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Prevalence of xerostomia in patients with type 2 diabetes mellitus: a systematic review and meta-analysis

Shuqi Huang[1†], Xin Zeng[1†], Sicheng Deng[2], Sixiu He[2] and Fan Liu[1*]

Abstract

Background Xerostomia is a common complication associated with diabetes mellitus. However, the prevalence of xerostomia in patients with type 2 diabetes mellitus (T2DM) remains unclear. Therefore, the present study aimed to synthesize results from existing research to investigate the prevalence of xerostomia in T2DM patients.

Methods A comprehensive search was conducted in November 2024 across four databases (PubMed, Scopus, Embase, and Web of Science). The search included English literature pertaining to the prevalence of xerostomia in adult patients with T2DM. Conference proceedings, reviews, and literature lacking complete data or containing other diseases affecting xerostomia prevalence were excluded. Two researchers independently assessed the quality of the included studies by using the Joanna Briggs Institute Standardized Critical Appraisal Checklist. Data analyses were performed using Stata version 18.0 software. A proportions approach was used for meta-analysis. If $I^2 > 50\%$, a random-effects model was utilized; otherwise, a fixed-effects model was employed. The pooled estimates of prevalence were calculated through double arcsine transformation. Subgroup analyses were conducted based on study design, continent, evaluation tool, disease duration, and HbA1c.

Results A total of 1355 studies were identified, of which 23 studies encompassing 2486 patients with T2DM met the inclusion criteria. The majority of these studies were small-sample analytical cross-sectional studies using questions about the subjective feeling of oral dryness to assess xerostomia. Risk assessment revealed 2 studies with high risk, 5 with medium risk, and 16 with low risk. The overall prevalence of xerostomia in T2DM patients was 42.49%(95%CI = 36.14–48.46). Subgroup analyses indicated no statistically significant differences based on study design, continent, evaluation tool, disease duration, and HbA1c level.

Conclusions The lack of high-quality prevalence studies may result in inaccurate estimation of xerostomia prevalence among patients with T2DM. Future research should prioritize large-scale prevalence studies by utilizing more accurate assessment tools.

Registration PROSPERO [CRD42022315150].

Keywords Xerostomia, Type 2 diabetes mellitus, Prevalence, Systematic review, Meta-analysis

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Background

Xerostomia, a subjective sensation of oral dryness, is primarily caused by insufficient salivary production, although various factors can contribute to this condition [1]. Xerostomia (subjective symptoms) frequently occurs in conjunction with hyposalivation (objective salivary insufficiency). Saliva plays a crucial role in maintaining oral health by lubricating oral surfaces, rinsing the mouth, and neutralizing acids, thereby preventing dental caries, erosive wear and tear, and mucosal membrane infections [2]. Reduced salivary production can lead to xerostomia, which may manifest as altered taste perception, oral ulcers, dry and cracked lips, halitosis, and occasionally burning sensation [3]. Moreover, xerostomia can result in several complications, including oral ulcers, dental decay, speech difficulties, mastication and deglutition issues, oral mucosal atrophy, respiratory infections, and bacterial accumulation associated with numerous local and systemic complications [4, 5]. Consequently, xerostomia warrants serious consideration and attention.

Xerostomia occurs more frequently in diabetic patients than in nondiabetic individuals. Previous research indicates that diabetic patients exhibit significantly lower total saliva levels at rest and experience greater degrees of dryness at night and upon awakening than their nondiabetic counterparts [6, 7]. This sensation of dryness may result from a substantial decrease in saliva production or alterations in saliva quality [4]. Hyperglycemia in diabetic patients induces polyuria and osmotic diuresis, leading to dehydration, which is associated with reduced salivary flow [1]. Furthermore, microvascular disease and neuropathy in diabetic patients result in endothelial dysfunction and deterioration of microcirculation; these conditions may impair salivary secretion and composition [8]. Additionally, hyperglycemia-induced reactive oxygen species (ROS) production may promote salivary gland damage, contributing to hyposalivation [9]. In patients with T2DM, certain hypoglycemic drugs or other medications and psychological factors may also contribute to xerostomia [6]. In summary, multiple diabetes-related mechanisms contribute to the development of xerostomia. The severity of xerostomia is strongly associated with patients' oral health quality of life and adverse health outcomes [10]. Therefore, it is critical to elucidate the prevalence of xerostomia in diabetic patients and develop effective management strategies.

Recent data from the International Diabetes Federation indicate that 536.6 million adults, representing 10.5% of the global adult population, have diabetes. This number is expected to increase to 783.2 million by 2045 [11]. Type 2 diabetes mellitus (T2DM) is the most prevalent form of diabetes, and previous studies [2, 12] have reported that the prevalence of xerostomia in T2DM patients ranges from 9.68 to 76.47%. These variations may reflect substantial cultural, social, and economic differences between populations as well as study characteristics such as measurement tools and study design. Furthermore, several demographic factors, including age, sex, country, and race, and disease characteristics, such as diabetes duration and glycemic control, may influence the prevalence of xerostomia in diabetic patients [13]. A synthesis of such studies could provide more valuable insights. To date, only one meta-analysis on the prevalence of xerostomia in T2DM patients has been reported [14]. However, this meta-analysis did not rigorously evaluate the quality of the selected literature and included studies only up to December 2014, a decade ago. Therefore, the present study aimed to conduct a comprehensive and updated literature review and synthesize the overall prevalence of xerostomia in T2DM patients to provide more reliable epidemiological data.

