Original Article

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# Impaired oral function in older adults with type 2 diabetes

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**Objective:** This cross-sectional study aimed to identify the occurrence of impaired oral functions (the number of teeth present, subjective difficulties in eating tough food and swallowing, oral moisture, chewing ability, and oral diadochokinesis (ODK)) in community-dwelling older adults with type 2 diabetes.

**Materials and Methods:** One hundred participants aged 60 and above in Lop Buri province, Thailand, were enrolled in this study. Demographic data, clinical data, and oral status were collected using questionnaires, medical records, and clinical examination. Oral moisture was measured using an oral moisture-checking device. Color-changeable chewing gum and a color scale were used to evaluate chewing ability. To evaluate ODK, the participants were asked to repeat each single syllable /pa/, /ta/, /ka/ for 5 seconds. The number of repetitions per second was recorded using the pen-dotting method. The data were analyzed using Pearson's chi-squared test, Fisher's exact test, correlation test, independent sample t-test, and the Mann-Whitney test.

**Results:** The most common impaired oral function was decreased ODK (85%), followed closely by a decrease in the number of posterior occluding teeth (83%), subjective difficulties in eating tough food (72%), compromised chewing ability (35%), and impaired oral moisture (23%). Only 8% of the participants reported swallowing difficulties. Eighty-three participants (83%) experienced ≥3 impaired oral functions.

**Conclusions:** This study revealed the presence of impaired oral function in a group of diabetic older persons. The rapidity of lip and tongue movement, chewing ability, and oral moisture decreased in function. A decrease in oral function tended to correspond with increasing age and blood glucose level.

**Keywords:** diabetes mellitus, diadochokinesis, mastication, mouth dryness, older adults, oral health, type 2 diabetes

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## Introduction

The increase in life expectancy has resulted in an increase in the world's older population. The aging process leads to a gradual decline in both physiological and functional aspects of several organs. This may result in reduced resistance to stressors and an increase in the risk of poor health that is called frailty. Therefore, frailty is one of the most important obstacles to healthy aging [1]. As a result, older individuals are at risk of becoming functionally impaired and require support or

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long-term care in the future. Oral and dental health is frequently overlooked among this population because of numerous comorbidities, such as neuromuscular diseases, and their poor manual dexterity. This vulnerability increases their susceptibility to developing many dental and oral diseases, such as caries, periodontitis, dry mouth, and tooth loss. These dental and oral diseases are responsible for mastication difficulties and difficulties in controlling chronic diseases [2]. Previous studies in older persons [3, 4] have demonstrated a relationship between poor oral health and poor oral function. This connection can lead to malnourishment, muscle weakness, sarcopenia, and frailty.

Oral functions play a crucial role in oral health and overall quality of life. They comprise motor, secretory, and sensory functions. Oral motor functions include occlusal force, tongue function, lip function, masticatory function, and swallowing function. Oral secretory function involves salivary secretion, whereas oral sensory functions include how the oral tissue perceives taste, texture, and temperature [5, 6]. In older adults, oral functions may decline due to age-related changes, systemic diseases, and oral diseases [7]. The oral functions in older people have been assessed based on two concepts to indicate oral function impairment: oral frailty [8] and oral hypofunction [9]. Oral frailty is related to aging and coincides with a decreased interest in oral health and reduced physical and mental reserve capacity. The criteria for diagnosing oral frailty are based on the number of present teeth, chewing ability, oral diadochokinesis (ODK) or tongue-lip motor function or articulatory oral motor skill, tongue pressure, and subjective difficulties in eating and swallowing [8]. The diagnosis of oral frailty is met when individuals have three or more of six of the mentioned criteria [8]. Oral hypofunction is defined as a disease where the oral function is complexly reduced, not only by aging, but also by various of factors, such as diseases and disorders. The evaluation components of oral hypofunction are oral uncleanness, oral dryness, a decline in occlusal force, a decline in motor function of tongue and lips, a decline in tongue pressure, masticatory function, and swallowing function. When three or more of the seven criteria are diagnosed, that person is evaluated as having oral hypofunction [10].

