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Associated factors of oral frailty in older adults with long-term T2DM duration of more than 10 years

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Abstract

Objective To identify the factors that affect oral frailty in older adults with type 2 diabetes mellitus (T2DM) with long-term disease duration of more than 10 years.

Methods This cross-sectional study was conducted at a National Metabolic Center in China from October 2023 to March 2024. Participants with T2DM (aged ≥ 60 years and a disease duration > 10 years) underwent comprehensive dental examinations to assess functional natural teeth (FNT) counts and oral restoration behaviors. Oral frailty and cognitive function were assessed using the Oral Frailty Index-8 (OFI-8) and the Clock Drawing Test (CDT), respectively. Demographic and clinical data were extracted from the hospital information system. Univariate analysis and hierarchical multiple linear regressions were performed to identify associated factors of oral frailty.

Results Among 211 participants (mean age 71.22 ± 6.35 years, mean diabetes duration 20.95 ± 7.34 years), the mean OFI-8 score was 5.08 ± 2.29, with 74.4% scoring ≥ 4 (indicating oral frailty). The final regression model was statistically significant ($F = 19.101$, $P < 0.001$). In the regression model, a lower number of FNTs was significantly associated with higher oral frailty scores ($\beta = -0.263$, $P < 0.001$), whereas different oral restoration behaviors vary in the effect on oral frailty, fasting blood glucose (FBG) ($\beta = 0.131$, $P = 0.014$) and cognitive impairment ($\beta = 0.255$, $P < 0.001$) were positively associated with OFI-8 scores.

Conclusions The study found that older adults with T2DM and a disease duration exceeding 10 years had a higher likelihood of exhibiting oral frailty. Individuals with fewer FNTs and those exhibiting cognitive impairment are the potential intervention targets to be concerned. Strict glycemic control and timely oral restoration are recommended to reduce oral frailty incidence in this population.

Clinical trial number Not applicable.

Keywords Older adults, Type 2 diabetes mellitus (T2DM), Oral frailty, Cognitive impairment

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Background

Globally, more than one in 10 adults are suffering from diabetes. People living with diabetes are at risk of developing several debilitating and life-threatening complications [1]. Emerging evidence highlights the critical interplay between diabetes and oral health deterioration. Compared to non-diabetics, diabetics exhibit significantly poorer oral health outcomes [2], mainly including periodontitis, dental caries and pulp necrosis [3]. Notably, prolonged diabetes duration exacerbates oral disease severity, suggesting a temporal relationship between metabolic dysregulation and oral problems [4]. Given the established link between oral health and overall health and well-being [5], addressing this issue is particularly urgent in older patients with a prolonged disease duration.

Poor oral health is commonly referred to as 'oral frailty', according to the Japan Dental Association, oral frailty a series of phenomena and processes that lead to changes in various oral conditions associated with aging, and accompanied by decreased interest in oral health, reduced physical and mental reserve capacity [6]. It is associated with mortality independent of physical and psychological frailty in older people [7]. Current research on the determinants of oral frailty mainly focuses on the number of teeth or impaired oral motor skills [8, 9]. While prosthetic interventions are increasingly adopted to address tooth loss [10–12], their differential impacts on oral frailty remain unexplored. Specifically, whether complete dental restoration confers protective effects compared to partial or suboptimal prosthetics requires rigorous investigation.

Suboptimal glycemic control in diabetes accelerates systemic complications through chronic hyperglycemia [13]. Both glycated hemoglobin (HbA1c) and fasting blood glucose (FBG) levels are crucial indicators for evaluating the glycemic control of diabetic individuals and play important roles in the daily management of diabetes [14]. Mechanistically, chronic inflammation plays a role in both oral disease and hyperglycemia [15]. High levels of glucose in diabetic individuals increase inflammatory events in periodontal tissue and worsen potential oral complications [16, 17]. Consequently, it is essential to clarify whether high HbA1c or FBG levels have adverse effects on the oral frailty of older people with T2DM with long-term disease duration.