Methods

This systematic review and meta-analysis adhered to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The protocol was registered in PROSPERO [PROSPERO ID: CRD42022315150].

Eligibility criteria

Inclusion criteria

We applied the following Population, Intervention, Comparator, and Outcomes (PICO) model to assess the document eligibility:

P) Participants consisted of patients with type 2 diabetes aged ≥ 18 years.

I) Observational study design, not involving interventions.

C) Observational study design, not involving comparisons.

O) The outcome is that the patient develops xerostomia.

Exclusion criteria

(a) retractions, reviews, meta-analyses, case reports, editorials, letters, meeting abstracts, personal comments, or book chapters; (b) studies with insufficient data for prevalence calculation; (c) other illnesses associated with xerostomia, such as Sjögren's syndrome; and (d)language other than English.

Search strategy

We conducted a comprehensive literature search in PubMed, Embase, Scopus, and Web of Science on February 7, 2022, and updated the search on November 1, 2024. The search strategy incorporated both thesaurus

terms specific to each database (such as MeSH and EMTREE) and free-text terms to ensure maximum sensitivity. The PubMed search form served as a template (Supplementary Table S1). Additionally, we manually examined references to identify further relevant studies. All references were managed using Endnote X9 v. 19.3.3 (Clarivate Analytics, US), which facilitated the removal of duplicate entries.

Study selection

Two reviewers (SQH and XZ) conducted an initial screening of titles and abstracts for all potentially eligible publications, with assistance from a third reviewer (FL). This process used broad criteria to ensure the inclusion of any potentially relevant studies for further evaluation. Following the exclusion of studies based on these criteria, the same reviewers assessed full-text articles for inclusion. Any disagreements during this process were resolved through consensus among the reviewers.

Data collection

Two authors (SQH and XZ) independently extracted the data from the selected articles. A standardized full-text analysis was conducted using Excel v. 2015 spreadsheets (Microsoft). The same two authors independently extracted and cross-checked the full-text article data, including study information (first author, year of publication, country, and study design), participant characteristics (sample size, sex, age, HbA1c, duration of disease, and diagnostic criteria for xerostomia), and information necessary for calculating pooled estimates of xerostomia prevalence (prevalence of xerostomia in T2DM patients, number of individuals with xerostomia among T2DM patients, and total number of individuals with T2DM).

Study risk of bias assessment

Two authors (SCD and SXH) independently used the Joanna Briggs Institute (JBI) Standardized Critical Appraisal Checklist for prevalence and analytical cross-sectional studies to evaluate the quality of the included studies [15]. Any discrepancies, when identified, were resolved through consensus or consultation with a third reviewer (FL). Since the checklist does not provide a cut-off score, we categorized studies based on the following criteria: a percentage of "yes" ≥75% indicated a low risk of bias, 50%~75% indicated a medium risk of bias, and < 50% indicated a high risk of bias.

Statistical analysis

This study employed a meta-analysis based on a proportions approach to determine the prevalence of xerostomia in patients with T2DM. Pooled estimates of prevalence were calculated using double arcsine transformation. Heterogeneity estimates for the pooled estimates of prevalence were quantified using the I^2 statistic, with significance determined by Cochran's Q test p value. Initially, a fixed-effects model was applied to detect heterogeneity. If $I^2 > 50\%$, a random-effects model was utilized; otherwise, a fixed-effects model was employed. Forest plots were constructed to graphically represent the overall effect and for subsequent analysis ($p < 0.05$ was considered significant). The effects of moderators (study design, continent, evaluation tool, disease duration, and HbA1c) were assessed by random effects moderator analysis of subgroup analyses. These moderators were selected a priori based on the hypothesized sources of heterogeneity.

To assess the robustness of the pooled results, sensitivity analyses were conducted. These analyses evaluated the impact of individual studies on the final estimates for each meta-analysis. Additionally, Egger's regression test (pEgger < 0.1) was employed to assess small-study effects, including publication bias. All statistical analyses were performed using Stata version 18.0 (Stata Corp) with user-written commands.

Results

Study selection

The updated search identified one article closely related to the topic. However, it was excluded due to incomplete data on the prevalence of xerostomia in T2DM [14]. The literature search yielded 1354 studies across four databases and 1 study from other sources. After removing duplicates, 865 records were screened by title and abstract, and 103 studies were reviewed for their full text. Of these, 23 studies met the eligibility criteria and were subsequently included in the meta-analysis (Fig. 1).

