scientific reports

Check for updates

OPEN

Periodontal health intervention for oral health-related outcomes in older type 2 diabetes patients: a randomized controlled trial in a Chinese tertiary hospital

Chunxiu Xiao[1,2,5], Lan Zhang[2,5], Zhaoxi Li[2,3], Qingnv Xu[2], Suping Lin[2], Siyu Zheng[2] & Hanping Shi[4]✉

As the sixth complication of diabetes, periodontitis interacts with diabetes to form a vicious circle. Periodontal health interventions can improve periodontal health and the quality of life in older patients with type 2 diabetes mellitus (T2DM). This study aimed to explore the effect of periodontal health interventions based on the Pender Health Promotion Model on periodontal outcome index and quality of life in this patient population. This randomized controlled trial enrolled 108 patients with T2DM from the endocrine and metabolism department of a tertiary hospital. Participants were randomly assigned to either an experimental group or a control group. The control group received routine diabetes health education and periodontal health-related knowledge education, they were general diabetes management and standard dental hygiene instructions. While the experimental group underwent a periodontal health intervention program in addition to the routine health interventions, it focuses on a combination of individualized and targeted comprehensive assessments, professional training, patient education, and behavioral interventions. Relevant outcome measures were assessed at baseline and after 12 weeks of intervention. The main outcomes were oral hygiene-related measures, including dental plaque, debris and calculus conditions, the secondary outcomes included subjective assessment of oral health and self-assessment of knowledge, attitude and behavior. Demographic questionnaires, Plaque Index (PLI), Geriatric Oral Health Assessment Index (GOHAI), Periodontal Health Knowledge, Attitude, and Behavior Questionnaire, as well as the Oral Hygiene Index-Simplified (OHI-S) (including Debris Index-Simplified (DI-S) and the Calculus Index-Simplified (CI-S)) were used to collect data. Statistical analysis was performed using Chi-square tests, Fisher's exact tests, and SPSS software version 27. A p-value of < 0.05 was considered statistically significant for all tests. Following the intervention, significant differences were identified between the groups in PLI, OHI-S, and Periodontal Health Knowledge, Attitude, and Behavior ($P < 0.05$). However, there was no significant difference in GOHAI scores between the groups ($P > 0.05$). Based on the results of this study, it can effectively prevent the occurrence or progression of periodontitis, as well as enhance periodontal health knowledge, attitudes, and behaviors while positively impacting the oral health index and quality of life of older patients with T2DM. This approach holds significant value in medical practice and provides strong support for the widespread promotion of periodontal health maintenance strategies.

Keywords Type 2 diabetes, Pender health promotion model, Periodontal health, Quality of life, Oral hygiene, Knowledge-attitude-behavior

Abbreviations

T2DM	Type 2 diabetes
HPM	Health promotion model

[1]School of Nursing, Fujian Health College, Fuzhou, China. [2]School of Nursing, Fujian Medical University, Fuzhou, China. [3]School of Medical, Xiamen Nanyang University, Xiamen, China. [4]Department of Stomatology, Fujian Medical University Union Hospital, No. 29 Xinquan Road, Gulou District, Fuzhou City, Fujian Province, China. [5]Chunxiu Xiao and Lan Zhang have contributed equally to this work. ✉email: 54251118@qq.com

PLI	Plaque index
PD	Periodontitis disease
OHI-S	Oral hygiene index-simplified
GOHAI	Geriatric oral health assessment index
DI-S	Debris index-simplified
CI-S	Calculus index-simplified
BOHSE	Kayser–Jones brief oral health status examination

Diabetes encompasses a group of metabolic disorders characterized by chronic hyperglycemia, influenced by both genetic and environmental factors. In China, where the aging population is expanding, approximately 260 million individuals are aged ≥ 60 years, representing 18.7% of the national population. Among this demographic, nearly 30% are affected by diabetes, with > 95% diagnosed with type 2 diabetes mellitus (T2DM)[1,2]. Periodontitis, recognized as the sixth most common complication of diabetes, is a chronic inflammatory condition triggered by dental plaque that leads to the progressive destruction of periodontal tissue[3]. Persistent periodontal infections exacerbate the systemic microinflammatory state, complicating glycemic control[4]. A consensus report from the International Diabetes Federation and the European Federation of Periodontology[5] highlights the critical role of periodontal health in diabetes management. Age significantly influences the prevalence of periodontitis[6], particularly in older patients with diabetes, who often lack sufficient knowledge about oral health. This gap leads to underestimating the risk posed by periodontitis and its impact on diabetes management. Awareness and education are essential for promoting behavioral changes, as adopting proper oral hygiene practices can mitigate the risk of periodontitis. Consequently, health interventions aimed at improving periodontal care and promoting effective dental plaque control are vital for preventing periodontitis and enhancing overall diabetes care.

Numerous studies, both domestic and international, have demonstrated that oral health interventions can improve the oral quality of life and periodontal indices in patients with diabetes. These interventions include oral health education[7–10], comprehensive healthcare[11], oral nursing combined with exercise guidance[12], and strategies to maintain the stability of the oral environment[13]. For instance, one study focused on older patients with T2DM in an intervention group who received a 20-min lifestyle modification and dental care intervention plan supplemented by personalized lifestyle counseling. During the intervention, nurses guided patients in goal setting and reinforced these goals through 15-min health education videos in the first and second months. The control group, by contrast, received routine care. Results revealed significant improvements in both periodontal condition and blood glucose levels in the intervention group after 3 months. However, the quasi-experimental study was limited by selection bias and insufficient rigor[14]. Similarly, a randomized controlled trial examined the impact of educational interventions based on health belief models in patients with T2DM. Participants in the trial group attended four educational sessions within 1 month, covering topics such as oral health risks, potential complications, benefits of preventive behavior, and disorders associated with poor oral health. They were subsequently encouraged to practice oral care. The control group received routine care. After 3 months, the experimental group exhibited heightened awareness of oral nursing practices. However, this study was limited by its reliance on a self-designed questionnaire as the sole outcome measure, lacking objective oral health indicators to evaluate intervention effectiveness[15].

Several studies have explored oral health education for older patients with diabetes in China. In one study, the experimental group received nursing interventions that included education on oral health knowledge, covering a diverse range of topics such as theoretical training in oral healthcare, oral nursing skills, timely oral examinations, and the prompt use of necessary treatment. Meanwhile, the control group received routine nursing care. The results demonstrated improvements in oral health and quality of life among patients in the experimental group following the intervention. However, it remains unclear whether the baseline characteristics of the participants in these studies were comparable[16]. Another study examined the effect of health education based on behavior change theory on the oral health of older patients with diabetes. The experimental group underwent an intervention that incorporated education on diabetes, oral health knowledge, and psychological support, structured through the stages of pre-intention, intention, preparation, action, and maintenance. The findings revealed that such interventions effectively improved patients' oral health awareness and behavioral habits, improved their quality of life, and contributed to better blood sugar control. Nevertheless, the study's extended duration limits its applicability to short-term hospitalization settings. Both research interventions primarily focused on theoretical knowledge education across various stages, with insufficient training in oral health protection skills[17]. In summary, several studies have demonstrated that oral health interventions can improve the oral quality of life and enhance the periodontal index in patients with diabetes. However, few intervention programs fully account for the unique needs of the older adult population. Most interventions focus predominantly on preventing oral problems in patients with diabetes, lack behavioral components for oral health, and demonstrate insufficient scientific rigor. Additionally, personalized interventions tailored to individual patient conditions are notably absent.