Cognitive impairment, a prevalent comorbidity in T2DM [18], may compound oral health deterioration. Evidence suggests bidirectional relationships between oral health status and cognitive dysfunction, with individuals exhibiting poor cognitive function often being accompanied by poor oral health status [19]. It was also suggested that variations in cognitive impairment in patients cause behavioral changes that may affect the ability to provide and maintain dental care [20]. Hence, cognitive impairment may also be potentially associated with oral frailty in older patients with T2DM.

Despite growing interest in oral frailty, existing studies primarily focused on community-dwelling older adults, with few investigations addressing patients with specific medical conditions, such as diabetes. Diabetes mellitus poses a high-risk for oral frailty, making it crucial to investigate the potential influencing factors in older patients with long-term disease duration. This study is specifically based on the following hypotheses (in addition to the number of teeth):

Restoration practices and oral frailty

It is hypothesised that different restoration practices have different effects on oral frailty. Specifically, it is postulated that complete dental restoration was associated with lower oral frailty scores compared to partial or no restoration.

Glycemic control and oral frailty

It is hypothesised that poorer glycemic control, as indicated by elevated HbA1c and FBG levels, is associated with an increased risk of oral frailty, whereas optimal glycemic control may correlate with better oral health and reduced oral frailty.

Cognitive impairment and oral frailty

The study further hypothesises that greater cognitive impairment, as measured by standardized cognitive assessment tools, is associated with worse oral frailty outcomes.

This study is among the first to integrate restoration patterns, glycemic control, and cognitive function as independent correlates of oral frailty in older adults with long-standing T2DM.

Materials and methods

Design and participants

This cross-sectional study was conducted at the endocrinology department of a National Metabolic Center in China from October 2023 to March 2024 through a convenience sampling method. Researchers approached all eligible hospitalized patients during the study period. Inclusion criteria were patients diagnosed with T2DM for at least 10 years, aged 60 years or older (as defined in Chinese guidelines [21], suitable for China's national conditions), and volunteered to participate in the study. Exclusion criteria were as follows: with oral trauma or oral malignancy; diagnosed with cognitive disorders, such as Alzheimer's disease; with severe acute complications, such as acute infection and diabetic ketoacidosis; with severe systemic comorbidities such as advanced cancer, end-stage renal disease.

The sample size was calculated using PASS (Power Analysis and Sample Size Software, version 2021). A minimum of 134 participants was needed for a multiple linear regression model with 13 variables, alpha error of 5%, power of 80%, and a medium effect size of 0.15.

This study was approved by the Ethics Committee of Nanjing Medical University (NMU2023-562) and conducted in accordance with the Declaration of Helsinki. All patients enrolled in this study signed the informed consent form.

Data collection

Demographic and clinical data

A trained medical staff consulted their medical records and extracted the demographic data (age, sex, body mass index [BMI; kg/m^2], smoking status [never, former, and current], drinking status [never, former, and current], and living status [living alone, living with spouse, and living with a child]) and clinical data (disease duration, HbA1c, FBG, and long-term medications) of the patients at this time of hospitalization. Polypharmacy was defined as taking five or more long-term medications per day [22]. After data collection, all the relevant data were double-checked with the patient to ensure that all data were correct if necessary.

Dental examination

All participants underwent a clinical dental examination by two trained and experienced dentists. The number of their functional natural teeth (FNT) and the use of dentures or implants were recorded in detail. FNT was defined as a tooth with the ability to chew, in other words, it was healthy and functional [23]. None of the examinations included third molars. Oral restoration behaviors were conducted using a standardized 5-item checklist based on the oral examination and consultation, mainly according to the objective restoration of missing functional teeth and the subjective satisfaction of patients [24]. The specific 5-item checklist is as follows: 1-Complete restoration, defined as the replacement of all missing teeth with no reported dissatisfaction; 2-Incomplete restoration, defined as partial missing FNTs have been repaired with no reported dissatisfaction; 3-Abnormal restoration, defined as subjective dissatisfaction with the restoration; 4-Completely unrestored, defined as with FNTs loss, but had either never received restoration treatment or had received restoration treatment but had not utilized the dentures for more than one month. 5-No need for restoration, defined as no loss of FNTs. The inter-examiner reliability in the assessment of FNTs and oral restoration behaviors was high, with a Cohen's kappa coefficient of 1.00.