Progressive declined or impaired oral function may range from little impairment that interferes with the quality of life, such as reduced salivation, to severe impairment, such as dysphagia, and may subsequently lead to death. According to Kamden *et al.* [11] and Tanaka *et al.* [12], poor oral health status based on evaluating masticatory function was an important factor that could lead to frailty. Kugimiya *et al.* [10] investigated the rate of oral frailty and oral hypofunction in rural community-dwelling older Japanese individuals and found that the proportion of participants with decreased occlusal force, the number of teeth present, ODK, tongue pressure, oral moisture, and masticatory performance increased with age in both men and women. Moreover, Shimazaki *et al.* [13] reported that approximately 60% of older adults had oral hypofunction, and decreased swallowing function was strongly associated with frailty. Among the various effects of oral health problems and decreased oral functions on the quality of life, older people may experience poorer nutritional status [14]. The results of previous studies [15], using various indicators in measuring oral functions and nutritional status, indicated that chewing ability affected the nutritional status and body mass index of older people, which might cause sarcopenia and subsequently lead to adverse physical health outcomes. Therefore, it is essential to promote the physical health and overall well-being of older adults by preventing

issues related to poor oral health and maintaining key oral functions, such as mastication, occlusion, swallowing, and enunciation. Additionally, some systemic diseases, for instance, diabetes mellitus (DM), high blood pressure, Parkinson's disease, and cardiovascular diseases, can affect almost all the criteria for impaired oral functions [16]. Several recent studies [17] indicated that tooth loss and reduced masticatory function worsened a patient's nutritional status. Moreover, reduced masticatory function has been reported to be associated with diabetes mellitus [18].

DM is a group of metabolic diseases that cause high blood sugar. It is characterized by chronic hyperglycemia and disturbances in carbohydrate, fat, and protein metabolism that are related to an absolute or relative deficiency in insulin secretion and/or insulin action. This condition leads to frailty, disability, decreased quality of life, shorter healthy life expectancy, and increased mortality and healthcare costs [19, 20]. Most DM patients in Thailand have type 2 diabetes. The incidence and prevalence of DM increase with age. Approximately 20-25% of people between 60 and 79 years old have DM [21]. Because diabetic patients tend to have less saliva and reduced secretory capacity of the salivary glands [22], hyposalivation may affect their oral health and masticatory function. Hence, screening for impaired oral functions could contribute to appropriate interventions to prevent poor clinical outcomes in older adults with DM. The relevant literature addressing the prevalence of impaired oral function in older Thai patients is scarce, and the studies are limited to a few aspects of oral functions [23, 24]. Therefore, investigating the impaired oral functions in older adults with type 2 diabetes using various conditions of oral status and oral function to diagnose impaired oral functions so that appropriate measures to improve oral function is required.

The aim of this study was to identify the occurrence of impaired oral functions. i.e., the number of present teeth, subjective difficulties in eating tough food and swallowing, oral moisture, chewing ability, and ODK in community-dwelling older adults with type 2 diabetes.

## Materials and Methods

### Study design, setting, and population

This cross-sectional study was conducted in the endocrine clinic at Nong Muang Hospital, Lop Buri province, north of Bangkok, Thailand, because of its large population of older persons with type 2 diabetes (24.4% compared with 20.4 % of the total Thai elderly population, in 2020) [25]. The study was approved by the Faculty of Dentistry, Faculty of Pharmacy, Mahidol University Institutional Review Board (COA.No.MU-DT/PY-IRB 2022/059.0911). The participants were informed about the objective of the study and briefly explained how to obtain the data. They were also assured that refusal to participate in the study did not affect the standard of care provided by the hospital. Anonymity, response confidentiality, and participation voluntarism were emphasized before written informed consent was obtained.

The required sample size was calculated based on the prevalence of oral dryness reported by Chomkhakhai *et al.* [23] at 55%. Using a simple formula (Daniel 2018) [26] at a 95% confidence interval, a precision of 0.05 ($\alpha$), p=0.55, and a margin of error (d) = 0.1, the estimated sample size was 96 participants. The target population was Thai individuals living in the community, aged 60 and above, with type 2 diabetes, without mental disabilities, and having ability to communicate. The participants had a score on the cognitive screening test using the Thai version questionnaire of Mini-Cog ≥ 3 out of 5 [27].

The exclusion criteria were individuals who had ketoacidosis [28] or those who had problems with neuro-muscular control of the head and neck that affected patients' swallowing and tongue movement, and those unwilling to participate. Individuals who had acute intra-oral lesions, such as acute candidiasis, suspected oral cancer lesions, and a tendency of a bleeding disorder, such as pyogenic granuloma were screened to be excluded.

Well-trained nurses performed person-to-person interviews using a questionnaire that covered demographic characteristics, medical history, nutritional status, and subjective difficulties in eating and swallowing. Two dentists collected the clinical data, including oral examination and testing for oral functions. One dentist performed the oral examination. The other dentist measured oral moisture, chewing ability, and ODK. Before the commencement of the experiment, the staff received instructions from the investigators regarding the protocols of each measurement. The examiners were calibrated against a specialist in performing oral examinations and measuring oral functions. The data were collected between December 2022 and March 2023.

