Mean (SD)	11.0 (23.4)	12.1 (24.2)	9.8 (22.4)
Pain/discomfort	Mean (SD)	26.3 (27.0)	26.0 (27.2)	26.6 (26.7)
Cognition	Mean (SD)	20.3 (26.0)	20.1 (25.7)	20.6 (26.2)
Interpersonal activities	Mean (SD)	13.9 (24.0)	13.5 (24.0)	14.4 (24.1)
Sleep/energy	Mean (SD)	22.1 (26.1)	20.6 (26.0)	23.7 (26.2)
Affect	Mean (SD)	25.4 (27.7)	24.1 (28.0)	27.0 (27.3)
Perceived stress	Mean (SD)	34.5 (27.2)	36.8 (28.5)	31.9 (25.4)

Data are % unless otherwise stated.

Health status (ie, self-care, pain/discomfort, cognition, interpersonal activities, sleep/energy, affect, and perceived stress) ranged from 0 to 100 with higher scores corresponding to worse health status.



**Figure 1** Prevalence of edentulism by presence or absence of diabetes. Bars denote 95% CI.

## DISCUSSION

### Main findings

This study, including around 175 800 people from 40 LMICs, showed that the prevalence of diabetes and edentulism was 2.9% and 6.0%, respectively. In addition, there

was a positive and significant association between diabetes and edentulism in the overall sample, low-income countries, and middle-income countries. Finally, participants with both diabetes and edentulism had worse health status in the domains of cognition, sleep/energy and perceived stress than those with diabetes only. To the best of our knowledge, this is one of the largest and one of the first multicountry studies conducted in LMICs investigating the diabetes–edentulism relationship.

### Interpretation of the findings

One major finding of this study is that diabetes was significantly associated with edentulism. Interestingly, the association between diabetes and edentulism has been at the center of an important scientific debate in the past years.<sup>2,7–11</sup> For example, a cross-sectional study of 15 965 Hispanic/Latino adults from the USA revealed a positive and significant association between uncontrolled diabetes (ie, diabetes with glycosylated hemoglobin (HbA1c) higher or equal to 7%), and having at least nine missing teeth or edentulism.<sup>7</sup> It was observed in another study, including 17 167 community-dwelling middle-aged and older adults from China, that diabetes was not significantly associated with edentulism after adjusting for a wide range of variables (eg, gender, place of residence and income level).<sup>10</sup> Finally, a study of Indonesian cross-sectional data (n=7994 older adults) found a negative relationship between diabetes and edentulism in men.<sup>9</sup>

**Table 2** Association between diabetes (and covariates) and edentulism (outcome) estimated by multivariable logistic regression

Characteristic		Overall		Low-income countries		Middle-income countries	
		OR	95% CI	OR	95% CI	OR	95% CI
Diabetes	No	Reference					
	Yes	1.40***	1.18 to 1.66	1.78**	1.21 to 2.62	1.24*	1.04 to 1.47
Age (years)	Per 1-year increase	1.07***	1.07 to 1.08	1.07***	1.06 to 1.08	1.07***	1.07 to 1.08
Sex	Female	Reference					
	Male	0.71***	0.64 to 0.78	0.81*	0.68 to 0.96	0.63***	0.56 to 0.72
Wealth	Poorest	Reference					
	Poorer	1.10	0.97 to 1.25	1.28	0.99 to 1.66	1.04	0.90 to 1.20
	Middle	0.95	0.82 to 1.11	1.04	0.76 to 1.42	0.95	0.80 to 1.13
	Richer	1.00	0.86 to 1.16	1.00	0.77 to 1.32	1.04	0.87 to 1.25
	Richest	0.94	0.79 to 1.12	1.21	0.88 to 1.64	0.82	0.66 to 1.01
Education	No formal	Reference					
	Primary	1.01	0.88 to 1.16	0.99	0.80 to 1.23	0.85	0.71 to 1.01
	Secondary	0.75**	0.63 to 0.89	1.00	0.77 to 1.31	0.56***	0.45 to 0.70
	Tertiary	0.50***	0.40 to 0.64	0.71	0.43 to 1.15	0.38***	0.29 to 0.50
Smoking	No	Reference					
	Yes	1.20**	1.07 to 1.34	1.22*	1.00 to 1.49	1.21**	1.06 to 1.38
Heavy drinking	No	Reference					
	Yes	0.85	0.66 to 1.10	0.82	0.55 to 1.21	0.90	0.67 to 1.21

Models are mutually adjusted for all variables displayed in the table and country.