The Health Promotion Model (HPM), developed by Pender, a prominent American nursing scholar of the twentieth century, provides a comprehensive theoretical framework for analyzing factors that affect health behaviors. This model serves as a robust theoretical foundation for understanding and explaining lifestyle choices and specific health-related behaviors. The HPM consists of three primary components: personal characteristics and experiences, specific behavioral cognition and emotions, and behavioral outcomes. Personal characteristics and experiences are subdivided into prior related behaviors and personal factors. Prior related behaviors refer to an individual's past behaviors, including their nature and characteristics, which can serve as predictors of current behaviors across physical, psychological, social, and cultural dimensions. Specific behavioral cognitions and emotions encompass perceived benefits of behavior, perceived barriers to action, cognitive self-efficacy, emotional

responses to actions, interpersonal influences, and situational factors. Behavioral outcomes include planned health-promoting actions, immediate needs and preferences, and health-enhancing behaviors[18,19]. The HPM has been widely used in clinical settings and has demonstrated effectiveness in improving patients' self-management skills, health behaviors, knowledge, and quality of life[20,21]. For example, a study based on peer education based on the Pender health promotion model improved quality of life, stress management, and self-efficacy in patients with multiple sclerosis[22]. In addition, an educational program developed based on the Pender health promotion model specifically targeted the six dimensions of health promotion to educate hemodialysis patients, improving self-efficacy and treatment adherence among patients receiving hemodialysis[23]. However, there is a lack of health intervention studies that utilize the HPM to address oral health among older patients with T2DM. It can not only be used to assess their awareness of periodontal healthy behaviors and their willingness to practice them, but also to identify the factors that restrict and promote them to adopt healthy behaviors. Through a comprehensive analysis of these factors, we can provide an empirical basis for the development of targeted interventions that can more effectively drive health promotion. This study aims to apply the HPM to develop a periodontal health program for older patients with T2DM, emphasizing the relationship between diabetes and periodontitis, the risk factors contributing to periodontal problems, and the influence of poor oral hygiene habits. By evaluating the knowledge, attitudes, behaviors, and personal factors associated with periodontal health, the program seeks to enhance patients' understanding of proper periodontal care, overcome barriers to oral health practices, and improve self-efficacy. Ultimately, the goal is to encourage patients to commit to periodontal health plans and adopt sustainable oral health behaviors.

This clinical randomized controlled trial aimed to evaluate the effectiveness of a periodontal health intervention program designed for older patients with T2DM using the Pender HPM. The findings aim to offer a theoretical foundation for the clinical advancement of periodontal health interventions tailored to this population.

Methods

Study design, setting, and participants

This study was approved by the Ethics Committee of Fujian Medical University Union Hospital (2023KY071). All patients signed informed consent, and all experiments were conducted in accordance with the Declaration of Helsinki. The trial was registered (ChiCTR2300073533, 13/07/2023) with the China Clinical Trial Registry prior to its commencement. This single-blind, single-center, randomized controlled trial was conducted at Fujian Medical University Union Hospital, China, from August 2023 to February 2024. The study employed quantitative research methods, incorporating clinical reagent tests and internationally recognized scales to assess outcomes. Additionally, a previously developed self-made scale was used for evaluation purposes, and written informed consent was obtained from all participants. Participants aged 60 years or older with T2DM were recruited from the Department of Endocrinology and Metabolism at a tertiary hospital in Fujian Province. Eligibility criteria included the following: (1) diagnosis of T2DM based on the World Health Organization (WHO) diabetes diagnostic criteria of 1999[24,25]; (2) ability to communicate effectively in Chinese; (3) capability to complete the questionnaire independently or with assistance from the researcher; (4) possession of at least 16 natural teeth[26]; and (5) ability to perform self-care, including brushing and mouth rinsing. Exclusion criteria were as follows: (1) presence of severe complications; (2) mental illnesses or emotional disorders; (3) use of hormones or antibiotics for more than 2 weeks within the past 3 months or recent scaling or scraping; and (4) history of systematic periodontal treatment within the previous year. Additionally, participants were excluded during the study if they: (1) demonstrated poor compliance during follow-up or were unable to adhere to long-term follow-up; (2) required the use of hormones or antibiotics for more than 2 weeks during the intervention period; (3) were unable to continue participation due to changes in their medical condition; or (4) withdrew or died during the study.

Blinding

Because this study was a different health intervention program, it was not possible to blind the study subjects and intervention implementers, and only endpoint observers and statistical analysts were blinded, but we minimized bias by using standardized assessment tools.

Study randomization

To address the challenge of a socially dispersed patient population and the limited number of hospital visitors meeting the minimum sample size requirements within a short timeframe, patients were enrolled consecutively into the study. Participants who fulfilled the inclusion and exclusion criteria and were officially included in the trial were sequentially numbered. A set of random sequences was generated in advance by external individuals not involved in the study using a randomization website. These random numbers, ranging from 1 to 108, were placed in sequentially numbered, sealed, and opaque envelopes, which were securely stored. Upon enrollment, researchers contacted the custodians of the random numbers by telephone to determine the participant's group assignment. The custodian opened the corresponding envelope to reveal the group allocation: participants with random numbers 1–54 were assigned to the test group, while those with numbers 55–108 were assigned to the control group.

Sample size

The sample size for this study was determined using a standard estimation method for experimental studies. The calculation formula is as follows: $n1 = n2 = 2\left[\left(\mu_\alpha + \mu_\beta\right)\sigma/\delta\right]^2 + 1/4\mu_\alpha^2$, where n1 and n2 represent the required sample sizes for the two groups, σ is the total standard deviation, and δ is the difference between the two population averages. Based on the literature[27] and accompanying tables, the ratio $\delta/\sigma = 0.69$, with $\mu_{0.05/2} = 1.96$,

and $\mu_{0.1} = 1.28$. Substituting these values into the formula yields $n1 = n2 \approx 45$. Considering the extended duration of the study and an anticipated 20% attrition rate, a minimum of 54 participants per group is required. Therefore, the total expected sample size for this study is 108 participants.

Protocol development

Based on the Pender health promotion model, this program was developed through a structured process. Firstly, the terms "Diabetes mellitus /Diabetes mellitus in the elderly", "Oral intervention/Oral health care" and "Periodontal health" were used as search terms in CNKI, China Biomedical Literature Database, PubMed, Web of science, and other databases, and the information of the included literature was analyzed, the first draft of the intervention plan was formed under the guidance of the three aspects of the P-ender health promotion model combined with the content of the knowledge-belief-acting questionnaire items tested for reliability and validity, and then used the Delphi expert correspondence method to conduct two rounds of correspondence and modification of the intervention program, and finally formed a periodontal health intervention program for elderly patients with T2DM.