Study characteristics

Table 1 and Supplementary Table S2 show the collected characteristics and variables. The 23 selected studies encompassed 2486 T2DM patients, of whom 1060 were diagnosed with xerostomia. The studies were geographically diverse: 8 in Europe (Finland, Sweden, Spain (2), UK, Poland, Netherlands, and Norway), 7 in Asia (Israel, Thailand, India (2), Iran, Saudi Arabia, and China), 1 in North America (United States), and 7 in South America (Brazil (6) and Chile). The prevalence of xerostomia in T2DM patients ranged from 9.68 [2] to 76.47% [12]. The mean age ranged from 45.9 [16] to 80.2 [17] years. There were 1347 females (62.22%) in the study reporting gender. The mean duration of diabetes ranged from 3.65 [18] to 15.95 [19] years. The mean HbA1c value ranged from 7.1 [20] to 9.7 [21]. Five studies recruited patients from primary health care facilities, while 17 studies involved patients from hospitals or clinics. Most studies were small-sample analytical cross-sectional investigations and primarily utilized subjective oral dryness assessments to evaluate xerostomia.

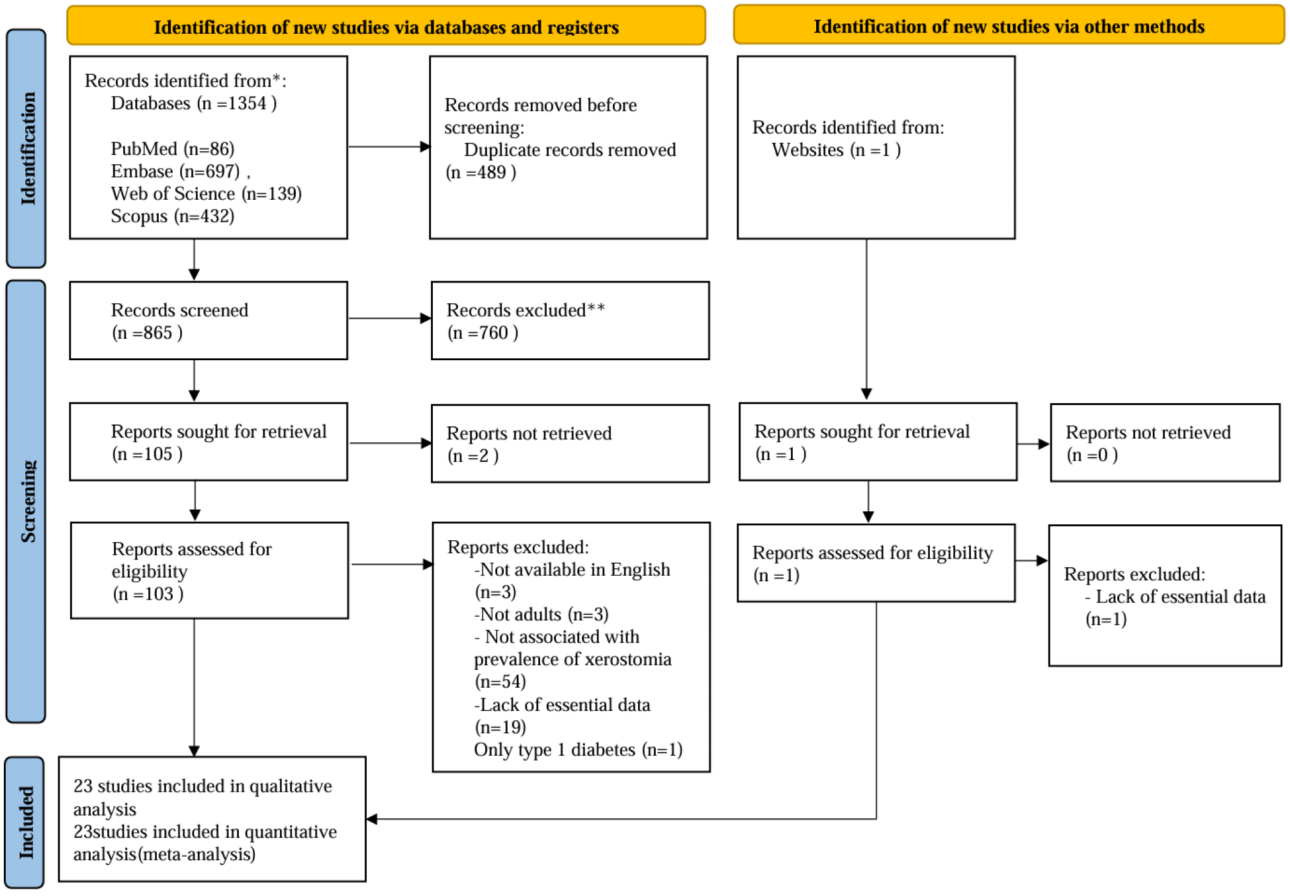

Fig. 1 Results of the literature search and selection process

Risk of bias in studies

The results of the risk of bias assessment showed that 2 studies were classified as high risk, 5 as medium risk, and 16 as low risk(Supplementary Tables S3, S4).