## Methods

### An interview questionnaire

Demographic characteristics

An interview questionnaire was used to collect the participants' demographic data (age, sex, education, marital status, occupation, medications used, blood pressure, systemic disease, denture wearing, smoking, alcohol drinking, subjective difficulties in eating and swallowing, and nutritional status). Diabetes therapy was collected from the medical records. The question regarding difficulties in eating tough food was based on the one proposed by the World Health Organization Oral Health Questionnaire for Adults [29]. The answer "yes" meant abnormal. Questions regarding difficulties in swallowing were assessed using the Thai version of the self-administered questionnaire for swallowing – the 10-item Eating Assessment Tool (EAT-10). An EAT-10 score of 3 or more indicated abnormal [30]. To evaluate the patients' functional status, cognitive function, and depression, the authors used the Barthel Index of Activities of Daily Living (basic ADL) [31], the Thai version of Mini-Cog [27], and the Thai version of Geriatric Depression Scale-6 (GDS-6) [32], respectively. The total possible scores for basic ADL ranged from 0-20, with lower scores indicating increased disability. The Mini-Cog < 3 indicated dementia and the GDS-6 scores > 2 indicated depression.

Nutritional status

Nutritional status was assessed using the Thai version of the Short-Form Mini Nutritional Assessment (MNA-SF) and the body mass index (BMI-kg/$m^2$). The MNA-SF score of 12-14 indicated normal nutritional status, 8-11 indicated risk of malnutrition, and 0-7 indicated malnourished [33]. Body mass index (BMI) was calculated by dividing body weight (kg) by height in meters squared ($m^2$). According to the Western Pacific Region Office (WPRO) criteria, the cut-off points for the Asian population are classified as: underweight (<18.5 kg/$m^2$), normal range (18.5-22.9 kg/$m^2$), overweight (23-24.9 kg/$m^2$) and obese (≥25.0 kg/$m^2$) [34]

### Oral examination

The oral examinations were performed using a mouth mirror and periodontal probe (Hu-Friedy® 23/CP-11.5B Screening Probe, Germany). Oral health status was evaluated by recording the number of teeth present (excluding third molars) and the number of functional units (posterior

opposing natural tooth pairs) [35, 36]. Teeth with severe decay, retained roots, and teeth with third-degree mobility were not considered functional teeth and were not counted. Less than 20 natural teeth and less than four pairs of functional units were diagnosed as impaired oral function [9]. The denture usage was also recorded. The Decayed, Missing, and Filled teeth (DMFT for permanent teeth), which reflected oral health status, were assessed using the protocol proposed by the World Health Organization [29]. Because periodontal diseases affect the supporting structures of the teeth, the Periodontal Screening and Recording (PSR) score was assessed. The periodontal health scores range from 0-5: no disease (score 0), plaque-associated gingivitis (scores 1-2), or chronic periodontitis (scores 3–4). Furthermore, oral hygiene and gingival condition status were assessed using the dental plaque index (PI) and gingival index (GI), respectively [37]. The PI score was calculated as the average and interpreted: score 0 (excellent oral hygiene), score 0.1-0.9 (good oral hygiene), score 1.0-1.9 (fair oral hygiene), and score 2.0-3.0 (poor oral hygiene). Similar to the PI, the GI score was calculated as a single score between zero and three. Mild inflammation was typically graded between 0.1 and 1.0, moderate inflammation is graded between 1.1 and 2.0, and severe inflammation was denoted by an average score between 2.0 and 3.0.

## Oral functions assessment

### Oral moisture measurement

The oral wetness was measured using the oral moisture checking device (Mucus®, Life Co., Saitama, Japan) [38]. The tip of the device covered with a covering sheet was placed on the dorsum of the tongue (10 mm apart from the tip of the tongue), and ≥ 200 g/cm² pressure was applied for 2 seconds. The measurement was repeated three times, and the average value for each participant was calculated. Oral moisture less than 27.9 indicated oral dryness [39].

### Chewing ability test

The masticatory performance consists of comminution ability and mixing ability. This study assessed mixing ability using color-changeable chewing gum (XYLITOL; Lotte Co., Ltd., Saitama, Japan). The color change in the gum was used to assess mixing ability. The participant was instructed to chew a piece of chewing gum that could change color from yellowish-green to red as it was masticated. Those with dentures were asked to wear them during the mastication process. As mastication proceeded, the chewing gum changed color from green to yellow, light pink, pink, and red. The participants were asked to masticate the chewing gum in a normal manner with approximately one stroke per second for 2 minutes. The chewing gum was collected, placed between two clear polyethylene films, and flattened to a 1.5 mm thickness controlled by two glass plates. The color of the chewed gum was determined immediately after chewing to minimize the time-related changes in color. The color was evaluated through the polyethylene film in 5 positions: at the center and four positions of 3 mm above, below, to the left, and to the right of the center spot. A five-color scale was used to assess the color change. The color within each square was classified into five categories: green, yellow, light pink, pink, and red. The scoring was counted by giving green one point, yellow two points, light pink three points, pink four points, red five points, and the mean score was calculated. The mean score of five positions ranging from 1 to 5 indicated 1: very poor, 2: poor, 3: moderate, 4: good, 5: very good chewing ability. The mean score ≤ 3 was assessed as impaired chewing ability [40].

