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Influencing factors of oral frailty in elderly patients with type 2 diabetes in China: a cross-sectional study based on the integral model of frailty

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Abstract

Objectives This study aimed to investigate the current status and influencing factors of oral frailty in elderly patients with type 2 diabetes mellitus to inform the development of oral management programs in this population.

Methods A total of 431 elderly patients with type 2 diabetes mellitus who visited two tertiary public hospitals in Nanchong City from March 2024 to October 2024 were enrolled in this study. The General Information Questionnaire, Oral Frailty Index-8 (OFI-8), Oral Health Assessment Tool (OHAT), Eating Assessment Questionnaire Tool-10 (EAT-10), Perceived Social Support Scale (PSSS), Geriatric Depression Scale (GDS-5), and Geriatric Self Efficacy Scale for Oral Health Scale (GSEOH) were used to investigate and assess the factors related to oral frailty.

Results The prevalence of oral frailty in elderly patients with type 2 diabetes was 32.95% (142/431). Multivariate logistic regression analysis revealed that advanced age(OR = 1.098, 95% CI: 1.054 ~ 1.146), glycated hemoglobin (HbA1c) ≥ 7%(OR = 3.745, 95% CI: 1.203–12.647), dysphagia(OR = 8.401, 95% CI: 2.276–43.846), and poor oral health status (OR = 2.213, 95% CI: 1.134–4.394) were risk factors of oral frailty, and the number of remaining teeth ≥ 20(OR = 0.105, 95% CI: 0.046–0.217) and high oral health-related self-efficacy(OR = 0.934, 95% CI: 0.898–0.970) were protective factors against oral frailty ($P < 0.05$).

Conclusions The Integral Model of Frailty provides a new theoretical framework for the study of oral frailty. The main OF infuencing factors in the elderly patients with type 2 diabetes mellitus are age, HbA1c, dysphagia, poor oral health status, the number of remaining teeth, and oral health-related self-efficacy. Healthcare professionals should develop and implement targeted oral health management strategies for this population to improve oral health outcomes.

Keywords Type 2 diabetes mellitus, Older adults, Oral frailty, Influencing factors

Background

According to the World Health Organization (WHO), diabetes mellitus is one of the four major non-communicable diseases (NCDs) requiring urgent attention [1], and as of 2021, data from the International Diabetes Federation (IDF) [2] show that the global prevalence of diabetes mellitus among adults is 10.5% (537 million), with type 2 diabetes mellitus (T2DM) accounting for more than 90% of the population [3]. The number of adult diabetic

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patients in China has reached as high as 148 million, ranking second globally [4], with approximately 30% of the elderly population suffering from diabetes, and type 2 diabetes mellitus (T2DM) accounting for more than 95% of cases [5]. Elderly patients with type 2 diabetes mellitus have become the mainstream population of diabetes mellitus in China, a situation that brings great challenges and far-reaching effects to patients, families, and the development of the country's actively aging society.

With the development of global aging, geriatric syndromes have become significant health concerns among older adults. Oral frailty is considered a geriatric syndrome [6], and it refers to a series of processes that occur in individuals as they age, including a reduction in the number of teeth, decreased oral hygiene and oral function, decreased interest in oral health, decreased physical and mental reserve capacity, and dysfunctional eating [7]. Oral frailty not only seriously affects the physical condition and disease progression in older adults but also significantly increases the risk of a number of adverse outcomes such as physical frailty, malnutrition, falls, disability, infections, incapacitation, and even death [8–10]. Previous studies have shown that the prevalence of oral frailty in diabetic patients ≥ 75 years of age is 53.2% [11]. Physiologically, patients with type 2 diabetes mellitus (T2DM) are at increased risk for a variety of oral complications due to their hyperglycemic state, including abnormal salivary secretion, dental caries, taste disorders, and periodontitis [12]. Cognitively, elderly T2DM patients have inadequate knowledge of oral health [13], mistakenly regarding symptoms of oral frailty such as changes in dietary structure and dry mouth as normal signs of aging or adverse effects caused by diabetes. Socially, the prevalence of social frailty in elderly type 2 diabetic patients was 47.61% [14], Social frailty causes patients to ignore the importance of oral hygiene and reduce oral cleaning behaviors, thus accelerating oral frailty [15]. Consequently, elderly T2DM patients are at a higher risk of oral frailty compared to non-diabetic patients.

Although global aging follows a similar trajectory, China's unique lifestyle and dietary culture, along with variations in treatment approaches for oral frailty in diabetic patients both domestically and internationally, may lead to different factors influencing oral frailty among Chinese older adults with T2DM. Compared to other nations, China has a large population of elderly patients with T2DM and a relatively low level of oral health literacy [16]. Moreover, the uneven distribution of oral health service resources across different regions and the limited scope of health insurance coverage contribute to the insufficiency of oral health management strategies for elderly T2DM patients. Therefore, studying the current status of oral frailty and its influencing factors among elderly T2DM patients in China, and identifying and intervening early with risk factors, is crucial for improving their oral and overall health outcomes. However, most current research focuses on the oral frailty of elderly individuals in the community and nursing homes, and studies on oral frailty in elderly T2DM patients are fewer and have not yet been conducted within a theoretical framework.