Results of individual studies

The prevalence of xerostomia was reported as 75.51% in China [18], 66% in Saudi Arabia [22], 61.97% in England [23], 61.69% in Thailand [24], 53.54% in Sweden [20], 43.75% in Finland [17], 42.5% in the United States [25], 38.29% in Iran [26], 37.30% in the Netherlands [27], 36.49% in Chile [28], 25.42% in Poland [29], 25% in Israel [16], and 9.68% in Norway [2]. In Spain, different prevalence values were achieved in the two studies: 76.47% [12] and 27.66% [6]. Studies conducted in India reported prevalence rates of 14% [30] and 52% [31]. In Brazil, six studies showed varying prevalence rates: 52.44% [21], 49.17% [19], 48.67% [7], 43.06% [32], 25% [33], and 12.5% [34].

Furthermore, 9 of 23 studies utilized a question about the subjective feeling of oral dryness to evaluate xerostomia [2, 16, 17, 20, 21, 25, 27, 32, 34]. Four studies employed Fox text-related tools [6, 28, 29, 31], one study used the visual analog scale (VAS) [19], and another study used the saliva flow rate [22]. The evaluation methods were unclear in three studies [7, 18, 30], and ffve studies employed other tools [12, 23, 24, 26, 33]. Detailed information about the different evaluation methods of xerostomia is provided in Supplementary Table S5.

Results of syntheses

Overall prevalence of Xerostomia in patients with T2DM

The estimated prevalence of xerostomia in patients with T2DM among the 23 studies was 42.49% (95% CI = 36.14–48.46) according to the random-effects model. The heterogeneity between the studies was high ($I^2 = 88.5\%$, $p < 0.001$) (Fig. 2).

Subgroup analyses

By study design The pooled estimated prevalence of xerostomia in patients with T2DM in analytical cross-sectional study is 44.47%(95% CI = 36.63–52.46), and in prevalence study is 35.19%(95% CI = 25.99–45.47),

Table 1 General characteristics of the included studies

Author /Year	Country (Continent)	Study design	source of Patients	Prevalence (xerostomia sample size/ T2DM patients)	Duration (year)	Sex (M/F)	Age	HbA1c (%)	Evaluation of xerostomia
Sreebny /1992 [25]	America (North America)	ACSS	H/C	17/40 (42.5%)	ND	19/21	48.3 ± 16.5	9.6 ± 2.4	Subjective feeling of xerostomia (Not specified)
Ben-Aryeh /1993 [16]	Israel (Asia)	ACSS	H/C	5/20 (25%)	7.6 ± 4.6	ND	45.9 ± 11.2	ND	Subjective feeling of xerostomia (Not specified)
Zielinski /1996 [17]	Finland (Europe)	ACSS	PHC	14/32 (43.75%)		11/21	80.23 ± 4.43		Subjective feeling of xerostomia (Not specified)
Sandberg/2000 [20]	Sweden (Europe)	ACSS	H/C	53/99 (53.54%)	9.9 ± 6.1	ND	ND	7.1 ± 1.4	Subjective feeling of xerostomia (Not specified)
Carda /2006 [12]	Spain (Europe)	ACSS	H/C	13/17 (76.47%)	ND	10/7	68 (26–86)	ND	Xerostomia subjective test
Bernardi/2007 [21]	Brazil (South America)	ACSS	PHC	43/82 (52.44%)	ND	33/49	56.45 ± 11.28	9.74 ± 2.13	Subjective feeling of xerostomia (Does your mouth usually fell dry? (Yes/no))
Siriban/2009 [24]	Thailand (Asia)	ACSS	H/C	95/154 (61.69%)	10	37/117	63 ± 10	7.8 ± 1.7	Three questions, modified from Fox
Vasconcelos/2010 [34]	Brazil (South America)	ACSS	H/C	5/40 (12.5%)	ND	20/20	57.7 ± 8.9	ND	Subjective feeling of xerostomia "Dose your mouth fell dry frequently? (Yes/no)"
Studies	**Country (Continent)**	**Study design**	**source of Patients**	**Prevalence (xerostomia sample size/ T2DM patients)**	**Duration (year)**	**Sex (M/F)**	**Age**	**HbA1c (%)**	**Evaluation of xerostomia**
Borges/2010 [33]	Brazil (South America)	PS	PHC	13/52 (25%)	ND	5/47	70.54 ± 7.19	ND	Two questions about xerostomia
Bajaj /2012 [30]	India (Asia)	ACSS	NA	7/50 (14%)	ND	ND	ND	ND	ND
Zaid /2012 [23]	England (Europe)	PS	H/C	44/71 (61.97%)	ND	ND	ND	ND	Five questions about symptoms
Nikbin/2014 [26]	Iran (Asia)	PS	H/C	134/350 (38.29%)	8.89 ± 7.05	86/264	55.04 ± 10.76	8.13 ± 1.55	Nine questions about xerostomia (Not specified)
Malicka/2014 [29]	Poland (Europe)	ACSS	H/C	15/59 (25.42%)	ND	31/28	65	ND	validated Fox's test
(Aitken-Saavedra /2015 [28]	Chile (South America)	ACSS	H/C	27/74 (36.49%)	ND	21/53	62.13 ± 10.13	8.63 ± 2.27	the Fox test
Kara /2015 [31]	India (Asia)	ACSS	H/C	26/50 (52%)	ND	ND	ND	ND	the Fox test
Kogawa /2016 [32]	Brazil (South America)	ACSS	H/C	31/72 (43.06%)	6.25 ± 6.5	25/47	57.15 ± 9.19	7.69 ± 1.79	Subjective feeling of xerostomia (Not specified)
Lima /2017 [19]	Brazil (South America)	ACSS	H/C	59/120 (49.17%)	15.95 ± 9.48	38/82	72.26 ± 6.53	ND	The Visual Analog Scale (VAS). The following guiding question was used: "how dry do you feel your mouth?"