Pilot-testing

Before the formal intervention, a total of 10 patients with (T2DM) from the Department of Endocrinology and Metabolism at a tertiary hospital in Fujian Province were enrolled in this study. They received a two-week periodontal health intervention program. The primary outcome measures were Plaque Index (PLI) and Geriatric Oral Health Assessment Index (GOHAI) scores, while the secondary outcomes included the Periodontal Health Knowledge, Attitude, and Behavior Questionnaire scores and Oral Hygiene Index-Simplified (OHI-S) (including Debris Index-Simplified (DI-S) and the Calculus Index-Simplified (CI-S)). These indicators were measured at baseline and two weeks post-intervention, and participant feedback was collected during the intervention period.

The results showed statistically significant differences ($P < 0.05$) in the PLI, DI-S, the Periodontal Health Knowledge, Attitude, and Behavior Questionnaire score, and its subdomain scores before and after the intervention. The intervention protocol may contribute to reducing dental plaque and debris in patients, while the Pender's Health Promotion Model-based program effectively enhances patients' knowledge, attitudes, and practices (KAP) regarding periodontal health. However, no significant differences were observed in the CI-S or the GOHAI score ($P > 0.05$). These nonsignificant results could potentially result from either the relatively brief intervention duration (2 weeks) or the limited number of study participants.

Interviews revealed that participants were generally satisfied with and receptive to the intervention. Nevertheless, several issues were identified: First, participants transitioning from long-term horizontal brushing to the modified Bass technique (horizontal vibratory and sweeping motions) reported discomfort and hesitation when applying pressure to the gingival sulcus. Second, some patients felt that the oral health education sessions were too lengthy, leading to reduced attention span in later segments. Finally, adherence to recommended practices at home during follow-up could not be fully ensured.

To address these issues, the intervention protocol was modified as follows: During the intervention, after practicing on dental models, researchers provided hands-on guidance by demonstrating proper brushing technique directly in patients' mouths to ensure correct pressure application, and oral health education was streamlined by integrating key points into skill-training sessions. During follow-up, patients were encouraged to maintain daily oral health behavior logs alongside glucose records, compliant participants received incentives (fundus examinations and glucose tests) and priority access to specialist consultations during in-person visits where periodontal health and log adherence were reassessed. The study ultimately developed an applied version of periodontal health intervention program based on Pender's Health Promotion Model, integrating scientific rigor, feasibility, and clinical practicality.

Intervention

Participants in the control group received routine diabetes health education and periodontal health-related knowledge education. Its contents include: Routine diabetes health education: (1) medication guidance, (2) dietary guidance, (3) blood glucose self-monitoring, (4) exercise guidance; Periodontal health-related knowledge education: (1) the relationship between diabetes and periodontitis (2) the causes and manifestations of periodontitis (3) the importance of oral hygiene and cleanliness (4) how to choose the type of toothpaste and toothbrush (5) demonstrate the use of pasteur brushing and dental floss, and ask patients to rinse their mouths and clean up food residues in their mouths after eating. Routine follow-up after the end of the intervention. The timing and frequency of intervention were routinely carried out in accordance with the regulations of the endocrinology department and diabetes management of the hospital.

In contrast, participants in the experimental group underwent a periodontal health intervention program designed using the Pender HPM. The program consisted of three key components: (1) evaluation of personal characteristics and experience, (2) cognitive and emotional interventions targeting behavioral characteristics, and (3) supervision and reinforcement of committed behaviors. The first component included an assessment of the patient's personal information, oral health factors, and behavioral patterns. The second component comprised five specific activities: recognizing the benefits of health-promoting actions, enhancing theoretical knowledge related to emotional responses, conducting practical skills training to boost self-efficacy, providing feedback and re-evaluation to address cognitive barriers to action, and addressing situational and interpersonal influences. The third component focused on strategies for managing unexpected situations during the intervention period and ensuring adherence to planned behaviors. The intervention was administered directly by the researcher over a 5-day period, with follow-up supervision extending for 12 weeks. Baseline assessments were conducted to evaluate personal characteristics and related behaviors in the early stages. On the second day, participants

received training on periodontal health knowledge and oral health protection techniques. Problem-solving feedback was integrated into the learning process and provided on days 2 and 4. Dietary and lifestyle guidance was delivered on day 5. Psychological support, temporary coping strategies, and planned behavior reinforcement were provided throughout the intervention period and continued during follow-up after the intervention.

In order to guarantee the compliance of the participants, in the first week after the end of the intervention, the daily telephone follow-up was conducted to understand the patient's recent situation, whether the oral care was completed as planned, and to put forward solutions and suggestions for the practical obstacles encountered by the patient. Since the National Center for Standardized Metabolic Disease Management (MMC) of the hospital in which all the study subjects were enrolled, MMC would notify the patients to return to the hospital for re-examination of blood glucose-related indicators at 4, 12, and 24 weeks after discharge, so when the patients returned to the hospital for re-examination at the 4th week, they were notified to bring the periodontal health promotion check-in form to check whether the patients completed periodontal health care as planned. At the 12th week, the offline evaluation of outcome indicators was carried out at the return of the hospital, and the patients' plaque index, simplified oral hygiene index, oral related quality of life, and oral periodontal condition were evaluated. In addition, the special feature of this study is to provide free fundus testing and blood glucose testing to patients participating in follow-up, and to provide help to make appointments for patients who need follow-up visits, so as to improve the compliance and enthusiasm of patients. An additional table provides more detail on the timing, frequency, and follow-up of interventions (see Supplementary Table S1).

Outcome measures

Main outcomes

The main outcome indicators of this study were Plaque Index (PLI) and Geriatric Oral Health Assessment Index (GOHAI).

Plaque index (PLI) Plaque Index (PLI) is an evaluation method that assesses the thickness of plaque on the surface of teeth and serves as an indicator of oral hygiene, helping to prevent periodontal disease. In 1962, Quigley and Hein introduced a plaque scoring system with a standard score of 0.5[28]. In 1970, Turesky improved this scoring system, making it more objective and specific[29]. The improved Turesky method of the Quigley–Hein PLI was used in this study. During the examination, the evaluator applies a plaque chromogenic liquid to a cotton swab, which is then used to swab the surface of the lip (cheek) and tongue of the six index teeth, resulting in a total of 12 examination areas. After 5 s, the participant rinses their mouth twice with clear water, allowing the plaque developer to leave pink stains on the areas where the plaque has adhered. The plaque accumulation is scored based on the extent of plaque coverage[30]. The plaque area is divided into six categories: (1) no plaque on the tooth surface, (2) scattered spot plaque at the gingival margin of the tooth neck, (3) plaque width at the tooth neck of no more than 1 mm, (4) plaque width greater than 1 mm but less than 1/3 of the tooth neck, (5) plaque width between 1/3 and 2/3 of the tooth neck, and (6) plaque width greater than 2/3 of the tooth neck. Scores ranged from 0 to 5, with higher scores indicating poorer oral health. The plaque areas of the 12 regions were quantified using this PLI method.