The Integral Model of Frailty was proposed by Dutch scholars [17] in 2010, and it indicates that frailty involves an integration of physical, psychological, and social dimensions of frailty, and that there are interactions among the dimensions and dynamic changes that can increase the risk of adverse outcomes. In this study, we constructed a model of factors influencing oral frailty in elderly patients with T2DM based on the integral model of frailty and adjusted the original model accordingly to derive the hypothesis diagram of this study. We hypothesize H1: oral frailty in elderly patients with T2DM is influenced by the following factors: life course factors (including gender, age, marital status, and educational level); disease factors (including duration of diabetes, glycated hemoglobin levels, multiple chronic diseases, and polypharmacy); physical frailty (including nutrition, daily activity ability, risk of falling, physical frailty, and oral health); psychological frailty (including depression and self-efficacy); and social frailty (including social support). Conversely, the null hypothesis H0: oral frailty in elderly patients with type 2 diabetes is not affected by the above factors. Figure 1 shows the theoretical model for this study. Therefore, based on this theoretical framework, this study aims to investigate the current status of oral frailty in elderly patients with T2DM and identify its associated factors, which will provide a reference for the development of an effective oral health management program.

Methods

Research target

This was a cross-sectional study, and elderly patients with T2DM who were hospitalized in the Department of Endocrinology of two public tertiary hospitals in Nanchong City, Sichuan Province, from March 2024 to October 2024 were selected for the study by convenience sampling method. The inclusion criteria were as follows: (1) diagnosed with T2DM according to the World Health Organization (WHO) criteria (1999); (2) duration of diabetes mellitus ≥ 1 year; (3) age ≥ 60 years; and (4) no cognitive impairment and with normal expression ability. Exclusion criteria: (1) patients with complete loss of teeth and full dentures; (2) those with combined acute complications of diabetes mellitus or other serious illnesses, who were unable to complete the questionnaire.

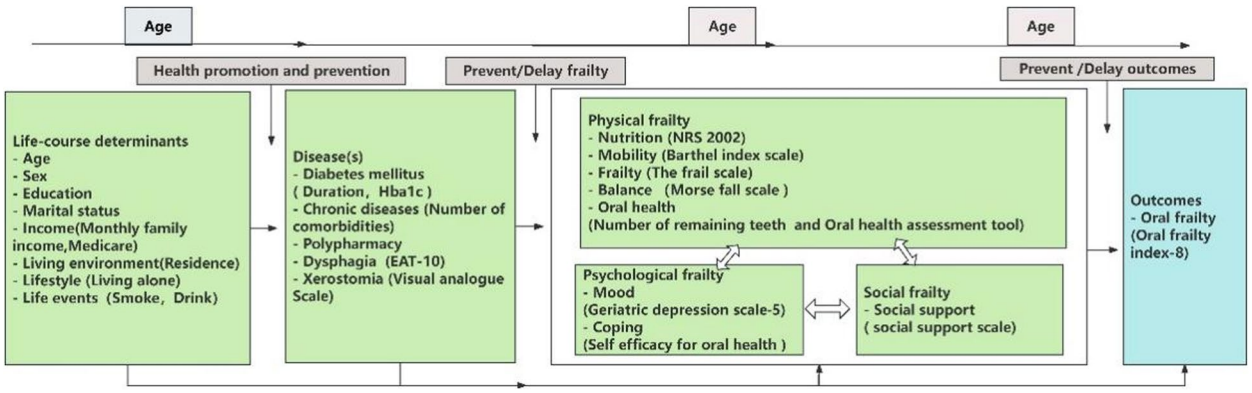

Fig. 1 Theoretical model diagram. Notes: green box: influencing factors; blue box: results; gray box: timing for prevention and management

Sample size estimation

The sample size was determined in accordance with the formula for determining the sample size of cross-sectional studies:

$$n = \frac{(Z_{a/2})^2 p(1-p)}{\delta^2}$$

We assumed an α value of 0.05 and an error (δ) of 0.05. The pre-test yielded a prevalence of oral frailty of 0.53% among elderly patients with T2DM. Therefore, the estimated sample size was 382, and a minimum of 425 cases should be included assuming a 10% dropout rate. The final sample size for the study was 431 cases.

Ethical considerations

All participants provided informed consent and signed a written consent form, and the study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Affiliated Hospital of North Sichuan Medical College (Ethics Approval Number: 2024ER132-1).

Data collection instrument

The General Information Questionnaire

This questionnaire was developed by reviewing relevant literature and included both general demographic and disease-related information. General demographic data covered sex, age, education level, marital status, and place of residence. Disease-related information included the duration of illness, the number of chronic diseases (based on the International Classification of Diseases-10 [ICD-10] [18], such as cardiovascular diseases, cancers, and chronic respiratory diseases), glycated hemoglobin (HbA1c) levels (defined according to the guidelines [5]; a reasonable target for HbA1c control is < 7.0%, and a HbA1c of ≥ 7.0% indicated poor glycemic control), polypharmacy (defined by the WHO as the use of ≥ 5 medications per day [19]), the number of remaining teeth, and the severity of dry mouth.

Oral Frailty Index-8

The OFI-8 was developed by Tanaka et al. [20], and in this study, we used the Chinese version developed by Chen et al. [21]. The questionnaire has five dimensions and eight items, including greater difficulty eating hard foods than six months ago; sometimes choking on tea or soup; using dentures; dry mouth; going out less than you did six months ago; being able to chew hard foods such as pickled radish and shredded squid; brushing at least twice a day; and visiting the dentist at least once a year. The total score ranges from 0 to 11, with a score of ≥ 4 considered a positive screening result for oral frailty. In the original validation of the Chinese version of the OFI-8, Chen et reported a Cronbach's alpha coefficient of 0.949, and in the current study, the Cronbach's alpha coefficient was 0.72.

Oral Health Assessment Tool (OHAT)

The OHAT was revised by Chalmers et al. based on the Brief Oral Health Checklist [22], and this study, we used the Chinese version developed and validated by Wang et al. [23] for use in Chinese populations. An eight-item questionnaire was used to assess various aspects of oral health, including the lips, tongue, gingival tissue, saliva, natural teeth, dentures, oral cleanliness, and the presence of toothache. Each item was evaluated based on the current condition and scored as follows: 0 for healthy, 1 for changes, and 2 for unhealthy. The total score ranged from 0 to 16, with a score of < 3 indicating good oral health and a score of ≥ 3 indicating poor oral health. A higher total score reflected a poorer oral health status. The Chinese version of the Oral Health Assessment Tool (OHAT) has

previously demonstrated a Cronbach's alpha coefficient of 0.71. In the current study, we obtained a Cronbach's alpha of 0.70, indicating acceptable internal consistency.