Table 1 (continued)

Studies	Country (Continent)	Study design	source of Patients	Prevalence (xerostomia sample size/ T2DM patients)	Duration (year)	Sex (M/F)	Age	HbA1c (%)	Evaluation of xerostomia
Trentin /2017 [7]	Brazil (South America)	ACSS	H/C	55/113 (48.67%)	ND	52/64	ND	ND	ND
Almusawi /2018 [22]	Saudi Arabia (Asia)	ACSS	H/C	66/100 (66%)	10	43/57	54.66 ± 8.97	8.88 ± 1.68	The saliva flow rate < 0.7 g/min
Esther /2018 [6]	Spain (Europe)	ACSS	H/C	13/47 (27.66%)	ND	19/28	61.02 ± 6.01	ND	Dodds xerostomia questionnaire 1997
Verhulst /2019 [27]	Netherlands (Europe)	PS	PHC	285/764 (37.30%)	ND	337/426	65.9 ± 10.7	ND	Subjective feeling of xerostomia (Do you sometimes suffer from a xerostomia?)
Li /2020 [18]	China (Asia)	ACSS	H/C	37/49 (75.51%)	3.65 ± 2.82	31/18	75.90 ± 6.77	ND	ND
Diep /2021 [2]	Norway (Europe)	PS	PHC	3/31 (9.68%)	ND	ND	ND	ND	"How often does your mouth feel dry? (Never, Occasionally, Frequently, and Always)"

ACCS: Analytical cross-sectional study; PS: Prevalence study; H/C: Hospital or clinic; PHC: Primary health care; NA: Not applicable; ND: Not described

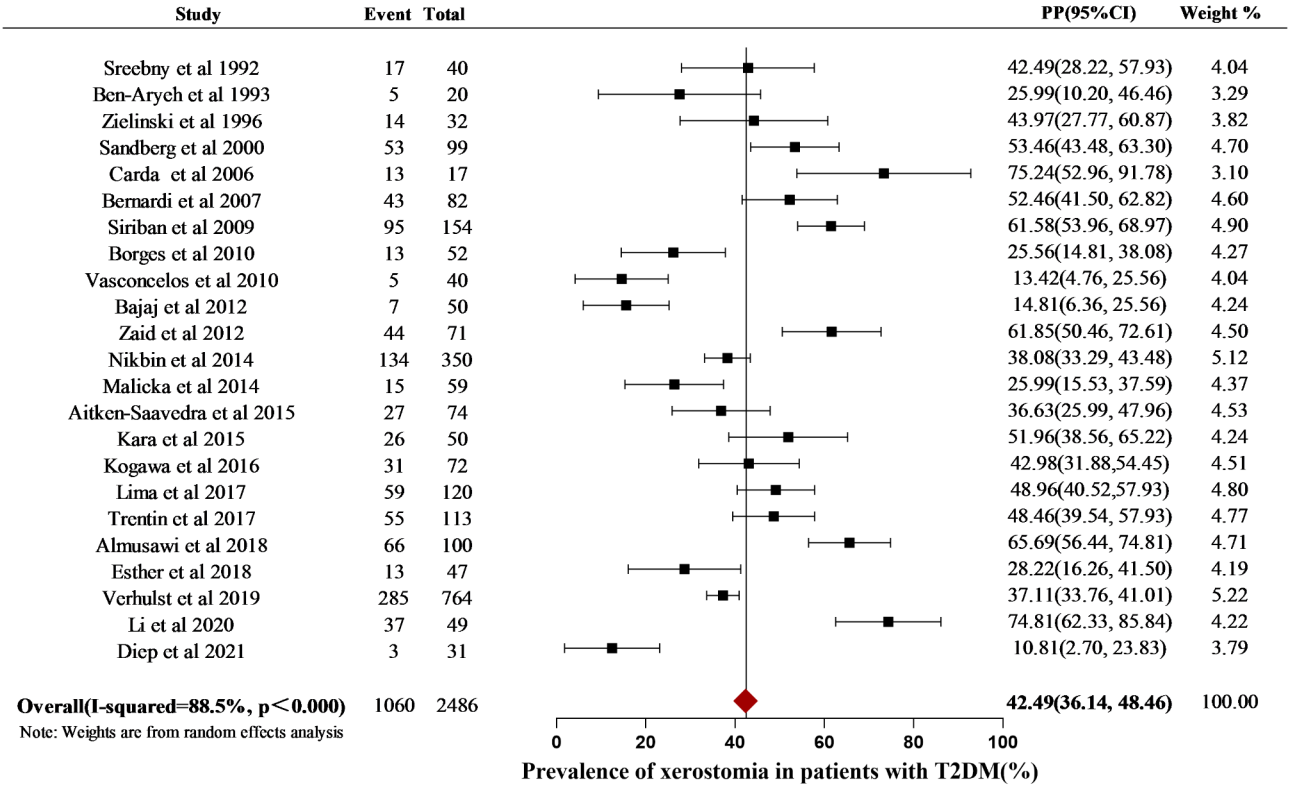

Fig. 2 Meta-analysis of the overall prevalence of xerostomia in patients with T2DM

$p = 0.30$(Supplementary Table S6 and Supplementary Fig. S1).