Oral frailty index-8 (OFI-8)

All participants were interviewed by two fixed specialist diabetes nurses with OFI-8 to assess their oral frailty. The OFI-8 scale was developed by Tanaka T et al. [25] and translated and validated by Chinese scholar Chen et al. with a Cronbach's α coefficient of 0.949 [26]. The eight items of the questionnaire are: (1) Do you have difficulty eating hard foods compared to six months ago (Yes: 2 points)? (2) Have you recently choked on your tea or soup (Yes: 2 points)? (3) Do you have dentures (Yes: 2 points)? (4) Do you often have a dry mouth (Yes: 1 point)? (5) Do you go out less frequently than last year (Yes: 1 point)? (6) Can you eat hard foods like squid jerky or pickled radish (No: 1 point)? (7) How many times do you brush your teeth in a day (< 3 times/day: 1 point)? and (8) Do you visit a dental clinic at least annually (No: 1 point)? The scoring ranges from 0 to 11 points, with a score of ≥ 4 considered to have oral frailty [22]. In this study population, Cronbach'α coefficient of OFI-8 was 0.837.

The clock drawing test (CDT)

The CDT is a quick to administer and score tool designed to identify and monitor changes in cognitive function among older adults [27], as developed by Watson et al. [28]. The test procedure in this study was consistent across all participants. Each participant was provided with a piece of 5.5 cm×7.5 cm blank paper and a pencil and was informed to follow the instructions: 'Draw a round clock. Put in all the numerals and set the time 10:10'. A 4-point scoring method was used. The scoring protocol for CDT was as follows: (1) Draw a closed circle, 1 point; (2) The clock dial includes the numbers 1 ~ 12, 1 point; (3) Place the numbers 1 ~ 12 correctly on the dial, 1 point; (4) Mark 10:10 correctly with the pointer, 1 point [29]. Two trained medical staff scored each test independently, and a third investigator scored the test in the event of a disagreement to determine the final score. A score of 0–2 points indicated the presence of cognitive impairment [30].

Statistical analysis

All data were analyzed using SPSS (version 27.0; IBM Corp., Armonk, NY, USA). Continuous variables, including age, disease duration, BMI, number of FNTs, HbA1c and FBG were reported as mean ± SD. Categorical variables like sex, polypharmacy, smoking status, and drinking status were summarized as numbers and percentages. In this study, the dependent variable was OFI-8 scores, and the remaining variables were independent variables. Univariate analysis was realized by independent sample *t*-test, pearson correlation analysis, one-way ANOVA, and the Kruskal-Wallis test.

Given our research hypothesis and existing evidence demonstrating the relationship between diabetes

duration or glycemic control on cognitive impairment [31], hierarchical multiple linear regression analysis was used to identify factors associated with oral frailty in this study. This analytical approach enables the hypothesis-driven variable entry and the evaluation of incremental predictive contributions from distinct variable clusters (restoration practices, glycemic control, and cognitive impairment) through sequential model construction. Furthermore, it allows us to assess the unique variance explained by each group of variables while controlling for the effects of previously entered variables. Statistically significant variables in univariate analysis were included in the hierarchical multiple linear regression step by step and a P value below 0.05 was considered statistically significant.