Geriatric oral health assessment index (GOHAI) The Geriatric Oral Health Assessment Index (GOHAI), introduced by American scholars in 1990, is a tool designed to measure the subjective oral health status of older individuals[31]. Compared with common scales such as OHIP-14, it is more specific for the elderly group and more applicable to the elderly in Asia, avoiding cultural biases. In addition to, there is a greater focus on improving oral function, which is consistent with the Pender model. It comprises 12 items categorized into three domains: functional limitation, psychological discomfort, and pain. The total score ranges from 0 to 48, with higher scores reflecting poorer oral health. The scale demonstrates strong reliability and validity, evidenced by a Cronbach's α coefficient of 0.88[32].

Secondary outcomes

The secondary outcomes of this study included assessments using the Periodontal Health Knowledge, Attitude, and Behavior Questionnaire, as well as the Oral Hygiene Index-Simplified (OHI-S).

Periodontal health knowledge, attitude, and behavior assessment questionnaire The self-developed questionnaire for assessing periodontal health in older patients with T2DM was organized into three dimensions: knowledge, attitude, and behavior. The knowledge dimension included 29 items, the attitude dimension contained 15 items, and the behavioral dimension comprised 12 items. After the preliminary research of the research group, it was shown that the questionnaire could be targeted to evaluate the knowledge, belief and action of the oral characteristics of elderly patients with type 2 diabetes, which was scientific, feasible and practical. The scale demonstrates strong reliability and validity, the Scale-level CVI (S-CVI) was 0.929, the item-level content validity index (I-CVI) of each item was ≥ 0.80, the average content validity was 0.991, the Cronbach's α coefficient was 0.898, and the test–retest reliability was 0.971.

Oral hygiene index-simplified (OHI-S) Greene and Vermillion (1964) introduced an evaluation method to assess the true status of oral health. This index was designed to be objective, simple, rapid, and reproducible. It comprises two components: Debris Index-Simplified (DI-S) and the Calculus Index-Simplified (CI-S). The examination method involved dividing the tooth surface from the gingival margin to the incisal margin, applying a plaque display agent, and visually assessing the area covered by plaque, soft dirt, pigment, or dental calculus. Only six teeth were examined: the lip and buccal surfaces of 16, 11, 26, and 31 and the tongue surfaces of teeth 36 and 46. Based on the extent of the soft scale coverage, the DI-S was categorized into four groups: no soft scale dirt

on the tooth surface, coverage less than 1/3 of the surface, coverage between 1/3 and 2/3, and coverage greater than 2/3. Scores ranged from 0 to 3, with higher scores reflecting poorer oral health. Similarly, the CI-S was categorized based on the extent of dental calculus coverage: no supragingival or subgingival calculus, supragingival calculus covering less than 1/3 of the surface, coverage between 1/3 and 2 /3 or scattered subgingival calculus near the neck of the tooth, and coverage exceeding 2/3 or continuous thick subgingival calculus in the neck of the tooth. Scores for the CI-S ranged from 0 to 3, with higher scores indicating poorer oral health.

Other variables

Questionnaire

The sociodemographic characteristics of the participants were assessed through a survey. The collected data encompassed age, sex, place of origin, disease duration, educational level, marital status, annual family income, smoking history, and alcohol consumption history.

Chinese Kayser–Jones brief oral health status examination (BOHSE)

The scale is a practical tool designed for non-oral health professionals to screen the oral health of older adults. It comprises 10 items: lymph nodes, lips, tongue, mucous membrane, gums, saliva, natural teeth, dentures, logarithm of chewing teeth, and oral cleaning. Each item is scored on a scale from 0 (normal) to 2 (problematic), with higher overall scores reflecting poorer oral health. The scale demonstrates strong reliability and validity, with a Cronbach's α coefficient of 0.873[33].

Data collection and measurement procedures

Baseline data were collected by trained data collectors using a custom-designed questionnaire administered directly to participants. Before beginning the surveys, the data collectors explained the study's purpose to the participants and obtained informed consent. The questionnaire is a one-on-one inquiry, which is filled in on the spot after being asked by the inquirer. Each questionnaire item was individually explained and completed in real time to ensure the objectivity and validity of the collected data. The PLI and OHI-S were measured with chromogenic reagents by data collectors at baseline and 12 weeks post-intervention.

Statistical analysis

Statistical analysis was performed using SPSS Statistics software (version 27.0). Continuous data were assessed using descriptive statistics and normality tests. For data following a normal distribution, the mean and standard deviation were used as summary measures. Between-group comparisons for normally distributed data were performed using independent t-tests, while within-group changes were analyzed using paired t-tests. For non-normally distributed data, the median (quartile interval) was reported, and the Wilcoxon signed-rank test was used to analyze the data. Categorical data were summarized as frequencies and constituent ratios, with chi-square and Fisher's exact tests employed for group comparisons, and the missing values were treated by mean imputation. All statistical tests were two-tailed, and a p-value of < 0.05 was considered statistically significant.

Results

Characteristics of the patients

A total of 108 participants were enrolled in this study and randomized equally into an intervention group (n = 54) and a control group (n = 54). During the study, five participants were lost to follow-up: three from the intervention group (5.56%) and two from the control group (3.70%), resulting in an overall loss to follow-up rate of 4.63%. Consequently, 103 participants completed the study and were included in the final statistical analysis (Fig. 1).

Among the 108 participants, the mean age was 67.55 ± 5.34 years. The majority of the participants were male (59.26%), while females comprised 40.74% of the cohort. Educational level was predominantly low, with 75% having completed junior high school or less and only 25% achieving a high school education. Furthermore, 96.3% of participants were married. Regarding medical coverage, the primary payment method was provincial or municipal health insurance, accounting for 65.74% of the cases. The median disease duration was 15 years, and the average initial oral examination score was 5.53 ± 1.65. No statistically significant differences in general demographics or baseline characteristics were observed between the two groups ($P > 0.05$) (Table 1).

Comparison of the outcome indicators before intervention

No significant differences were observed between the two groups in the following pre-intervention outcome indicators: PLI score ($Z = -0.961$, $P = 0.337$), GOHAI score ($t = 1.020$, $P = 0.310$), DI-S score ($t = 0.219$, $P = 0.827$), CI-S score ($Z = -0.782$, $P = 0.434$), total score of knowledge, attitude, and behavior ($t = 0.645$, $P = 0.521$), knowledge dimension score ($Z = -1.046$, $P = 0.296$), attitude dimension score ($t = -0.250$, $P = 0.803$), behavior dimension score ($t = 0.780$, $P = 0.437$) (Table 2).

Comparison of the outcome indicators after intervention

After the intervention, no significant difference was observed in the GOHAI scores between the two groups ($t = -0.676$, $P = 0.50$). However, significant differences were found in several other measures. The PLI score showed a notable increase ($Z = -6.220$, $P < 0.001$), as did the DI-S score ($Z = -7.167$, $P < 0.001$), and the CI-S score ($Z = -2.724$, $P = 0.006 < 0.05$). Additionally, the total score for knowledge, attitude, and behavior significantly increased ($t = 3.582$, $P < 0.001$), along with improvements in the knowledge dimension score ($t = 3.226$, $P = 0.002$), attitude dimension score ($t = 3.235$, $P = 0.002$), and behavior dimension score ($Z = -3.601$, $P < 0.001$) (Table 3).