By continent The pooled estimated prevalence of xerostomia in patients with T2DM was 40.52% (95% CI = 30.03–51.96) in Europe, 47.96% (95% CI = 33.29–62.33) in Asia, 42.49% (95% CI = 28.22–57.93) in North America, and 38.56% (95% CI = 29.12–48.46) in South America. Notably, the heterogeneity among the included studies was high, $p < 0.001$.(Fig. 3 and Supplementary Table S6). Six consecutive meta-analyses, stratified by paired continents and tested for between-subgroup differences, can be found in Supplementary Table S6 and Supplementary Figs. S2a, b, c, d, e, f. Comparison between all groups $p > 0.05$.

By evaluation tool The prevalence of xerostomia in patients with T2DM as assessed by the subjective feeling of oral dryness yielded a prevalence of 36.14%(95% CI = 22.77–44.97), while the Fox questionnaire revealed a prevalence of 36.14% (95% CI = 29.58–36.63), $p = 0.95$. (Supplementary Table S6 and Fig. 4).

By disease duration The prevalence of xerostomia in patients with diabetes duration of less than 7 years was 48.96% (95% CI = 22.98–75.24), whereas it was 53.46% (95% CI = 42.49–64.26) in patients with diabetes duration exceeding 7 years, $p = 0.78$ (Supplementary Table S6 and Supplementary Fig. S3).

By HbA1c The results revealed that the prevalence of xerostomia was 53.46% (95% CI = 42.98–63.78) among patients with HbA1c levels below 8.0% and 46.96% (95% CI = 35.66–58.91) among those with HbA1c levels exceeding 8.0%, $p = 0.42$ (Supplementary Table S6 and Supplementary Fig. S4).

Sensitivity analysis

A sensitivity analysis was conducted to evaluate the influence of individual studies on the overall results. The combined effect sizes, calculated by sequentially excluding one study at a time, were within the 95% CI of the total