The Eating Assessment Tool-10 (EAT-10)

The EAT-10, developed by Belafsky et al. [24], is primarily used to assess the severity of dysphagia. In this study, we employed the Chinese version of the EAT-10 scale. The instrument comprises 10 items, each rated on a 5-point Likert scale ranging from 0 ('no problem') to 4 ('very severe'), resulting in a total score ranging from 0 to 40. A total score of ≥ 3 indicates indicated dysphagia, with higher scores representing more severe swallowing difficulties.

Visual analog scale (VAS) [25]

The VAS was used to evaluate patients' subjective symptoms of dry mouth. Patients marked a position on a 10-cm VAS strip to reflect the severity of their symptoms, with the researcher recording the corresponding score. The scale ranges from left to right, where 0 indicates a moist mouth with no sensation of dryness, scores from 1 to 3 represent mild dry mouth, 4 to 6 indicate moderate dry mouth, and scores from 7 to 10 represent severe dry mouth.

The Frailty (FRAIL) Screening Scale

This FRAIL scale was developed by geriatric experts from the International Society for Nutritional Health and Aging [26], and the Chinese version, adapted by Wei Y et al. [27]. was used in this study. It comprises five items: fatigue, reduced resistance/endurance, limited mobility, the presence of more than five comorbidities, and decreased body mass. Each item is scored as 1 point, with a total score ranging from 0 to 5. A score of 0 indicates a healthy status, 1–2 points signify pre-frailty, and a score of 3 or higher indicates frailty. The Cronbach's alpha coefficient of the original scale was 0.826, while the coefficient in this study was 0.71.

The Geriatric Depression Scale (GDS-5)

The GDS-5, developed by Hoyl et al. [28], is a screening tool designed to detect depression in older adults. it consists of five items, each scored from 0 to 1, with a total score of 2 or higher indicating the presence of depression. The scale has demonstrated good reliability and validity in the elderly population. [29], and in this study, the Cronbach's alpha coefficient was 0.77.

The Geriatric Self Efficacy Scale for Oral Health (GSEOH)

The GSEOH was developed by Ohara et al. [30], and the Chinese version, adapted by Xu Yuxin et al. [31]. was used in this study. The scale comprises three dimensions: oral hygiene habits (items 1–8), oral function (items 9–17), and oral consultation habits (items 18–20), for a total of 20 items. Each item is scored on a 4-point Likert scale, ranging from 1 ("not at all confident") to 4 ("very confident"), with a total score range of 20 to 80 points. Higher scores indicate greater self-efficacy in oral health. The Cronbach's alpha coefficient for the Chinese version of the GSEOH was 0.924, and it was 0.90 in this study.

Perceived social support scale (PSSS)

The PSSS, developed by Zimet et al. [32], is used to assess an individual's level of social support. The scale comprises 12 items divided into three dimensions: support from family, friends, and significant others. Each item is rated on a 7-point Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"), with higher scores indicating a greater perception of social support. In this study, the Cronbach's alpha coefficient for the PSSS was 0.902, demonstrating excellent internal consistency.

Data collection

A research team was established, led by the principal investigator. The team included two diabetes specialist nurses, both holding master's degrees and with over 10 years of experience in endocrinology, as well as two nursing students currently pursuing their master's degrees. Data and information were collected by the research team using a pre-designed questionnaire on influencing factors. Prior to the study, all team members underwent standardized training. Before the formal survey, the researcher explained the study's purpose, significance, instructions for completing the questionnaire, and estimated time required to the patients. Confidentiality was assured, and after obtaining their informed consent, the questionnaires were distributed on-site. For participants who had difficulty completing the questionnaires, such as individuals with lower levels of education or older adults, the researcher read the questionnaire aloud and assisted them in completing it based on their responses. The average time required to complete each questionnaire was approximately 25–30 min. After the survey, health education on diabetic oral health was provided to the participants based on their responses. All questionnaires were distributed and collected on-site. A total of 435 questionnaires were distributed, with four excluded due to a missing data rate exceeding 50%. In total, 431 valid questionnaires were collected, resulting in a valid response rate of 99.1%. The General Information Questionnaire, including age, gender, marital status, and disease-related data, was obtained by the investigator from the hospital's electronic medical records system. Additionally, the risk of falls, risk of malnutrition, and

activities of daily living were assessed by endocrinology nurses within 24 h of the patient's hospital admission.

Statistical methods

The questionnaire data of this study were entered using EpiData 3.1 software, and the data were organized and analyzed using R 4.3.1 software. The "tableone" program package was used to describe the data. Normally distributed variables were presented using the mean and standard deviation and compared using the t-test. Variables that were not normally distributed were presented using the median and interquartile range, and the Mann–Whitney U-test was used to compare them. Categorical variables were expressed as frequency and percentage, and the chi-square test or Fisher's test was used to compare them. Correlation analysis and visualization were performed using the "corrplot" package. Logistic regression and stepwise regression analyses were performed using the "glm" package, and the logistic regression model was constructed by screening with backward stepwise culling. The logistic regression model was screened by the backward stepwise elimination method, and the forest plot was drawn using the "forestploter" package. A p-value of <0.05 was considered statistically significant, and the significance level was set at $\alpha=0.05$.