Table 1 Sociodemographic and clinical characteristics ($n = 211$)

Variable	Number	Percentage (%)	Mean ± SD
Age, years			71.22 ± 6.35
Sex			
Male	110	52.13	
Female	101	47.87	
Disease duration, years			20.95 ± 7.34
BMI, kg/m^2			24.18 ± 3.25
Polypharmacy			
Yes	102	48.34	
No	109	51.66	
Smoking status			
Never	120	56.87	
Former	58	27.49	
Current	33	15.64	
Drinking status			
Never	122	57.82	
Former	54	25.59	
Current	35	16.59	
Living status			
Living alone	24	11.37	
Living with spouse	135	63.98	
Living with a child	52	24.65	
Number of FNTs			20.13 ± 8.79
Oral restoration behaviors			
Complete restoration	54	25.59	
Incomplete restoration	48	22.75	
Abnormal restoration	4	1.90	
Completely unrestored	68	32.23	
No need for restoration	37	17.53	
HbA1c, %			8.64 ± 1.57
FBG, mmol/L			7.92 ± 2.19
Cognitive impairment			
Yes	84	39.81	
No	127	60.19	

BMI: body mass index; FNTs: functional natural teeth; HbA1c: glycated hemoglobin, FBG: fasting blood glucose

Results

Sociodemographic and clinical characteristics of the participants

A total of 220 eligible patients were reached during the study period of whom 1 had a history of tooth loss due to trauma and 8 refused to participate in the study. Finally, 211 older T2DM patients aged 71.2 ± 6.4 years with a diabetes duration of 20.95 ± 7.34 years were included in this study, with a response rate of 95.9%.

The average number of FNTs of the participants was 20.13 ± 8.79, and 174 individuals (82.46%) had tooth loss. Among them, 84 (39.81%) exhibited signs of cognitive impairment. Regarding oral frailty, the average score of OFI-8 was 5.08 ± 2.29 points. Among all the participants, 157 (74.41%) scored more than 4 points, indicating the presence of oral frailty. Details of the sociodemographic and clinical characteristics are detailed in Table 1.

Univariate analysis of factors influencing oral frailty

Pearson correlation analysis showed that the OFI-8 scores were positively correlated with age ($r = 0.266$, $P < 0.001$), HbA1c ($r = 0.166$, $P = 0.016$) and FBG ($r = 0.154$, $P = 0.026$) and negatively correlated with the number of FNTs (r = -0.509, $P < 0.001$). The Kruskal-Wallis test showed that the OFI-8 scores differed between patients with different oral restoration behaviors ($H = 55.485$, $P < 0.001$). Independent sample t-test showed that patients with cognitive impairment had higher OFI-8 scores (6.23 ± 2.18 vs. 4.32 ± 2.03, $t = 6.455$, $P < 0.001$).

There were no statistical correlation between disease duration ($r = 0.021$, $P = 0.759$), BMI ($r = 0.038$, $P = 0.578$) and OFI-8 scores. There were no difference in OFI-8 scores among patients with different sex (t = -0.684, $P = 0.495$), with polypharmacy or not (t = -0.088, $P = 0.930$), different smoking status ($F = 0.331$, $P = 0.719$), drinking status ($F = 0.002$, $P = 0.998$), or living status ($F = 1.026$, $P = 0.360$).

Hierarchical multiple regression of oral frailty

As OFI-8 scores are approximately normally distributed, a hierarchical multiple linear regression analysis was conducted to identify which key variables assessed in the study were significant factors related to oral frailty (Table 2).

In the first step, the number of FNTs ($\beta = 0.471$, $P < 0.001$) entered into the model ($F = 38.137$, $P < 0.001$) and explained 26% of the variance in OFI-8 scores. In the second step, patients with incomplete restoration ($\beta = 0.156$, $P = 0.025$), abnormal restoration ($\beta = 0.187$, $P = 0.001$), and participants who were completely unrestored ($\beta = 0.037$, $P = 0.048$) exhibited higher OFI-8 scores compared to individuals with complete restoration, whereas patients with no need for restoration scored lower points of oral frailty (β = -0.223, $P = 0.005$).