### ODK, Articulatory oral motor skill

The ODK test, or articulatory motor skill, was

used to assess decreased tongue-lip motor function by evaluating the speed and regularity of articulatory organs at the lips, tongue tip, and tongue dorsum. To test the articulatory oral motor skill, the participants were asked to repeat each single syllable -/pa/, /ta/, /ka/- sequentially as fast as possible, in one breath or for 5 seconds. Each syllable was repeated twice to avoid fatigue for the participant [41]. The number of repetitions per second was recorded by a dentist using the pen dotting method synchronized with the syllables and calculated as the repetition speed per second of the syllables. The number of any given syllable -/pa/, /ta/, /ka/- produced per second less than six indicated articulatory oral motor skill deterioration [16].

### Statistical analysis

The questionnaires were checked for completeness, and the score for each part of each individual was summarized. The complete data of the participants was analyzed by a prepared database. The outcome of this research was the occurrence of impaired oral function in older adults with type 2 diabetes. Statistical analysis was performed by IBM SPSS 28 (Chicago: SPSS Inc.). Descriptive statistics were employed to summarize the characteristics of participants as frequency, percentage, mean (±SD) or median (first and third quartile). Pearson's chi-squared test and Fisher's exact test were used to determine the association of qualitative variables. Correlation was used to determine the correlation of quantitative variables. Independent samples t-test and Mann-Whitney test were used to compare mean and median. The statistical significance threshold was set at $p < 0.05$ for all analyses.

## Results

### Demographic characteristics

The demographic and clinical data of the participants are presented in Table 1. The participants' age, GDS-6 score, MNA-SF score, ADL score, and Mini-Cog score did not have a normal distribution, thus, the average values are shown as the median (first quartile, third quartile). One-hundred diabetic patients with a median age of 68 years (64, 72.75) (age range: 60-88 years) participated in the study. The median duration of DM among the population involved in this study was 10 years (8.0, 11.0). Two-thirds of the participants were female (63%) and married (70%). Eighty percent of the participants had completed primary school, and 73% were still working. Most of them (91%) did not have regular dental visits. Only 13% and 5% of the patients had habits of alcohol drinking and smoking, respectively.

Table 1 Socio-demographic characteristics

| Characteristic | n (%) / Median ($P_{25}$, $P_{75}$) | | | *p-value* |
|---|---|---|---|---|
| | Total | Female (n = 63) | Male (n = 37) | |
| Age (years) | 68 (64, 72.75) | 66 (63, 72) | 68 (64, 73.5) | 0.264 |
| - 60-69 | 62 | 41 (65.1) | 21 (56.8) | |
| - 70-79 | 34 | 20 (31.7) | 14 (37.8) | |
| - ≥ 80 | 4 | 2 (3.2) | 2 (5.4) | |

Table 1 Continued

| Characteristic | n (%) / Median ($P_{25}$, $P_{75}$) | | | *p-value* |
|---|---|---|---|---|
| | Total | Female (n = 63) | Male (n = 37) | |
| Marital status | | | | |
| - Married | 70 | 41 (65.1) | 29 (78.4) | 0.362 |
| - Single | 10 | 7 (11.1) | 3 (8.1) | |
| - Widowed/ Divorced | 20 | 15 (23.8) | 5 (13.5) | |
| Educational level | | | | |
| - Illiterate | 6 | 5 (8.2) | 1 (2.8) | 0.068 |
| - Primary school | 80 | 51 (83.6) | 26 (72.2) | |
| - Above primary school | 14 | 5 (8.2) | 9 (25.0) | |
| Occupation | | | | |
| - Still working | 73 | 45 (71.4) | 28 (75.7) | 0.816 |
| - Pensioner/Not working | 27 | 18 (28.6) | 9 (24.3) | |
| Alcohol drinking | | | | |
| - No alcohol drinking | 87 | 62 (98.4) | 25 (67.6) | 0.001* |
| - Alcohol drinking | 13 | 1 (1.6) | 12 (32.4) | |
| Smoking habit | | | | |
| - Non-smoking | 87 | 63 (100.0) | 24 (69.4) | 0.001* |
| - Quit smoking (> 6 months) | 8 | 0 (0) | 8 (21.6) | |
| - Smoking | 5 | 0 (0) | 5 (13.5) | |
| Regular dental check-up | | | | |
| - Every 6 months - 1 year | 9 | 6 (9.5) | 3 (8.1) | 1.000 |
| - When symptoms are present | 91 | 57 (90.5) | 34 (91.9) | |
| Number of types of drugs taken | | | | |
| - ≤ 5 drugs | 34 | 23 (36.5) | 11 (29.7) | 0.521 |
| - > 5 drugs | 66 | 40 (63.5) | 26 (70.3) | |
| Hypertension | | | | |
| - Yes | 83 | 54 (85.7) | 29 (78.4) | 0.412 |
| - No | 17 | 9 (14.3) | 8 (21.6) | |
| Dyslipidemia (DLP) | | | | |
| - Yes | 84 | 57 (90.5) | 27 (27.0) | 0.027* |
| - No | 16 | 6 (9.5) | 10 (73.0) | |
| Cardiovascular disease | | | | |
| - Yes | 10 | 5 (7.9) | 5 (13.5) | 0.492 |
| - No | 90 | 58 (92.1) | 32 (86.5) | |