Results

General characteristics

A total of 431 elderly patients with type 2 diabetes mellitus (T2DM) were included in the study. Oral frailty was identified in 142 patients, representing 32.95% of the cohort. The mean age of participants was 71.44 ± 7.47 years. Among them, 197 patients (45.71%) were male, and 234 (54.29%) were female. Most participants were married ($n=355$, 82.37%) and resided in towns or cities ($n=268$, 62.18%). Sixty-two patients (14.39%) lived alone.

Regarding monthly household income, 207 patients (48.03%) earned less than 3,000 yuan, 112 patients (25.99%) earned between 3,000 and 5,000 yuan, and another 112 patients (25.99%) earned 5,000 yuan or more. Health insurance coverage included residents' health insurance for 231 patients (53.60%), employees' health insurance for 195 patients (45.23%), and self-payment or other types of health financing for 5 patients (1.16%).

Lifestyle factors revealed that 159 patients (36.89%) were current smokers, and 153 patients (35.50%) consumed alcohol. Polypharmacy (use of multiple medications) was observed in 230 patients (53.36%). In terms of xerostomia (dry mouth), 78 patients (18.09%) reported no symptoms, 211 patients (48.96%) had mild symptoms, 137 patients (31.79%) had moderate symptoms, and 5 patients (1.16%) experienced severe symptoms. Additionally, 59 patients (13.69%) had swallowing dysfunction, and 172 patients (39.91%) had fewer than 20 remaining teeth.

Concerning comorbidities, 25 patients (5.80%) had no other chronic diseases, 90 patients (20.88%) had one chronic disease, 107 patients (24.83%) had two chronic diseases, and 209 patients (48.49%) had three or more chronic diseases.

Analysis of the correlation between the risk of developing oral frailty and other factors in elderly patients with type 2 diabetes mellitus

We calculated the correlation coefficient matrix between oral frailty and other factors, along with the matrix of significant p-values (Fig. 2). The results indicated that age had the strongest positive correlation with oral frailty ($r=0.44$, $P<0.001$), while the number of remaining teeth showed the strongest negative correlation ($r=-0.48$, $P<0.001$). These findings are illustrated in Fig. 2.

Univariate analysis of the risk of developing oral frailty in elderly patients with type 2 diabetes mellitus

Univariate analysis indicated that several factors were significantly associated with the occurrence of oral frailty in elderly patients with type 2 diabetes mellitus ($P<0.05$). These factors included age, gender, educational level, marital status, polypharmacy, dysphagia, number of remaining teeth, multiple comorbidities, glycated hemoglobin (HbA1c) levels, risk of falls, activities of daily living (ADL), risk of malnutrition, physical frailty, depression, oral health status, social support, and oral health-related self-efficacy scores. The occurrence of these important factors and the difference were statistically significant ($P<0.05$) (Table 1).

Multifactorial analysis of the risk of developing oral frailty in elderly patients with type 2 diabetes mellitus

To further investigate the factors influencing oral frailty, we conducted a logistic regression analysis using oral frailty occurrence (score ≥ 4) as the dependent variable. Variables that showed statistical significance in the univariate analysis were included in the regression model, and a backward elimination method was applied for variable selection. The results indicated that age (OR = 1.098, 95% CI: 1.054–1.146, $P<0.001$), dysphagia (OR = 8.401; 95% CI: 2.276–43.846; $P=0.004$), glycated hemoglobin (HbA1c) $\geq 7\%$ (OR = 3.745; 95% CI: 1.203–12.647; $P=0.027$), and poor oral health status (OR = 2.213; 95% CI: 1.134–4.394; $P=0.021$) were significant risk factors for oral frailty in elderly patients with type 2 diabetes mellitus. Conversely, having ≥ 20 remaining teeth (OR = 0.105; 95% CI: 0.046–0.217; $P<0.001$) and higher levels of oral health-related self-efficacy (OR = 0.934; 95%

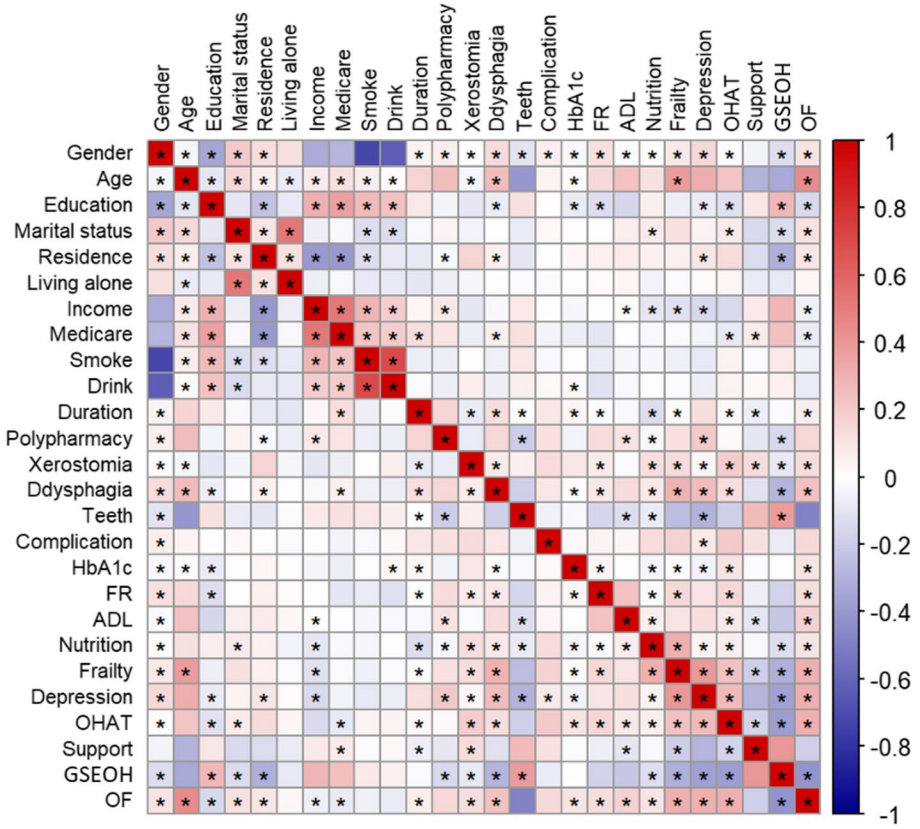

Fig. 2 Heat map of correlation. OF: oral frailty; ADL: activities of daily living; FR: fall risk; Support: PSSS. Blue represents a positive correlation, and red represents a negative correlation. Darker colors indicate a stronger correlation. Each square in the figure corresponds to the correlation coefficient between two variables. Significant correlations are indicated by *

CI: 0.898–0.970; $P=0.001$) were significant protective factors against oral frailty in this population. ($P<0.05$) (Table 2 and Fig. 3).