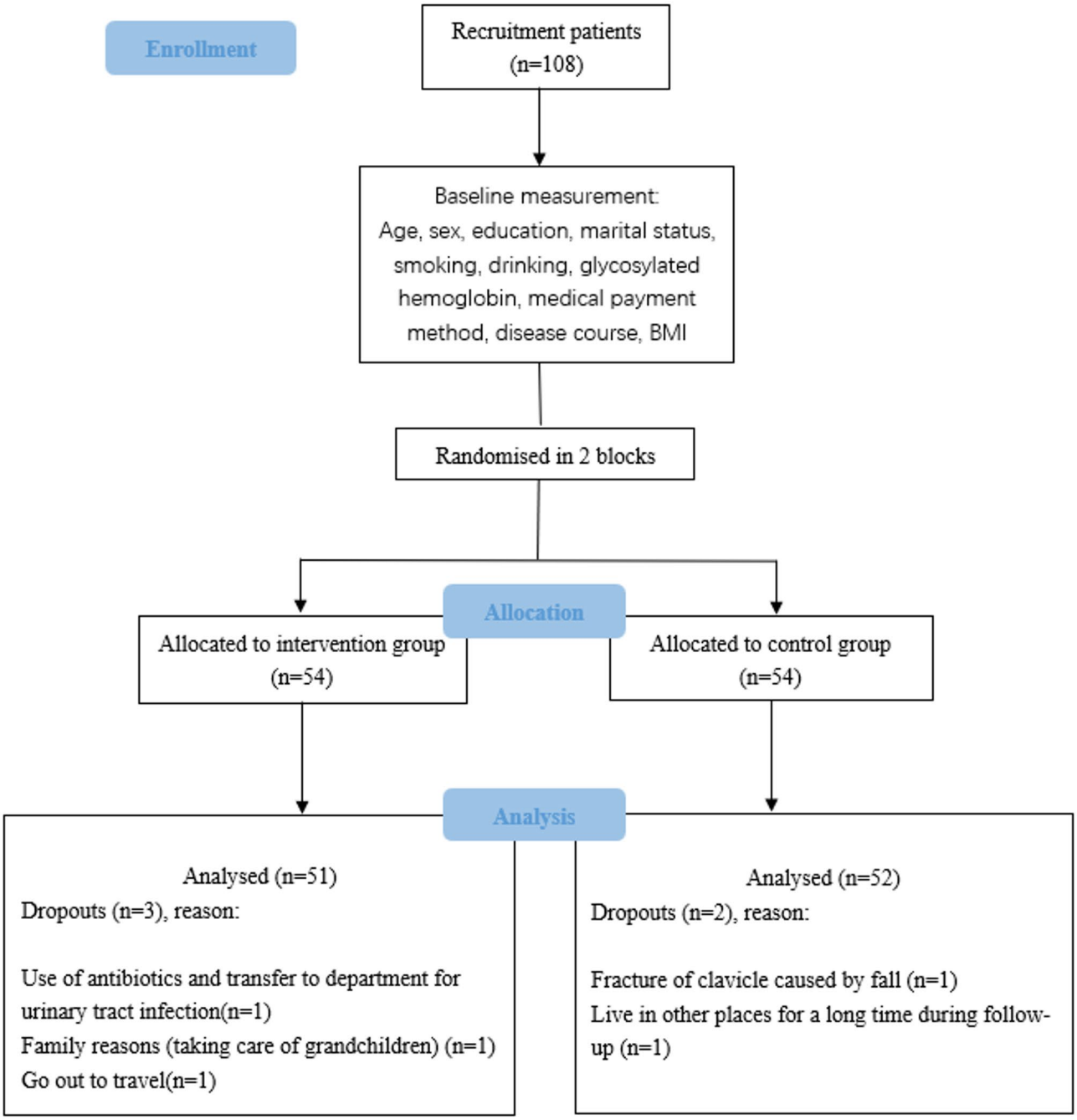

Fig. 1. Flowchart of the study.

Comparison of the outcome indicators in the experimental group before and after intervention

Significant improvements were observed in the experimental group after the intervention across multiple measures: PLI score ($Z=-6.461$, $P<0.001$), GOHAI score ($t=11.672$, $P<0.001$), DI-S score ($Z=-6.415$, $P<0.001$), CI-S score ($Z=-5.195$, $P<0.001$), total score of knowledge, attitude, and behavior ($t=-13.640$, $P<0.001$), knowledge dimension score ($Z=-6.163$, $P<0.001$), attitude dimension score ($t=-5.009$, $P<0.001$), behavior dimension score ($t=-8.409$, $P<0.001$) (Table 4).

Comparison of the outcome indicators in the control group before and after intervention

No significant differences were observed in the control group before and after the intervention for the PLI score ($t=1.868$, $P=0.068$), GOHAI score ($t=1.983$, $P=0.053$), DI-S score ($t=1.958$, $P=0.056$), total score of knowledge, attitude, and behavior ($t=0.485$, $P=0.630$), knowledge dimension score ($t=0.164$, $P=0.870$), attitude dimension score ($t=-0.340$, $P=0.735$), behavior dimension score ($Z=-1.686$, $P=0.092$). However, a significant improvement was observed in the CI-S score ($Z=-5.195$, $P<0.001$) (Table 5).

Variable	Total (n = 108)	Experiment (n = 54)	Control (n = 54)	F/χ^2	P
Age, years	67.0 (63,72)	67.5 (63,72)	67.0 (62,72)	− 0.308[a]	0.758
Sex				0.153[b]	0.695
Male	64 (59.26)	31 (57.41)	33 (61.11)		
Female	44 (40.74)	23 (42.59)	21 (38.89)		
Education, %				3.391[b]	0.335
Elementary school or less	39 (36.11)	15 (27.78)	24 (44.44)		
Middle school graduate	42 (38.89)	23 (42.59)	19 (35.19)		
High school or secondary specialized school	15 (13.89)	9 (16.67)	6 (11.11)		
Junior college or more	12 (11.11)	7 (12.96)	5 (9.26)		
Marital status, %				/	0.745
Unmarried	2 (1.85)	2 (3.70)	0 (0.00)		
Married	104 (96.30)	51 (94.44)	53 (98.15)		
Bereaved	2 (1.85)	1 (1.85)	1 (1.85)		
Smoking, %				1.313[b]	0.252
No	94	45	49		
Yes	14	9	5		
Alcohol consumption, %				1.313[b]	0.252
No	94	49	45		
Yes	14	5	9		
Glycosylated hemoglobin	8.35(7.20, 10.08)	8.30 (7.20, 9.83)	8.55 (7.28, 10.63)	− 0.565[a]	0.572
Medical payment method, %				2.014[b]	0.156
Urban medical insurance	37(34.26)	15 (27.78)	22 (40.74)		
Provincial and municipal medical insurance	71(65.74)	39 (72.22)	32 (59.26)		
Disease course, years	15.0 (10,20)	15.0 (10,20)	12.5 (8,20)		
BMI, kg/m^2	5.53 ± 1.65	5.63 ± 1.62	5.43 ± 1.66	0.222[c]	0.525

Table 1. Comparison of general data between the two groups. BMI, body mass index [a]U-test; [b]χ^2 test; [c]t-test.