Table 1 Continued

| Characteristic | n (%) / Median ($P_{25}$, $P_{75}$) | | | *p-value* |
|---|---|---|---|---|
| | Total | Female (n = 63) | Male (n = 37) | |
| Chronic kidney disease | | | | |
| - Yes | 12 | 7 (11.1) | 5 (13.5) | 0.756 |
| - No | 88 | 56 (88.9) | 32 (86.5) | |
| Retinopathy | | | | |
| - Yes | 26 | 17 (27.0) | 9 (24.3) | 0.818 |
| - No | 74 | 46 (73.0) | 28 (75.7) | |
| Neuropathy | | | | |
| - Yes | 22 | 17 (27.0) | 5 (13.5) | 0.139 |
| - No | 78 | 46 (73.0) | 32 (86.5) | |
| FBS (mg/dl) | 143 (123, 167) | 144 (123, 164) | 141 (121, 171.5) | 0.200 |
| - < 130 | 35 | 19 (30.2) | 16 (43.2) | |
| - ≥ 130 | 65 | 44 (69.8) | 21 (56.8) | |
| HbA1C (n = 92) | 7.3 (6.33, 8.5) | 7.45 (6.4, 8.5) | 7.2 (6.17, 8.57) | 0.517 |
| - < 7.5 | 49 | 29 (50.0) | 20 (58.8) | |
| - ≥ 7.5 | 43 | 29 (50.0) | 14 (41.2) | |
| ADL score | 20 (19,20) | 20 (19,20) | 20 (19,20) | 0.272 |
| Nutritional status (MNA-SF) score | | | | |
| - Malnourished | 4 | 3 (4.8) | 1 (2.7) | 1.000 |
| - At risk of malnutrition | 41 | 26 (41.3) | 15 (40.5) | |
| - Normal nutrition | 55 | 34 (54.0) | 21 (56.8) | |
| Body mass index ($kg/m^2$) | | | | |
| - Underweight (< 18.5) | 4 | 3 (4.8) | 1 (2.7) | 0.772 |
| - Normal (18.5 -22.9) | 25 | 15 (23.8) | 10 (27.0) | |
| - Overweight (23 – 24.9) | 25 | 14 (22.2) | 11 (29.7) | |
| - Obese (≥ 25) | 46 | 31 (49.2) | 15 (40.5) | |
| Psychosocial status (Mini-Cog) | 4 (3,5) | 3 (3,5) | 4 (3,5) | 0.217 |
| Depression (GDS-6) score | 0 (0,0) | 0 (0,0) | 0 (0,0) | 0.233 |
| - Normal | 92 | 56 (88.9) | 36 (97.3) | |
| - Tend to depression | 8 | 7 (11.1) | 1 (2.7) | |

Abbreviation: FBS = fasting blood sugar; ADL = activity of daily living

Regarding the clinical examination, more than 80% had hypertension and dyslipidemia (DLP). More than half of the participants (65%) had fasting blood sugar (FBS) levels of ≥ 130 mg/dl, and 46.7% had HbA1C ≥ 7.5, which were classified as poorly controlled diabetes [42]. In addition, all participants over 76 years old had FBS ≥ 130 mg/dl. Among this group of patients, the results revealed that those 70 years and older were significantly associated with poorly controlled diabetes (FBS ≥ 130 mg/dl) ($p$ = 0.042). The median ADL score of the whole participants was 20 (19, 20) (score range: 12-20) which was classified as socially bound older persons. The median MNA-SF score was 12 (10,13) (score range: 4-13), classified as normal nutrition (55%) to risk of malnutrition (41%). According to their BMI score, 46% of the participants were categorized as obese and 25% as overweight. The median Mini-Cog score was 4 (3,5) (score 3-5), and no participants had dementia. No subjects had impaired cognitive function based on the median GDS-6 score of 0. Two-thirds of the participants took more than five medicines daily [43].