\*P<0.05; \*\*p<0.01; \*\*\*p<0.001.

**Table 3** Association between edentulism/diabetes groups and health status (outcome) estimated by multivariable linear regression

Health status (outcome)	Edentulism (+)	Edentulism (-)	Edentulism (+)
	Diabetes (-)	Diabetes (+)	Diabetes (+)
	B-coefficient (95% CI)	B-coefficient (95% CI)	B-coefficient (95% CI)
Self-care	2.90*** (1.69 to 4.10)	5.43*** (3.36 to 7.50)	8.93*** (4.85 to 13.01)
Pain/discomfort	1.98** (0.72 to 3.24)	9.28*** (7.55 to 11.01)	8.04*** (4.46 to 11.61)
Cognition	3.48*** (2.18 to 4.77)	4.38*** (2.52 to 6.23)	12.01*** (8.52 to 15.50)
Interpersonal activities	0.84 (-0.42 to 2.10)	4.42*** (2.55 to 6.28)	5.67** (1.72 to 9.63)
Sleep/energy	1.75** (0.50 to 3.00)	7.72*** (5.61 to 9.82)	11.76*** (8.40 to 15.12)
Affect†	0.06 (-1.29 to 1.40)	8.46*** (6.32 to 10.60)	7.05*** (3.39 to 10.71)
Perceived stress‡	1.23 (-0.13 to 2.60)	3.11** (1.25 to 4.97)	8.75*** (3.91 to 13.58)

Symbol '+' denotes presence; symbol '-' denotes absence. Reference category is edentulism (-), diabetes (-).

Health status was the outcome and scores ranged from 0 to 100 with higher scores corresponding to worse health status.

Models are adjusted for age, sex, wealth, education, smoking, heavy drinking, and country.

\*\*P<0.01; \*\*\*p<0.001.

†Morocco is not included due to lack of data.

‡Brazil, Hungary, and Zimbabwe are not included due to lack of data.

Several factors may explain the discrepancy between the findings of these various studies. These pieces of research were conducted in different countries, and as there are substantial differences in the management of diabetes and oral health between countries,<sup>30 31</sup> one may hypothesize that the diabetes–edentulism relationship is context specific. Moreover, the definition of diabetes and edentulism varied between these studies, which could partly explain the differential results. For example, diabetes was self-reported<sup>2</sup> or defined using biological parameters (eg, HbA1c and fasting glucose),<sup>7</sup> while edentulism was assessed based on self-report<sup>10</sup> or oral examination.<sup>8</sup> Lastly, it should also be noted that regression models were not adjusted for the same set of variables, potentially resulting in different effect sizes.

**Table 4** Association between edentulism and health status (outcome) among those with diabetes estimated by multivariable linear regression

Health status	B-coefficient	95% CI
Self-care	3.50	-1.07 to 8.07
Pain/discomfort	-1.24	-5.17 to 2.68
Cognition	7.63***	3.62 to 11.65
Interpersonal activities	1.26	-3.06 to 5.58
Sleep/energy	4.04*	0.10 to 7.98
Affect†	-1.41	-5.63 to 2.82
Perceived stress‡	5.64*	0.59 to 10.69

Health status was the outcome and scores ranged from 0 to 100 with higher scores corresponding to worse health status. Models are adjusted for age, sex, wealth, education, smoking, heavy drinking, and country.

\*P<0.05; \*\*\*p<0.001.

†Morocco is not included due to lack of data.

‡Brazil, Hungary, and Zimbabwe are not included due to lack of data.

The present study, including a sample of 40 countries, adds to the literature by showing that, overall, there is an association between diabetes and edentulism in LMICs. Although the design of the study was cross-sectional, several hypotheses may be elaborated to explain the diabetes–edentulism relationship. First, diabetes is frequently associated with oral symptoms,<sup>12</sup> and these manifestations may favor the occurrence of edentulism in people with diabetes. One systematic review of 15 studies revealed that the prevalence of xerostomia was higher in people with diabetes (12.5%–53.5%) than in their counterparts without diabetes (0%–30%).<sup>32</sup> Another study, including 65 295 participants from Spain, further found a significant association between diabetes and periodontal disease.<sup>33</sup> In turn, both xerostomia<sup>34</sup> and periodontal disease<sup>35</sup> are risk factors for the occurrence of tooth loss and edentulism. Second, the effects of diabetes on edentulism may be mediated by several factors. Indeed, diabetes is a well-known risk factor for depression,<sup>14</sup> and depression may lead to edentulism via poor oral health, changes in the salivary immunity and changes in the oral flora.<sup>13</sup> In addition, there is some research suggesting that cognitive impairment is relatively frequent in people with diabetes,<sup>16</sup> and cognitive impairment is associated with poor oral care and ultimately with edentulism.<sup>15</sup> Finally, neuropathic pain is a frequent complication of diabetes,<sup>17</sup> and pain has been identified as a predictor of edentulism.<sup>18</sup>