Table 2 Hierarchical multiple linear regression of variables on oral frailty ($n=211$)

Steps and predictor variables	Model 1		Model 2		Model 3		Model 4	
	β	*P*	β	*P*	β	*P*	β	*P*
Step 1								
Age	0.115	0.069	0.114	0.056	0.091	0.122	0.038	0.505
Number of FNT	-0.471	< 0.001	-0.337	< 0.001	-0.317	< 0.001	-0.263	< 0.001
Step 2								
Complete restoration			Ref.		Ref.		Ref.	
Incomplete restoration			0.156	0.025	0.162	0.018	0.138	0.035
Abnormal restoration			0.187	0.001	0.197	0.001	0.173	0.002
Completely unrestored			0.037	0.048	0.010	0.089	-0.023	0.754
No need for restoration			-0.223	0.005	-0.220	0.005	-0.238	0.002
Step 3								
FBG					0.138	0.014	0.131	0.014
HbA1c					0.087	0.122	0.066	0.216
Step 4								
Cognitive impairment							0.255	< 0.001
R^2	0.269		0.379		0.406		0.462	
ΔR^2	0.269		0.110		0.026		0.057	
F/P	38.137/<0.001		20.683/<0.001		17.154/<0.001		19.101/<0.001	

OFI-8: oral Frailty Index-8; FNTs: functional natural teeth; FBG: fasting blood glucose; HbA1c: glycated hemoglobin

β: standardized regression coefficient; R^2: coefficient of determination; ΔR^2: coefficient of determination change

In the third step, FBG ($\beta=0.138$, $P=0.014$) entered into the model, whereas no statistically significant relationship was observed between HbA1c ($\beta=0.087$, $P=0.122$) and oral frailty. In the fourth step, cognitive impairment ($\beta=0.255$, $P<0.001$) also entered into the model and explained an additional 5.7% of the variation in OFI-8 scores.

In the final model, the number of FNTs was negatively associated with oral frailty, and different oral restoration behaviors varied in the effect on oral frailty. FBG and cognitive impairment were positively associated with oral frailty. Each block of variables introduced improved the model's variance. The final model explained 46.2% of the variance in OFI-8 scores ($F=19.101$ $P<0.001$), which indicated high fit goodness.

Discussion

In our study, oral frailty was common among participants with T2DM and a long-term disease duration of more than 10 years. Four significant predictors of oral frailty were identified: fewer FNTs, suboptimal dental restoration status, elevated FBG levels, and coexisting cognitive impairment.

According to a recent meta-analysis, the pooled prevalence of oral frailty among older adults when using the OFI-8 scale was 44.1% [32]. In our study population, however, the detection rate of oral frailty was notably higher at 74.41% (157/211) compared to findings from other studies. This discrepancy may reflect population-specific characteristics, as corroborated by Hessain et al. [33] who reported that individuals with T2DM had an increased risk of reporting poor oral health compared to people without diabetes [33]. We speculated that this is related to the fact that diabetes can exacerbate several oral problems, such as periodontitis, particularly when glycemic levels are not well-controlled [3, 17]. Furthermore, individuals with diabetes were reported to have limited oral health knowledge and poor oral health behaviors [34]. Consequently, early screening and targeted interventions for oral frailty among older patients with T2DM are essential.

This study confirms that the number of FNTs is a significant predictor of oral frailty, which is in accordance with earlier findings [9]. A key novel finding of this study is that denture restoration can help alleviate oral frailty, and the effects of different restoration practices on oral frailty is different. Individuals with no need for restoration exhibited the lowest levels of oral frailty. Among patients with tooth loss, those with incomplete or abnormal restoration demonstrated significantly higher levels of oral frailty than those with complete restoration. It has been reported that salivary flow and masticatory function are ensured by using appropriate dentures in older adults [35]. There was also evidence that different dental prosthetic treatments had positive effects on individuals' oral health-related quality of life [36]. Therefore, in clinical practice, medical personnel should encourage patients with missing teeth to undergo complete oral restoration as early as possible.