Variable	Experiment (n = 54)	Control (n = 54)	Z/t	P
PLI	1.75 (1.5, 2.08)	1.64 ± 0.41	− 0.961[a]	0.337
GOHAI	17.69 ± 5.18	16.72 ± 4.52	1.020[b]	0.310
DI-S	1.77 ± 0.48	1.75 ± 0.43	0.219[b]	0.827
CI-S	1.00 (0.67, 1.33)	0.83 (0.67, 1.17)	− 0.782[a]	0.434
Total score of knowledge, attitude, and behavior	85.43 ± 15.39	83.54 ± 14.77	0.645[b]	0.521
Knowledge dimension score	39.00 (32.00,42.00)	37.30 ± 6.74	− 1.046[a]	0.296
Attitude dimension score	21.98 ± 4.55	22.19 ± 3.82	− 0.250[b]	0.803
Behavior dimension score	24.93 ± 5.45	24.06 ± 6.03	0.780[b]	0.437

Table 2. Comparison of the outcome indicators before intervention. PLI, Plaque Index; GOHAI, Geriatric Oral Health Assessment Index; DI-S, Debris Index-Simplified; CI-S, Calculus Index-Simplified [a]Wilcoxon signed-rank test; [b] t-test.

Discussion

Periodontal health intervention programs based on the Pender HPM can improve the knowledge, attitude, and behavior of older adults with T2DM regarding oral health. These programs encourage greater attention to oral health, effectively manage plaque build-up to prevent the occurrence or progression of periodontitis, and improve overall oral hygiene. Such interventions are of great significance in improving the oral health status of older individuals.

For assessing oral health-related quality of life (OHRQoL), the Oral Health Impact Profile-14 (OHIP-14) is one of the most widely used instruments. However, while OHIP-14 effectively evaluates the impact of oral diseases on the general adult population, it lacks specificity for elderly individuals. Therefore, in the present study, we selected the Geriatric Oral Health Assessment Index (GOHAI), which has been validated as more suitable for Asian older adults, thereby minimizing potential cultural bias. Moreover, GOHAI places greater emphasis on functional improvement in oral health, aligning with the core principles of the Pender Health Promotion Model, which prioritizes enhancing individuals' capacity for self-care and functional well-being.

The reasons why periodontal parameters such as probing depth (PD), bleeding on probing (BOP) and clinical attachment loss (CAL) were not measured in this experiment were mainly based on the following practical

Variable	Experiment (n = 51)	Control (n = 52)	*Z/t*	*P*
PLI	1.25 (1.08, 1.42)	1.65 ± 0.39	− 6.220[a]	< 0.001
GOHAI	15.98 ± 5.03	16.62 ± 4.39	− 0.676[b]	0.500
DI-S	1.00 (0.83, 1.33)	1.71 ± 0.41	− 7.167[a]	< 0.001
CI-S	0.83 (0.50, 1.17)	1.01 ± 0.35	− 2.724[a]	0.006
Total score of knowledge, attitude, and behavior	94.44 ± 15.30	83.50 ± 15.43	3.582[b]	< 0.001
Knowledge dimension score	42.13 ± 7.37	37.37 ± 7.17	3.226[b]	0.002
Attitude dimension score	25.04 ± 4.54	22.25 ± 4.10	3.235[b]	0.002
Behavior dimension score	27.28 ± 5.51	23.00 (19.00, 28.25)	− 3.601[a]	< 0.001

Table 3. Comparison of the outcome indicators after intervention. PLI, Plaque Index; GOHAI, Geriatric Oral Health Assessment Index; DI-S, Debris Index-Simplified; CI-S, Calculus Index-Simplified; [a] Wilcoxon signed-rank test; [b] t-test.

Variable	Before (n = 54)	After (n = 51)	*Z/t*	*P*
PLI	1.75 (1.5,2.08)	1.25 (1.08,1.42)	− 6.461[a]	< 0.001
GOHAI	17.69 ± 5.18	15.98 ± 5.03	11.672[b]	< 0.001
DI-S	1.77 ± 0.48	1.00 (0.83,1.33)	− 6.415[a]	< 0.001
CI-S	1.00 (0.67,1.33)	0.83 (0.50,1.17)	− 5.195[a]	< 0.001
Total score of knowledge, attitude, and behavior	85.43 ± 15.39	94.44 ± 15.30	− 13.640[b]	< 0.001
Knowledge dimension score	39.00 (32.00, 42.00)	42.13 ± 7.37	− 6.163[a]	< 0.001
Attitude dimension score	21.98 ± 4.55	25.04 ± 4.54	− 5.009[b]	< 0.001
Behavior dimension score	24.93 ± 5.45	27.28 ± 5.51	− 8.409[b]	< 0.001

Table 4. Comparison of the outcome indicators in the experimental group before and after intervention. PLI, Plaque Index; GOHAI, Geriatric Oral Health Assessment Index; DI-S, Debris Index-Simplified; CI-S, Calculus Index-Simplified; [a] Wilcoxon signed-rank test; [b] t-test.

Variable	Before(n = 54)	After(n = 52)	*Z/t*	*P*
PLI	1.64 ± 0.41	1.65 ± 0.39	1.868[b]	0.068
GOHAI	16.72 ± 4.52	16.62 ± 4.39	1.983[b]	0.053
DI-S	1.75 ± 0.43	1.71 ± 0.41	1.958[b]	0.056
CI-S	0.83 (0.67, 1.17)	1.01 ± 0.35	− 5.195[a]	< 0.001
Total score of knowledge, attitude, and behavior	83.54 ± 14.77	83.50 ± 15.43	0.485[b]	0.630
Knowledge dimension score	37.30 ± 6.74	37.37 ± 7.17	0.164[b]	0.870
Attitude dimension score	22.19 ± 3.82	22.25 ± 4.10	− 0.340[b]	0.735
Behavior dimension score	24.06 ± 6.03	23.00 (19.00, 28.25)	− 1.686[a]	0.092

Table 5. Comparison of the outcome indexes in the control group before and after intervention. PLI, Plaque Index; GOHAI, Geriatric Oral Health Assessment Index; DI-S, Debris Index-Simplified; CI-S, Calculus Index-Simplified; [a] Wilcoxon signed-rank test; [b] paired t-test.

considerations: First, the measurement of PD, CAL and other parameters required professional periodontal probing equipment and rigorously calibrated examiners, and this study lacked more time, professional training and equipment investment, which exceeded the budget of this project; Second, PLI and OHI-S, as sensitive indicators of oral hygiene, can effectively reflect the improvement effect of the intervention on patients' self-oral care. In addition to, for older adults, the acceptance and adherence of a comprehensive periodontal examination is lower, and the choice of simpler, non-invasive metrics can help improve participation rates and data integrity.

This study demonstrates that periodontal intervention programs can improve periodontal health knowledge, attitudes, and behaviors in older adults with T2DM. These findings align with the conclusions of previous studies[34,35]. The Pender HPM has been instrumental in guiding the development of disease prevention strategies. It helps identify and analyze factors that hinder health-promoting behaviors[36], emphasizing the importance of evaluation in health promotion. Furthermore, the model underscores the need for a systematic and comprehensive approach to formulating targeted nursing interventions[37]. In this study, an individualized intervention was designed using the Pender HPM framework, as well as the theory of knowledge, attitude, and behavior. A thorough evaluation of the patient's existing knowledge, attitude, and behavior was conducted to factor in individual barriers to health behavior and integrate theoretical principles with real-life circumstances.