Discussion

In this study, 142 out of 431 elderly patients with type 2 diabetes mellitus (T2DM) had oral frailty (OFI-8 score ≥ 4), representing an incidence of 32.95%. This rate was lower than that reported in Japanese patients with type 2 diabetes mellitus (53.2%)in a study by Ishii et al. [11], patients with rheumatoid arthritis (44.4%) [33], community elders in India (67%) [34], community elders in South Korea (44.75%) [35], elderly patients undergoing maintenance hemodialysis in China (45.2%) [36], and rural Chinese community elderly (44.7%) [37]. Several factors may contribute to the lower incidence observed in our study:(1) Compared to participants in foreign studies, our study population was younger, had a shorter duration of diabetes onset, and excluded patients with complete tooth loss or full dentures. A significant proportion of our participants resided in urban areas (62.18%) and had employee medical insurance (45.23%). The urban environment offers more opportunities to access professional oral health knowledge and advice. Additionally, having employee medical insurance may provide more financial resources to invest in oral health care. (2) Compared with patients suffering from other diseases, T2DM requires regular physical examinations and blood glucose monitoring once the disease develops, which provides T2DM patients with more opportunities for health education and oral health examinations; whole grains rich in dietary fiber are usually consumed due to dietary management [38], which may help maintain chewing and swallowing functions; physical exercise is an essential part of T2DM treatment, helping to enhance muscle strength and delay the onset of oral frailty. Additionally, metformin, a commonly used hypoglycemic agent in T2DM patients, can alleviate oral lesions and reduce the risk of tooth loss [39], which may also be a potential reason for the lower incidence of oral frailty.

Table 1 Univariate analysis of the risk of developing oral frailty in elderly patients with type 2 diabetes mellitus

Variables	Level	Overall (*n* = 431)	OF group (*n* = 142)	Non-OF group (*n* = 289)	*P*
Age, years (mean [SD])		71.44 (7.47)	66.86 (6.32)	73.69 (6.96)	**< 0.001**
Duration (mean [SD])		11.48 (8.28)	10.56 (7.36)	11.94 (8.67)	0.106
Sex, number (%)	Male	197 (45.71)	76 (53.52)	121 (41.87)	0.029
	Female	234 (54.29)	66 (46.48)	168 (58.13)	
Education, number (%)	Less than lower primary school	261 (60.56)	70 (49.30)	191 (66.09)	0.005
	Middle school	100 (23.20)	46 (32.39)	54 (18.69)	
	Upper secondary or vocational training	49 (11.37)	19 (13.38)	30 (10.38)	
	College degree or above	21 (4.87)	7 (4.93)	14 (4.84)	
Marital status, number (%)	Currently married	355 (82.37)	126 (88.73)	229 (79.24)	0.022
	Unmarried/divorced/widowed	76 (17.63)	16 (11.27)	60 (20.76)	
Residence, number (%)	Rural	268 (62.18)	98 (69.01)	170 (58.82)	0.052
	Urban	163 (37.82)	44 (30.99)	119 (41.18)	
Living alone, number (%)	No	369 (85.61)	124 (87.32)	245 (84.78)	0.574
	Yes	62 (14.39)	18 (12.68)	44 (15.22)	
Monthly family income (RMB) (%)	< 3000	207 (48.03)	63 (44.37)	144 (49.83)	0.561
	3000–5000	112 (25.99)	39 (27.46)	73 (25.26)	
	> 5000	112 (25.99)	40 (28.17)	72 (24.91)	
Medicare, number (%)	Residents' medical insurance	231 (53.60)	69 (48.59)	162 (56.06)	0.181
	Employee medical insurance	195 (45.24)	70 (49.30)	125 (43.25)	
	Private expense and other types	5 (1.16)	3 (2.11)	2 (0.69)	
Smoking, number (%)	No	272 (63.11)	84 (59.15)	188 (65.05)	0.277
	Yes	159 (36.89)	58 (40.85)	101 (34.95)	
Drinking, number (%)	No	278 (64.50)	84 (59.15)	194 (67.13)	0.129
	Yes	153 (35.50)	58 (40.85)	95 (32.87)	
Polypharmacy, number (%)	No, < 4 kinds	201 (46.64)	82 (57.75)	119 (41.18)	0.002
	Yes, ≥ 5 kinds	230 (53.36)	60 (42.25)	170 (58.82)	
Xerostomia, number (%)	No dry mouth symptoms	78 (18.09)	31 (21.83)	47 (16.27)	0.107
	Slight dry feeling in the mouth	211 (48.96)	76 (53.52)	135 (46.71)	
	Noticeable dryness and some discomfort	137 (31.79)	33 (23.24)	104 (35.99)	
	Intense dryness, significantly affecting speaking and eating	5 (1.16)	2 (1.41)	3 (1.04)	
Dysphagia, number (%)	No	372 (86.31)	139 (97.89)	233 (80.62)	**< 0.001**
	Yes	59 (13.69)	3 (2.11)	56 (19.38)	
Remaining teeth, number (%)	< 20	172 (39.91)	9 (6.34)	163 (56.40)	**< 0.001**
	≥ 20	259 (60.09)	133 (93.66)	126 (43.60)	
Number of chronic diseases, number (%)	0	25 (5.80)	13 (9.15)	12 (4.15)	**0.005**
	1	90 (20.88)	40 (28.17)	50 (17.30)	
	2	107 (24.83)	30 (21.13)	77 (26.64)	
	≥ 3	209 (48.49)	59 (41.55)	150 (51.90)	
HbA1c, number (%)	< 7%	29 (6.73)	15 (10.56)	14 (4.84)	0.043
	≥ 7%	402 (93.27)	127 (89.44)	275 (95.16)	
Fall risk, number (%)	Low risk	95 (22.04)	39 (27.46)	56 (19.38)	0.031
	Moderate risk	259 (60.09)	86 (60.56)	173 (59.86)	
	High risk	77 (17.87)	17 (11.97)	60 (20.76)	
Barthel index, number (%)	No dependency	91 (21.11)	43 (30.28)	48 (16.61)	0.003
	Mild dependency	263 (61.02)	83 (58.45)	180 (62.28)	
	Moderate dependency	60 (13.92)	13 (9.15)	47 (16.26)	
	Severe dependency	17 (3.94)	3 (2.11)	14 (4.84)	
Nutrition, number (%)	Normal nutritional status	351 (81.44)	124 (87.32)	227 (78.55)	0.038