Another finding from the study was that FBG levels in people with T2DM were also a predictor of oral frailty. Previous studies have shown that insulin resistance is the main mechanism of hyperglycemia and diabetes, and inflammation is closely related to endothelial dysfunction

and insulin resistance [37, 38]. Insulin resistance and higher blood sugar may lead to increased production of pro-inflammatory cytokines, which promote the destruction of periodontal tissue and reduce the clearance of oral pathogens [3], ultimately leading to poor oral health and exacerbating oral frailty. It was reported that tooth loss was approximately two times higher in patients with hyperglycemia than in individuals without hyperglycemia in the US population [39]. Meanwhile, it was also found that poor oral hygiene was associated with increased FBG levels in non-diabetic subjects in Korea [40], which was similar to the findings in our study population. Consequently, this study adds new evidence supporting the importance of monitoring and maintaining optimal FBG levels for patients with T2DM, as it is crucial for them to preserve oral health and reduce oral frailty.

Notably, our hierarchical regression model failed to establish HbA1c as an independent predictor, potentially attributable to the unique glycemic profile of elderly T2DM patients characterized by frequent hypoglycemic episodes that may lower HbA1c values [41], especially those with long disease duration. New blood glucose assessment indicators including glycemic variability and time in range are worthy of attention in the future [42].

This study also identified cognitive impairment as a predictor of oral frailty within the study population. It was found that the oral health status of older hospitalized patients over 60 years with cognitive frailty was worse than that of patients with non-cognitive frailty [43]. The relationship between cognitive function and oral health is characterized by worsening oral hygiene owing to difficulties in voluntary oral cleaning behavior following cognitive decline [44]. However, due to the cross-sectional design of this study, there is a possibility that this association is bidirectional. As there was also evidence suggesting that oral dysfunction is not only a result of cognitive impairment in older people, but could also be a causative factor for the onset of cognitive impairment [45]. Therefore, longitudinal studies are needed to further explore the interrelationships between the two variables.

There are some limitations and prospects in this study. Firstly, considering that fixed dental implants and removable denture wearers may have different impacts on oral health [46], we will further expand the sample size and conduct relevant comparative studies between these different groups in the future. Secondly, with advances in treatment techniques, subgroups of abnormal oral restoration may be underrepresented in the dataset. Thirdly, existing literature still lacks widely recognized evaluation parameters for the classification of oral restoration behaviors, and more studies are needed in the future. Lastly, this study was designed as a cross-sectional study via convenience sampling method, and it may limit the generalizability of the findings to the broader diabetic population due to potential sampling bias.

Conclusions

The findings of this study add new evidence supporting the high incidence of oral frailty in older adults with long-term T2DM duration of more than 10 years. Individuals with fewer FNTs and those exhibiting cognitive impairment should be the key population to be assessed and intervened. The strict control of FBG levels plays an important role in promoting optimal oral health. In addition, patients with tooth loss should be encouraged to pursue complete oral restoration to reduce the possibility of oral frailty. All these findings support the integration of oral frailty screening into routine geriatric assessments to enable early interventions.

Abbreviations

T2DM	Type 2 diabetes mellitus
FNT	Functional natural teeth
OFI-8	Oral Frailty Index-8
CDT	Clock Drawing Test
HbA1c	Glycated hemoglobin
FBG	Fasting blood glucose

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None.

Author contributions

Jian Yu: Conceptualization, Investigation, Methodology, Writing - original draft. Anna Ye: Investigation, Writing - original draft; Yang Fei: Data analysis. Dandan Wang: Methodology. Yu Zhang: Data analysis. Xianwen Li: Conceptualization, Supervision, Writing - review & editing.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Nanjing Medical University (NMU2023-562). All patients enrolled in this study signed the informed consent form.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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