This enabled patients in the experimental group to better understand the relationship between diabetes and periodontitis, recognize the benefits of proper periodontal care, and address behavioral challenges such as mobility disorders. Ultimately, the intervention led to a change in attitudes, encouraging greater attention to periodontal health. Simultaneously, hands-on, face-to-face teaching enhanced patients' learning retention, improved their oral cleaning skills, boosted their self-efficacy, and fostered consistent adherence to periodontal health behavior.

In addition, periodontal health intervention programs have been shown to improve the periodontal health of older individuals with T2DM, aligning with findings from other studies[15,38,39]. Research confirms that tooth brushing is associated with a reduced risk of T2DM[40]. However, long-term adherence to health behaviors, such as proper oral hygiene, depends on patient compliance[41]. Ensuring good compliance involves increasing factors that promote health behavior while reducing those that hinder it. In this study, a systematic and targeted periodontal health intervention was implemented, which provided older adults with T2DM with a comprehensive understanding of the importance of maintaining periodontal health. The program included skills training on proper brushing techniques (including the Pap brushing method), the use of auxiliary cleaning tools such as dental floss and toothpicks, and correct gargling practices. As a result, individuals improved their oral health-related behaviors and self-efficacy, fostering better compliance. Consequently, the intervention led to a reduction in dental plaque, soft scales, and dental calculus.

However, there was no significant difference in GOHAI scores between the experimental and control groups following the intervention. This lack of difference may be attributed to the fact that the GOHAI scale assesses physiological function, and oral care alone cannot substitute for dental restorative treatments aimed at improving oral physiological function[42]. In addition, the 12-week follow-up may be insufficient for perceived benefits to emerge, as GOHAI reflects long-term adaptation and cultural normalization of oral dysfunction in aging populations may attenuate self-reported changes, which explain why perceived oral health quality of life did not improve in parallel with clinical measures. Despite this, GOHAI scores in both groups decreased post-intervention. Periodontal interventions can improve oral health and relieve discomfort. Additionally, the correct cleaning method not only results in cleaner teeth and fresher breath but also improves older adults' satisfaction and self-esteem regarding their oral health. These improvements support their fundamental needs for self-expression and social interaction while also having a positive impact on their psychological and social well-being.

Limitations and prospects

The study has some limitations. First, due to the constraints in time, human resources, and geographic scope, the research was conducted as a single-center study. Participant recruitment was restricted to older self-sufficient adults with T2DM from a tertiary hospital in Fujian Province, which limits the representativeness of the sample and, consequently, the generalizability of the findings. When carrying out relevant studies in the future, we can consider more detailed division of patients in different regions, places, different disease durations, and different age groups, so as to further explore the feasibility and effectiveness of this intervention program. Second, our inclusion criterion (≥ 16 natural teeth) may exclude elderly diabetics with severe tooth loss, who represent a distinct subgroup requiring prosthetic-focused care. While this limits the generalizability of the intervention program to a certain extent, it ensured internal validity for evaluating plaque control in patients with remaining functional dentition. Future trials should test adapted interventions in edentulous populations. Third, due to resource constraints on periodontal probe equipment, specialist staff, and funding, and our original design focus on self-manageable oral hygiene behaviors in older diabetic patients, the study focused only on periodontal health-related outcome measures and failed to measure relevant parameters such as clinical attachment level (CAL), bleeding on probing (BOP), and probing pocket depth (PPD), which limits the ability to evaluate the direct clinical effectiveness of the intervention on periodontal status. It is recommended that future studies include complete periodontal assessment measures where resources permit. In addition, although the GOHAI instrument comprises three subdomains (functional limitation, psychological discomfort, and pain), this study focused primarily on assessing overall OHRQoL changes and thus did not systematically collect or analyze subdomain-specific data. Future investigations should explore domain-specific effects to identify targeted areas for clinical intervention. Finally, the follow-up period of this study is short, 12 weeks may not be sufficient to assess long-term adherence, and no follow-up assessment of periodontal health was performed after the 12-week intervention, and follow-up can be continued at 12 weeks to explore the periodontal health of patients after the end of the intervention cycle in the future.

Conclusions

The intervention program enhances the awareness, attitudes, and behaviors of older individuals with T2DM regarding periodontal health. It motivates them to address oral health proactively, facilitates effective plaque control to prevent the onset or progression of periodontitis, and significantly improves overall oral hygiene quality. Future research should explore the effects and mechanisms of long-term intervention, optimize personalized intervention strategies, and recommend that periodontal intervention be included in the comprehensive management guidelines for diabetes, promote regular periodontal check-ups covered by medical insurance, and integrate oral health education in community health programs to reduce the risk of periodontitis and diabetes complications in elderly patients with T2DM.

Data availability

The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request; E-mail: 54251118@qq.com.

Received: 20 February 2025; Accepted: 24 July 2025
Published online: 31 July 2025