## Oral examination

Table 2 presents the oral health status in the diabetic patient group. Tooth decay and periodontal disease were observed. The PI and GI scores indicated that the participants had fair oral hygiene with mild to moderate gingival inflammation. The median PSR score was 3 (2.75, 4), with

Table 2 Oral health status

| Evaluated aspects | n (%) / Median ($P_{25}$, $P_{75}$) | | | *p-value* |
|---|---|---|---|---|
| | Total | Female (n = 63) | Male (n = 37) | |
| Dental status | | | | |
| Number of teeth | 13 (1.5, 21.75) | 11 (1, 19) | 16 (5, 23) | 0.146 |
| - Edentulous | 22 (22) | 15 (23.8) | 7 (18.9) | |
| - < 20 teeth | 50 (50) | 34 (54.0) | 16 (43.2) | |
| - ≥ 20 teeth | 28 (28) | 14 (22.2) | 14 (37.9) | |
| Number of functional unit | 0 (0, 2) | 0 (0, 2) | 0 (0, 2) | 0.990 |
| - 0 occluding pairs | 65 (65) | 41 (65.0) | 24 (64.9) | |
| - 1-3 occluding pairs | 18 (18) | 11 (17.5) | 7 (18.9) | |
| - ≥ 4 occluding pairs | 17 (17) | 11 (17.5) | 6 (16.2) | |
| DMFT | 18 (12.25, 28) | 19 (13, 28) | 17 (10, 24) | 0.178 |
| Periodontal status | | | | |
| PSR score (n = 78) | 3 (2.75, 4) | 3 (2, 4) | 3 (3, 4) | 0.131 |
| PI score | 1.27 ± 0.358 | 0.916 ±0.604 | 1.108 ± 0.607 | 0.129 |
| GI score | 1.70 (1.05, 1.92) | 1.54 (0.5, 1.38) | 1.79 (1.52, 1.91) | 0.123 |
| Denture wearing (yes) | 31 (31) | 23 (23) | 8 (8) | 0.179 |

Abbreviation: DMFT = Decay Missing Filling tooth; PSR = Periodontal Screening and Recording; PI = Plaque Index; GI = Gingival Index

periodontitis affecting more than half of the participants. Seventy-eight participants retained their natural teeth. The median number of remaining teeth was 13 (1.5, 21.75) (maximum: 28). Only 28% of the participants had 20 teeth or more, and 22% had complete edentulism. Pearson's chi-squared test illustrated that an education level of primary school or less was significantly associated with having fewer than twenty remaining teeth ($p$ = 0.020). When the functional units were considered, the results indicated that 65% had no posterior occluding teeth, and 18% had 1-3 pairs of posterior occluding teeth. Among the participants reporting difficulties in eating tough food (72%), only 31% wore removable dentures for mastication.

There were no statistical differences in the demographic characteristics, clinical data and oral health status between male and female participants, except for dyslipidemia (DLP), alcohol drinking and smoking (Table 1 and 2). Females were associated with dyslipidemia, in contrast, males were associated with alcohol drinking and smoking habits. Therefore, the subsequent analyses were performed in the whole study group.

## Occurrence of impaired oral functions

The occurrence of various aspects of impaired oral functions is shown in Table 3. The most common impaired oral function was decreased tongue-lip oral motor function (ODK, /ta/, /ka/ sounds) (85%), followed by the number of posterior occluding teeth (83%), number of teeth and subjective difficulties in eating tough food (72%), chewing ability (35%), and impaired oral moisture (23%). In contrast, subjective difficulties in swallowing were uncommon in this diabetic group because only 8% of the participants reported this. Regarding the subjective and objective measures of chewing, subjective difficulties in eating tough food were not significantly related to chewing ability ($p$ = 0.103). Furthermore, the results revealed that 6% of the participants (median age: 63 years) had no impaired oral function and 11% (median age: 64 years) experienced 1-2 impaired oral functions and 83% (median age: 68 years) experienced three or more measures (Table 4). However, a gradual decrease in oral functions tended to correspond with increasing age (r = 0.038) ($p$ = 0.001) (Figure 1).