Table 1 (continued)

Variables	Level	Overall (*n* = 431)	OF group (*n* = 142)	Non-OF group (*n* = 289)	*P*
	At risk of malnutrition	80 (18.56)	18 (12.68)	62 (21.45)	
Frailty, number (%)	Robust	143 (33.18)	75 (52.82)	68 (23.53)	**< 0.001**
	Pre-frailty	207 (48.03)	55 (38.73)	152 (52.60)	
	Frailty	81 (18.79)	12 (8.45)	69 (23.88)	
Depression, number (%)	No	271 (62.88)	119 (83.80)	152 (52.60)	**< 0.001**
	Yes	160 (37.12)	23 (16.20)	137 (47.40)	
OHAT, number (%)	< 3 points, healthy	83 (19.26)	52 (36.62)	31 (10.73)	**< 0.001**
	≥ 3 points, unhealthy	348 (80.74)	90 (63.38)	258 (89.27)	
Social support (mean [SD])		55.23 (11.02)	58.18 (10.35)	53.78 (11.07)	**< 0.001**
GSEOH (mean [SD])		52.91 (9.04)	58.25 (7.57)	50.28 (8.54)	**< 0.001**

SD standard deviation, *OHAT* Oral Health Assessment Tool, *GSEOH* Geriatric Self Efficacy Scale for Oral Health Scale

Table 2 Multifactorial analysis of the risk of developing oral frailty in elderly patients with type 2 diabetes (*n* = 431)

Variables	Beta	SE	*P*	OR (95% CI)
Education (ref = 1)				
(ref = 2)	−0.579	0.336	0.085	0.56 (0.289–1.082)
(ref = 3)	0.559	0.436	0.200	1.749 (0.749–4.173)
(ref = 4)	0.704	0.589	0.232	2.022 (0.647–6.671)
Age	0.093	0.021	**< 0.001**	1.098 (1.054–1.146)
Dysphagia (ref = 1)	2.128	0.739	**0.004**	8.401 (2.276–43.846)
HbA1c (ref = 1)	1.320	0.597	**0.027**	3.745 (1.203–12.647)
OHAT (ref = 1)	0.795	0.344	**0.021**	2.213 (1.134–4.394)
Teeth (ref = 1)	−2.257	0.394	**< 0.001**	0.105 (0.046–0.217)
GSEOH	−0.068	0.020	**0.001**	0.934 (0.898–0.970)

SE standard error, *OR* odds ratio, *95% CI* 95% confidence interval, *ref* reference group

Oral frailty in elderly patients with type 2 diabetes is influenced by multiple factors

Advanced age was a risk factor for the development of oral frailty in elderly patients with T2DM, a finding that consistent with the predictions of the integrated frailty model. This model suggests that life course factors, such as age, are associated with the progression of oral frailty, with older age correlating to a higher risk of developing oral frailty (OR = 1.098, $P < 0.001$). It is also consistent with the results of a previous study by Ishii et al., which noted that the oral frailty questionnaire scores were positively correlated with age in T2DM patients ≥ 75 years of age and that the prevalence of oral frailty increased with age [11]. Several reasons may explain this association. As age increases, there is a progressive decline in both the structure and function of the oral cavity among the elderly. Common issues include tooth wear, enamel thinning or demineralization, degenerative changes in periodontal tissues, and a weakened oral immune system. These problems lead to decreased masticatory efficiency and reduced saliva synthesis and secretion, resulting in conditions like periodontitis and oral mucositis, which in turn induce oral frailty [40]. Additionally, oral health literacy in elderly T2DM patients gradually decreases with age [16], Low health literacy is closely associated with more severe periodontitis, higher plaque indices, and increased tooth loss [41]. Furthermore, as the duration of diabetes extends, glycemic control becomes more challenging, and the incidence of diabetes-related complications rises. These complications are risk factors for oral diseases, which may also contribute to the higher susceptibility to oral frailty in older T2DM patients. Therefore, healthcare professionals should pay special attention to the oral health of elderly T2DM patients, providing personalized health education based on the patients' age, level of education, and diabetes control status to enhance their oral health literacy, and recommend regular oral health assessments and examinations to identify potential oral issues promptly.