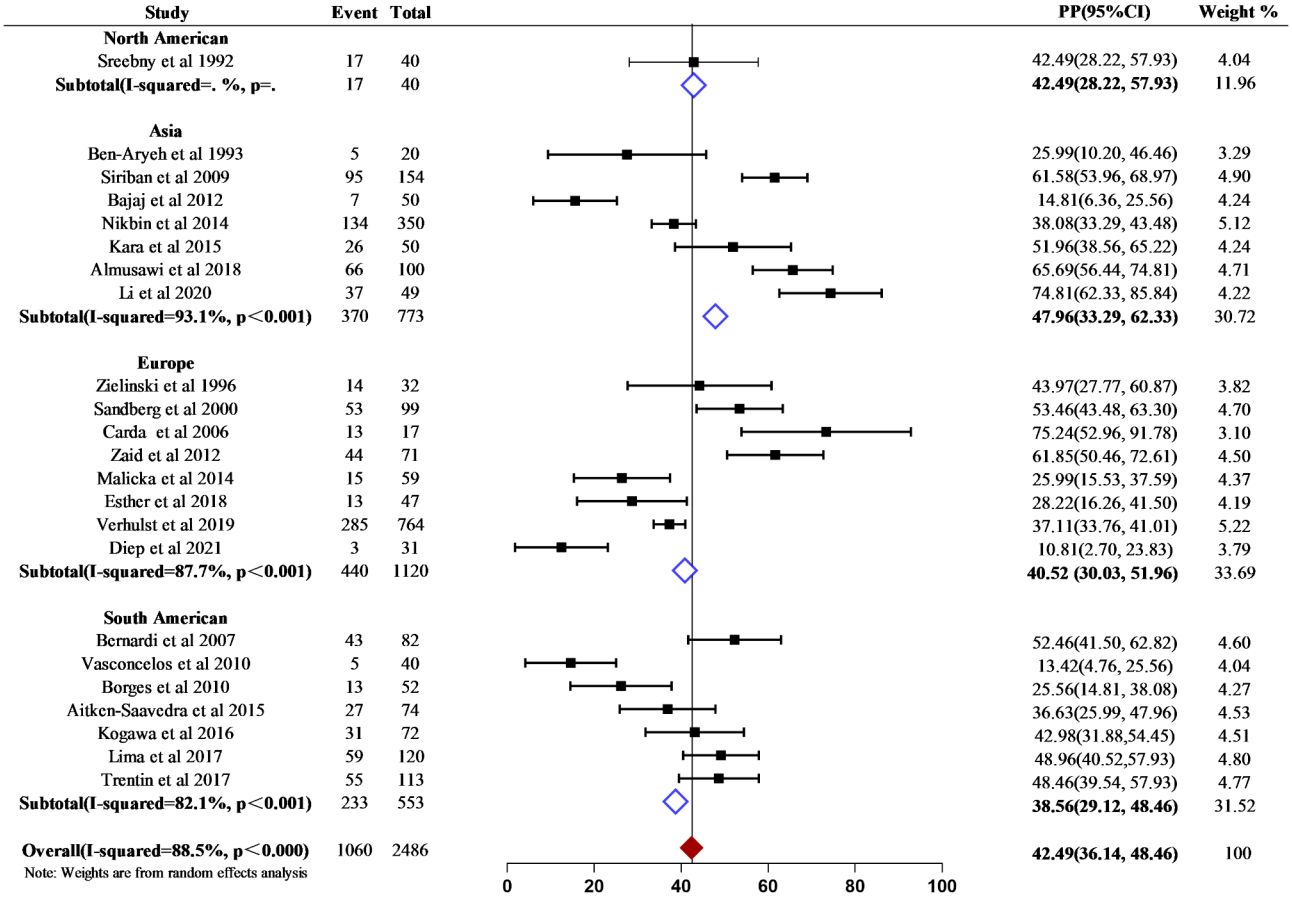

Fig. 3 Results of the subgroup analysis by continent

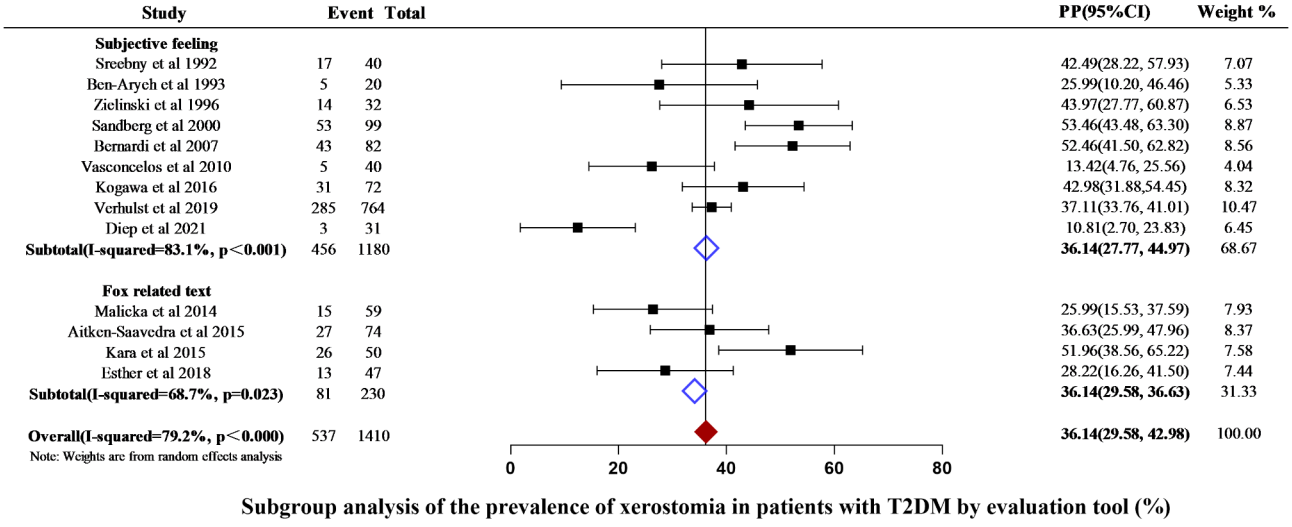

Fig. 4 Results of the subgroup analysis by evaluation tool

combined effect size, indicating that our meta-analysis was statistically stable (Fig. 5).

Publication bias

The funnel plot analysis indicated that the included studies were relatively symmetrical on both sides of the median, with a Begg's test *p* value of 0.355 and an Egger's test *p* value of 0.809 (Fig. 6).

Discussion

This systematic review and meta-analysis encompassed 23 published studies comprising a total sample of 2486 participants across 16 countries. The analysis revealed that the prevalence of xerostomia in patients with T2DM was 42.49%. Notably, the heterogeneity of these studies was high and can be, in part, accounted for by methodological and contextual differences among studies. Firstly, the included studies were mainly analytical cross-sectional studies (78.3%), the purpose of such studies was not to explore the prevalence, there were significant differences in the study populations and small sample sizes, and the research objectives of the included prevalence studies were not designed exclusively to address the prevalence of xerostomia in patients with T2DM, so differences in the populations and methodologies of the studies may have contributed to the large heterogeneity. Secondly, current assessments of xerostomia are mainly based on subjective feelings, and subjective bias may also have contributed to the heterogeneity among studies. Considerable heterogeneity remains after accounting for the effect of a priori moderators on heterogeneity, indicating that many underlying heterogeneity factors remain poorly explained and need further exploration. Xerostomia is an uncomfortable sensation that can lead to negative oral and systemic effects, resulting in a high symptom burden [35, 36]. Consequently, it is imperative for dental professionals and clinicians to recognize the necessity of assessing and managing xerostomia in this patient population.