**Table 3** Occurrence of various aspects of impaired oral functions

| Evaluation aspects | Criteria for impaired oral function | n (%) |
|---|---|---|
| Number of teeth | < 20 | 72 (72) |
| Number of functional units | < 4 pairs | 83 (83) |
| Subjective difficulties in eating | yes | 72 (72) |
| Subjective difficulties in swallowing | EAT-10 score ≥ 3 | 8 (8) |
| Oral moisture | ≤ 27.9 | 23 (23) |
| Chewing ability | ≤ 3 | 35 (35) |
| Decreased tongue and lip oral motor function | | |
| - /pa/sounds | < 6 per sec | 72 (72) |
| - /ta/sounds | < 6 per sec | 85 (85) |
| - /ka/sounds | < 6 per sec | 85 (85) |

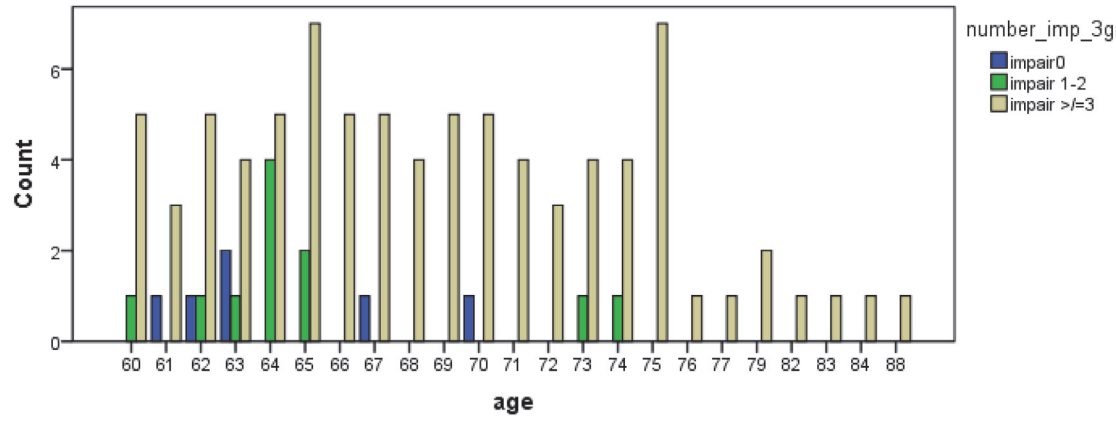


Figure 1 Number of impaired oral function that increase with age

Table 4 Number and median age of participants affected by 0, 1-2, ≥3 impaired oral functions

| Number of impaired oral function | Median age | Number of subjects |
|---|---|---|
| 0 | 63 | 6 |
| 1-2 | 64 | 11 |
| ≥ 3 | 68 | 83 |
| Total | | 100 |

## Discussion

Previous studies [16, 44, 45] have found a significant association between age, DM, and oral function with frailty. These reports strongly support the hypothesis that a decline in mastication and other oral functions is important for physical frailty [8, 46]. Therefore, early detection and improving impaired oral functions in diabetic patients will be beneficial to their health. The present study investigated the impaired oral functions as determined by the number of natural teeth, oral moisture, chewing ability, articulatory oral motor skill, and subjective difficulties in eating and swallowing. These six aspects of impaired oral functions could not be defined as oral frailty, because no tongue pressure measurement was conducted; therefore, the six criteria of oral frailty were not covered.

In the present study, the number of edentulous older participants was 22%. This value was greater than the 8$^{th}$ Thailand oral health survey [47] that reported only 8.7% edentulism among general older adults aged 60-75. Because edentulism is an indicator of poor oral health, the results indicated that older people with DM should be made aware of the importance of oral health care to avoid tooth loss. It also signifies that a public health policy to provide an educational campaign to increase oral health literacy and awareness to all adults before they reach old age is needed.

In general, potential causes of oral dryness include aging, side effects of some medications, such as antihypertensive drugs, antidepressants, and some systemic diseases. Oral dryness has also been reported as a complaint of some diabetic patients. The occurrence of impaired oral moisture determined in this study was 23%, which was in accordance with Kugimiya *et al.* [7] who used an oral moisture checker (Mucus®) to evaluate oral moisture and reported 27% impairment in their study. In contrast, Chomkhakhai *et al.* [23] evaluated oral moisture in Thai patients with metabolic syndrome, and higher oral dryness (55%) was observed. The participants likely had

different systemic conditions, and the evaluation method used to determine oral moisture differed. The present study used the oral moisture checker to measure oral moisture, however, Chomkhakhai *et al.* evaluated oral moisture by observing a film of saliva that covered the oral mucosa and pooling of saliva on the floor of the mouth.