Subjective dysphagia was also a risk factor for oral frailty in elderly patients with T2DM(OR = 8.401, $P < 0.001$). This finding is consistent with the results of Nishida et al. [42] and aligns with the predictions of the integrated frailty model, which posits that disease factors can accelerate the development of oral frailty. The possible reasons for this include: (1) The prevalence of sarcopenia in patients with T2DM can be as high as 29.3% [43], When sarcopenia affects the swallowing muscle groups, it manifests as reduced pharyngeal contraction and upper esophageal sphincter dysfunction, leading to difficulty in swallowing. Additionally, the reduction of pharyngeal muscle mass decreases pharyngeal pressure, increasing the risk of choking when drinking water [44]. (2) Patients with T2DM often have a narrower choice of foods and less dietary diversity due to necessary dietary

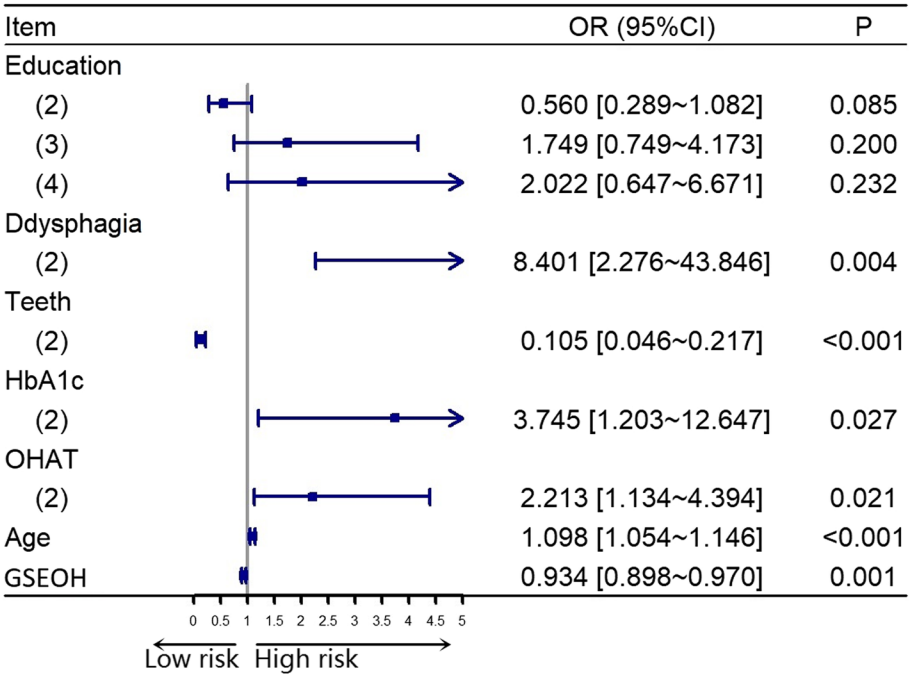

Fig. 3 Forest plot of the results of the logistic regression analysis

restrictions. Patients with dysphagia may also suffer from malnutrition because they have difficulty meeting their nutritional requirements with a conventional diet. Ultimately, poorer nutritional status elevates the risk of developing oral frailty [45]. Therefore, it is recommended that healthcare professionals assess the dietary habits, chewing, and swallowing functions of patients with type 2 diabetes.They should develop targeted dietary plans for patients with dysphagia and guide patients through oral exercises and mouth-opening training. These interventions can improve swallowing ability, increase the possibility of oral intake, and prevent malnutrition.

In this study, glycated hemoglobin (HbA1c) ≥ 7% was identified as a risk factor for the development of oral frailty in elderly patients with type 2 diabetes (OR = 3.745, $P = 0.027$), which is consistent with the findings of Demmer et al. [46] and aligns with the predictions of the integrated frailty model. This suggests that effectively managing disease factors such as HbA1c levels is crucial for preventing or reducing the incidence of oral frailty among elderly patients with type 2 diabetes. Specifically, patients with glycated hemoglobin (HbA1c) ≥ 7% had poorer oral health compared to patients with good glycemic control [47]. There is a complex bidirectional relationship between glycemic control and oral health. Chronic poor glycemic control (HbA1c ≥ 7.0%) calters the oral microenvironment, leading to increased salivary glucose levels, which promotes bacterial growth and the formation of plaque and periodontitis. And periodontitis not only leads to loosening and loss of teeth, but also triggers a systemic inflammatory response, which further aggravates insulin resistance and leads to elevated blood glucose levels [48]. This vicious cycle worsens the oral health status of diabetic patients and also increases the difficulty of diabetes management [47]. In contrast, good glycemic control can significantly improve oral health [49]. Therefore, this study recommends that healthcare professionals should pay attention to the interplay between glycemic control and oral health when providing medical services to elderly patients with type 2 diabetes, assist patients in setting individualized glycemic control goals, encourage patients to regularly monitor HbA1c levels, and emphasizing the important role of maintaining stable blood glucose for oral health through health education.

Poor oral health was identified as a risk factor for developing oral frailty (OR = 2.213, $P < 0.001$), which is consistent with the findings of Hanako et al. [50]. This result corresponds to the physical frailty dimension of the integrated frailty model, which states that patients with poor oral health are more likely to develop oral frailty. Poor oral health is characterized by reduced saliva production (dry mouth), worn or missing teeth, inadequate oral cleanliness, and oral pain. Firstly, reduced saliva production increases the risk of oral fungal infections, and diabetes mellitus heightens susceptibility to opportunistic

oral infections. Secondly, a decreased number of teeth leads to reduced tongue pressure and impaired oral motor function Additionally, microbial dysbiosis in dental plaque resulting from insufficient oral hygiene can induce oral frailty [51], and dental pain can further exacerbate this condition. Therefore, it is recommended that healthcare providers dynamically assess and document patients' oral health status to identify individuals with poor oral health and provide early interventions. By helping patients develop good oral hygiene habits and ensuring adequate oral cleanliness, oral health can be effectively improved.