Another interesting result of the present study is that participants with both diabetes and edentulism had a lower health status than their counterparts with diabetes only. This critical finding underlines the cumulative deleterious effects of these two chronic conditions on health. A substantial body of research suggests that the presence of periodontal diseases is a risk factor for insufficient glycaemic control in patients affected by diabetes.<sup>11 36–39</sup> A

longitudinal study, including 105 participants with non-insulin-dependent diabetes mellitus from the USA, found a significant association between severe periodontitis at baseline and poor glycemic control at follow-up.<sup>38</sup> Meanwhile, periodontal diseases favor the occurrence of tooth loss and ultimately edentulism.<sup>40</sup> Furthermore, a systematic review and meta-analysis of 25 studies (n=976 individuals) indicated that periodontal treatment might be associated with a significant decrease in HbA1c levels.<sup>36</sup> Given that poor oral health leads to insufficient glycemic control, patients with diabetes with poor oral health may be at a particular risk for diabetes complications, and indirectly for poor overall health. It should also be noted that edentulism may have deleterious effects on specific aspects of health (eg, cognition, sleep and perceived stress) that are independent of diabetes, highlighting the fact that the higher risk of poor health status in adults with both diabetes and edentulism compared with their counterparts with diabetes only is likely to be a multifactorial phenomenon.

### Clinical implications and directions for future research

Based on the findings of this study, measures should be taken to reduce the higher risk of edentulism in adults with diabetes, and these measures may include the promotion of regular tooth brushing,<sup>41</sup> use of fluoride toothpaste,<sup>42</sup> and decreased tobacco consumption.<sup>43</sup> The prevention of oral disorders is of utmost importance in LMICs where access to dental care is limited for financial and geographical reasons.<sup>44</sup> In terms of future research, more data of longitudinal nature are needed to better characterize the causality of the association between diabetes and edentulism, and to better identify factors playing a potential mediating role in this relationship. Besides, future studies should also investigate the reverse association (ie, edentulism leading to insufficient glycemic control and diabetes) and the underlying mechanisms (eg, poor nutrition<sup>45</sup>).

### Strengths and limitations

Major strengths of this study are the large sample size and the use of multicountry data. However, this study also has several limitations, and the findings should also be interpreted with some caution. First, the definition of diabetes and edentulism relied on yes-no questions, and this may have biased the results of this study. It is possible that particularly in resource-limited settings, there is an underdiagnosis of diabetes, while those with a diabetes diagnosis may be those with severe diabetes. Second, there were no data on the severity of diabetes, and it was therefore not possible to analyze the impact of the severity of diabetes on the risk of edentulism. Third, some confounding factors (eg, frequency of tooth brushing<sup>46 47</sup>) were not included in the regression analysis, and this may have biased the study findings. Fourth, this study only included people with a valid home address, and as poor oral health may be higher in homeless or institutionalized individuals,<sup>48</sup> the prevalence of edentulism may have been underestimated in this study.

Fifth, the data were collected in 2002–2004, and thus it is possible that the results do not reflect the current situation as the profiles of diabetes and edentulism could have changed. Sixth, this was a cross-sectional study, and it was not possible to determine the causality or the temporality of the association between diabetes and edentulism. Thus, these results should be considered preliminary, and future prospective studies are warranted on this topic.

### CONCLUSIONS

This study conducted in LMICs found a positive and significant relationship between diabetes and edentulism. In addition, individuals with both diabetes and edentulism had a worse health status than those with diabetes only. In this context, there is an urgent need to promote oral health in people with diabetes. Finally, more research is warranted to corroborate or invalidate the present findings, while future longitudinal studies should identify the mechanisms involved in the association between diabetes and edentulism.

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