In most studies on chewing performance, the investigators determined the degree of food breakdown by sieving the comminuted food to quantify masticatory performance. However, participants with compromised oral function probably could not break down the test food. Hence, sieving fragmented food particles may be inappropriate for subjects with problematic oral functions [48]. Another method to determine masticatory performance is to evaluate the ability to mix and knead a food bolus using paraffin wax, chewing gum, or gummy jelly. The present study evaluated chewing performance by testing the mixing ability using a color-changeable chewing gum. This modified chewing gum has been widely used [24, 40, 49, 50] because it is simple to use and can differentiate between the levels of masticatory performance. The chewing gum has been tested for its applicability and reproducibility in natural dentate patients and complete denture wearers [51, 52]. Color changes can be assessed using a colorimeter and visual methods. Both methods were compared and the result confirmed the validity and reliability of colorimetric analysis of color-changeable chewing gum using a five-color scale to evaluate masticatory performance [53]. Therefore, the present study assessed the color changes using visual evaluation with a five-color scale. To collect the information on chewing ability, the investigator used an objective measure assessing the color changes in the chewing gum and a subjective measure inquiring about difficulties in eating tough food, so that the participants could express their perception of their chewing capacity. When the two methods were compared, the results indicated that there was no significant association between the objective measure of chewing ability and subjective difficulties in eating. This is not surprising, because the participants' expectation of their ability to chew various foods, personal eating habits, and food preferences may affect their answers. Hence, subjective measures for chewing ability depend on individual satisfaction and may not be comparable with the objective measures.

ODK is universally used for assessing motor speech disorders. The ability to speak is controlled by many body parts, including the cerebellum, central nervous system, and muscles of the face, mouth, and throat [54]. To assess the oro-motor function, ODK relies on counting the repetition of each syllable using various methods, such as the IC (integrated circuit) method, the calculator method, the pen dotting method, and an automatic counting device named KENKOU-KUN handy [9, 55, 56]. The mean value obtained from many studies conducted in community-dwelling older adults was 6-7 times per second for each syllable [9]. The present study used the pen dotting method, and the measurement of each syllable was repeated twice to minimize counting inaccuracy. The number of repetitions per second was calculated and recorded as the repetition speed. The results of this study revealed that impaired tongue-lip motor function was the most common impaired function found. The results confirmed a previous study [16] which reported that a decreased oral function was an age-dependent change and tongue muscle strength declined with age.

The results of this study revealed the presence of impaired oral functions in a group of diabetic older persons. Evaluation of oral function by dentists should not be overlooked. Early detection and appropriate management can

improve oral function. Moreover, patients should be made aware of their decreased oral functions that can lead to deterioration of general health, and the importance of improving oral function through daily training in muscle exercises, particularly tongue-lip motor function exercises [57]. Older people who have difficulty in mastication need to adjust the texture of their food. Additionally, diet counseling with nutritionists would be beneficial because they can help individuals make healthy food choices and develop healthy eating habits. Furthermore, using dental prostheses to replace missing teeth can help maintain the number of occluding teeth and improve masticatory function.

Regarding the data collection of impaired oral functions, we conducted the experiment using objective measures to assess almost all target oral functions, except for swallowing. This approach is a strength of this study due to its reliability compared with using only a questionnaire. Moreover, all participants had passed the cognitive screening test before enrolling in the experiment; therefore, they could understand the tests' instructions and were very cooperative. However, the present study has some limitations. The number of participants involved in this study was limited due to the strict inclusion criteria. All participants had to pass the cognitive screening test and present their blood test reports, including the blood sugar level during the last six months. The limited sample size resulted in an inability to classify the participants by age and sex to obtain clearer results. Furthermore, the current study had a cross-sectional design. Hence, the researchers could not accurately detect the causes and effects of impaired oral functions. Finally, the COVID-19 pandemic caused some restrictions on health services provided by health personnel, and most people, especially older people, avoided going to a hospital. Due to this situation, our participants were recruited from only one hospital. Therefore, this limits the generalizability of the results and they should be interpreted carefully. In a future investigation, researchers should perform a longitudinal study and conduct it using a larger sample size based on various areas so that the causes and effects of impaired oral functions, including physical frailty, can be better determined. In addition, the relationship between various factors and impaired oral functions should be explored.

## Conclusion

This study revealed the presence of impaired oral functions in a group of diabetic older persons. The rapidity of lip and tongue movement, chewing ability, and oral moisture decreased in function. A decrease in oral functions tended to correspond with increasing age and blood glucose levels. Our findings suggest that older people with diabetes should improve their oral health care to avoid tooth loss and maintain masticatory functions. Furthermore, in addition to dental and oral diseases, dentists should pay attention to oral functions to detect impairment and improve oral functions, thereby prolonging their healthy life expectancy.

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