The number of retained teeth ≥ 20 was a protective factor against oral frailty in elderly patients with T2DM (OR = 0.105, $P < 0.001$), in line with the physiological frailty dimension of the integrated frailty model,which is consistent with the findings of Kurinami et al. [52], This study proposed that the number of remaining teeth or healthy teeth is significantly lower in T2DM patients than in non-T2DM patients, and that the number of remaining teeth ≥ 20 is an important indicator of good prognosis in T2DM patients. Zhang et al. [53]. also observed a significant correlation between the number of remaining teeth and the degree of periodontal inflammation in patients with periodontitis and type 2 diabetes. Those with ≥ 20 remaining teeth exhibited significantly lower levels of periodontal inflammation and HbA1c compared to those with fewer than 20 teeth. The reduction in the number of remaining teeth not only exacerbates periodontal inflammation but also impairs normal chewing and occlusal functions, potentially leading to masticatory dysfunction [54], defined in the study as having fewer than 20 teeth. Therefore, healthcare providers should pay attention to the number of remaining teeth in elderly T2DM patients, advocate for advocate retaining ≥ 20 teeth and ensuring masticatory function as the goal of oral health management, and emphasize the importance of tooth retention through health education. and provide timely prosthetic restorations or dental implant interventions to restore masticatory function for patients who already have missing teeth.

A high level of oral health-related self-efficacy was a protective factor for the occurrence of oral frailty in elderly patients with T2DM (OR = 0.934, $P < 0.001$), which is consistent with the findings of Wen et al. [55] and supports the prediction of the integrated frailty model, which posits that increased self-efficacy reduces the risk of developing oral frailty. Oral health-related self-efficacy refers to an individual's subjective perception or judgment of their ability to effectively maintain oral health [30], It is a critical factor in personal oral health maintenance and plays a decisive role in oral health behaviors. Research has demonstrated that high levels of oral health-related self-efficacy enhance self-care capabilities in patients with type 2 diabetes [56]. Additionally, it triggers greater demands for oral hygiene and motivates positive health behaviors, encouraging these patients to prioritize oral hygiene. This focus effectively improves oral diseases and glycated hemoglobin levels, thereby reducing the risk of oral frailty. Conversely, patients with low self-efficacy are more prone to oral health-related problems [57], increasing their risk of developing oral frailty. Therefore, it is recommended that healthcare professionals strengthen communication with elderly T2DM patients to better understand their oral care needs, correct misconceptions, and establish accurate beliefs regarding oral health management. Enhancing oral health-related self-efficacy in these patients can improve their self-care abilities and effectively prevent oral frailty.

According to the results of this study, we confirmed Hypothesis H1, which states that oral frailty in elderly patients with type 2 diabetes mellitus is influenced by multidimensional factors, consistent with the integrated frailty model. Previous studies have shown a direct correlation between social frailty and oral frailty [15]. However, in this study, the correlation between social frailty and oral frailty was not significant after multivariate regression analysis and was therefore not included in the final model. This finding may be influenced by cultural differences. Under the unique cultural context of China, where filial piety is highly valued, the social support system of the elderly is predominantly family-dependent, with fewer instances of living alone [58]. This cultural background leads to insufficient perception and utilization of social support from sources beyond the family. Additionally, Chinese culture emphasizes introversion and self-reliance, and the elderly are more inclined to solve problems independently rather than actively seeking support from friends or the community. Previous studies have shown that smoking [59], alcohol consumption [60], low literacy [61], and being widowed/unmarried [62] are risk factors for oral frailty, but this study was not significant and may be related to oral health behaviors, but information to oral health behaviors was not collected in this study, and further explorations of the above factors may be considered in future studies.

Limitations

The present study has the following limitations: First, the cross-sectional design of this observational study limits the ability to infer causality from the findings. Future research should employ multicenter longitudinal or qualitative studies with larger sample sizes and extended follow-up periods to thoroughly investigate the relevant influencing factors in greater depth. Second, this

study used a convenience sampling method to investigate patients in Nanchong, Sichuan Province, which may affect the generalizability of the findings due to dietary and cultural differences, and third, the reliance on subjective scales to assess the status of patients' xerostomia and dysphagia did not assess the looseness of the remaining teeth, the number of caries, and the use of dentures, which may also affect the results of the study. Therefore, it is recommended that future studies incorporate this more objective indicators to address the above issues more comprehensively.

Conclusion

Based on the Integrated Frailty Model, this study constructed a predictive model for oral frailty in older adults with elderly T2DM patients, providing a strong theoretical framework for research on oral frailty. The study identified advanced age, dysphagia, glycated hemoglobin (HbA1c) ≥ 7%, and poor oral health status as risk factors for oral frailty, while retaining 20 or more teeth and higher oral health-related self-efficacy were identified as protective factors. Therefore, it is recommended that healthcare professionals develop personalized and long-term oral health management services for elderly T2DM patients, targeting these modifiable factors to improve oral health outcomes.

Abbreviations

GSEOH	Geriatric Self Efficacy Scale for Oral Health
IDF	International Diabetes Federation
NCD	Non-communicable diseases
OHAT	Oral Health Assessment Tool
PSSS	Perceived Social Support Scale
SHIP	Study of Health in Pomerania
VAS	Visual analog scale
WHO	World Health Organization

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions

WY Land and LZ contributed to the study concept and design. WY L, JF Z, and LY Q were responsible for data acquisition. WY L conducted the analysis and interpretation of data. WY L and LZ drafted the manuscript. LZ critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to patient privacy concerns but are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Affiliated Hospital of North Sichuan Medical College (Ethics Approval Number: 2024ER132-1).All participants provided informed consent by signing the consent form prior to participation.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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