References

1. National Bureau of Statistics. Statistical Bulletin of National Economic and Social Development of the People's Republic of China in 2019 [1] [N]. People's Daily, 2020–02–29 (0.05). https://doi.org/10.28655/n.cnki.nrmrb.2020.002110.
2. Li, Y. et al. Prevalence of diabetes recorded in mainland China using 2018 diagnostic criteria from the American Diabetes Association: National cross sectional study. *BMJ* **369**, m997 (2020).
3. Löe, H. Periodontal disease. The sixth complication of diabetes mellitus. *Diabetes Care* **16**, 329–334 (1993).
4. Lin, Z. J. Study on the emergency treatment effect of insulin in patients with diabetic ketoacidosis. *China Med. Pharm.* **11**(17), 216–219 (2021).
5. Sanz, M. et al. Scientific evidence on the links between periodontal diseases and diabetes: consensus report and guidelines of the joint workshop on periodontal diseases and diabetes by the International Diabetes Federation and the European federation of periodontology. *J. Clin. Periodontol.* **45**, 138–149 (2018).
6. Demmer, R. T. et al. The influence of type 1 and type 2 diabetes on periodontal disease progression: Prospective results from the Study of Health in Pomerania (SHIP). *Diabetes Care* **35**, 2036–2042 (2012).
7. Lina, J. Effect of continuous oral health education on oral health behavior of patients with periodontal disease. *Gansu Med. J.* **38**, 406408 (2019).
8. Ting, L., Xin, C. & Xiaomei, X. Analysis of oral problems in patients with diabetes mellitus and its nursing methods. *Diabetes New World.* **24**, 147–151 (2021).
9. Min, G., Fei, H., Dan, X. & Peipei, W. Maintenance of oral hygiene in patients with diabetes. *Jiangsu J. Health Care* **5**, 11 (2022).
10. Fengwei, Q. Effect of oral health education on elderly diabetic patients with periodontitis. *J. Qilu Nurs.* **24**, 86–88 (2018).
11. Jia, W. Epidemic status, prevention and treatment of diabetic oral diseases. *Doctor* **3**, 98–99 (2018).
12. Chen, J. Study on the significance of oral hygiene combined with exercise intervention guidance in diabetic patients with chronic periodontitis. *Chin. Pract. Med.* **16**, 203–205 (2021).
13. Yan, Z., Hongwei, G. & Wei, Z. Study on the effect of oral homeostasis on oral health in elderly patients with diabetes mellitus. *J. Changchun Univ. Trad. Chin. Med.* **37**, 927–929 (2021).
14. Saengtipbovorn, S. & Taneepanichskul, S. Effectiveness of lifestyle change plus dental care (LCDC) program on improving glycemic and periodontal status in the elderly with type 2 diabetes. *BMC Oral Health* **14**, 72 (2014).
15. Maryam, M. et al. A randomized controlled trial of an educational intervention to promote oral and dental health of patients with type 2 diabetes mellitus. *BMC Public Health* **20**, 287 (2020).
16. Jiqiang, L. & Chuanshun, Z. Effect of oral health education on elderly patients with diabetes mellitus. *Bipedal Health Care.* **27**, 107–108 (2018).
17. Lijuan, X., Puxin, C., Yurui, H. & Weiyan, L. Effect of health education based on behavior change theory on oral health of elderly patients with diabetes mellitus. *Qilu. J. Nurs.* **27**, 92–95 (2021).
18. Pender, N., Murdaugh, C., & Parsons, M. Health promotion in vulnerable populations. *In: Health Promotion in nursing practice*. 4th ed. Upper Saddle River: Prentice Hall; 2002.
19. Xiaomei, L. & Xianqiong, F. *Introduction to nursing* 4th edn. (People's Medical Publishing House, 2017).
20. Esmaeili Ahangarkolaei, M., Taghipour, A. & Vahedian, S. M. Improvement of self-care for the elderly with high blood pressure based on Pender's model: a semi-experimental study. *Caspian J. Health Aging* **2**, 52–58 (2018).
21. Omidi, A., Soltanian, A. & Esmaili, M. M. The effect of health-related lifestyle self-management intervention on health promotion behaviors in patients with ischemic heart disease. *Avicenna J. Nurs. Midwif. Care* **24**, 174–183 (2016).
22. Mostafa, B. et al. The effect of peer education based on Pender's health promotion model on quality of life, stress management and self-efficacy of patients with multiple sclerosis: A randomized controlled clinical trial. *BMC Neurol.* **22**(1), 144–144 (2022).
23. Masoudi, R. et al. Evaluating the effect of Pender's health promotion model on self-efficacy and treatment adherence behaviors among patients undergoing hemodialysis. *J. Educ. Health Prom.* **9**(1), 197–197 (2020).
24. World Health Organization. Definition and diagnosis of diabetes mellitus and intermediate hyperglycemia: report of a WHO/IDF consultation. 2006. Geneva: WHO Document Production Services; 2006.
25. World Health Organization. Use of glycated haemoglobin (HbA1c)in the diagnosis of diabetes mellitus. Abbreviated report of a WHO consultation; 2011[EB/OL]. (2013-11-12).
26. Tonetti, M. S. et al. A new classification scheme for periodontal diseases. *J. Clin. Periodontol.* **45**(Suppl 20), S1–S8 (2018).
27. Zenthöfer, A. et al. Improving oral hygiene in the long-term care of the elderly–a RCT. *Commun. Dent. Oral Epidemiol.* **41**, 261–268 (2013).
28. Quigley, G. A. & Hein, J. W. Comparative cleansing efficiency of manual and power brushing. *J. Am. Dent. Assoc.* **65**, 26–29 (1962).
29. Turesky, S., Gilmore, N. D. & Glickman, I. Reduced plaque formation by the chloromethyl analogue of victamine C. *J. Periodontol.* **41**, 41–43 (1970).
30. Deyu, H. *Oral Preventive Medicine* 30–31 (People's Medical Publishing House, 2012).
31. Atchison, K. A. & Dolan, T. A. Development of the geriatric Oral Health assessment index. *J. Dent. Educ.* **54**, 680–687 (1990).
32. Weini, X. & Junyi, L. A comparative study of OHIP-14 Chinese version and GOHAI Chinese version. *J. Oral Sci. Res.* **03**, 252257 (2014).
33. Caijun, Z. & Fu, D. Study on the Sinicization, reliability and validity of Kayser-Jones concise oral health checklist. *Nurs. Manag. China* **16**, 38–41 (2016).
34. Feng, N. Observation and evaluation of oral health education for patients with diabetic periodontitis. *Diabetes New World* **23**, 135–137 (2020).
35. Cinar, A. B., Freeman, R. & Schou, L. A new complementary approach for oral health and diabetes management: Health coaching. *Int. Dent. J.* **68**, 54–64 (2018).
36. Junwen, L. et al. Qualitative study on influencing factors of dietary compliance in patients with chronic liver disease based on Pender health promotion model. *Chin. Evid.-Based Nurs.* **9**, 3336–3340 (2023).
37. Poudel, P. et al. Oral health knowledge, attitudes and care practices of people with diabetes: A systematic review. *BMC Public Health* **18**, 577 (2018).
38. Yuan, W., Chunmei, Z. & Xiaoyan, G. Effect of comprehensive nursing intervention on oral treatment of diabetic patients with chronic periodontitis. *Chin. Mod. Med.* **27**(228–30), 234 (2020).
39. Ping, Z. & Kui, W. Effect of intensive oral exercise on oral health of diabetic patients with periodontitis. *Chin. Gen. Pract. Nurs.* **20**, 1531–1533 (2022).
40. Wang, Y. et al. Associations of oral hygiene with incident hypertension and type 2 diabetes mellitus: A population based cohort study in Southwest ChinaJ. *J. Clin. Hypertens. (Greenwich)* **24**, 483–492 (2022).
41. Eckerd, L. C. Complementary and alternative therapy use in breast cancer: Notable findings. *J. Christ. Nurs.* **30**, 218–225 (2013).
42. Yufei, L. *Study on the Effect of Comprehensive Oral Nursing Intervention for the Elderly in Pension Institutions* (Jilin University, 2019).

Acknowledgements
We thank all the participants for their voluntary participation in this study. We also acknowledge the support from the Department of Endocrinology and Metabolism, a tertiary hospital in Fujian Province, for recruiting the study participants.

Author contributions
CXX, LZ, and ZXL wrote the first draft. QNX, SPL, and SYZ contributed to data collection. CXX, LZ, and ZXL contributed to all the data, statistical analyses, and data interpretation. HPS contributed to the research concept, supervised the study, and revised the manuscript. All the authors have read and approved the final version of the manuscript.

Funding
This study was supported by National Key R&D Program of China (No.2020YFC2008500).

Declarations

Competing interests
The authors declare no competing interests.

Ethical approval
This study was approved by the Ethics Committee of Grade Tertiary Hospital in Fuzhou City, China (IRB No. 2023KY071), and written informed consent was obtained from all participants. The study protocol was registered with the China Clinical Trial Registry (ChiCTR2300073533) prior to its commencement.

Additional information
Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-025-13434-0.

Correspondence and requests for materials should be addressed to H.S.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.