Our study yielded noteworthy findings concerning geographical distribution. First, the subgroup analyses revealed inadequate representation of continents. The meta-analysis indicated that the prevalence of xerostomia in patients with T2DM varied across continents: Asia (47.96%) > North America (42.49%) > Europe (40.52%) > South America (38.56%). However, the data from North America comprised only one study, while six out of seven South American studies were conducted in Brazil. This limited representation necessitates further investigations to obtain more comprehensive conclusions about these geographic regions. Second, substantial variations were observed between studies conducted within the same country. For instance, two Brazilian studies reported prevalence rates of 52.44% and 12.50%. Similarly, Spanish studies showed prevalence rates of 76.47% and 27.66%, while Indian studies reported prevalence rates of 52% and 14%. Further analysis suggested that these discrepancies may be attributed to differences in study tools, population characteristics, and research quality. These factors potentially exert significant influence on the prevalence of xerostomia in T2DM patients and may contribute to the high heterogeneity observed across studies.

Precise definitions and validated assessment tools are crucial for accurately determining the prevalence of xerostomia; however, the definition and assessment tools for xerostomia remain highly controversial. A relevant study highlighted that xerostomia is a subjective sensation of oral dryness, often associated with decreased salivary volume, while hyposalivation refers to an objective

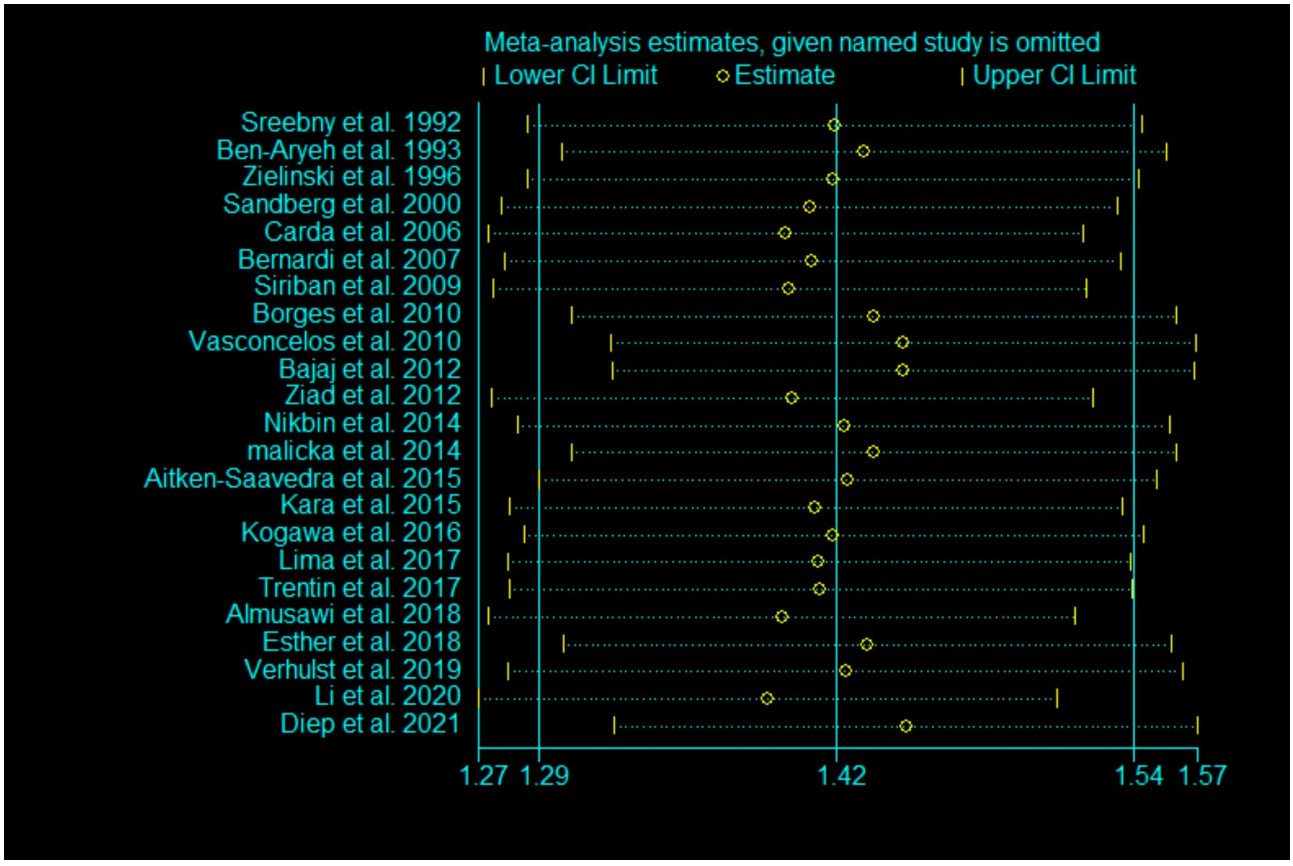

Fig. 5 Results of the sensitivity analysis

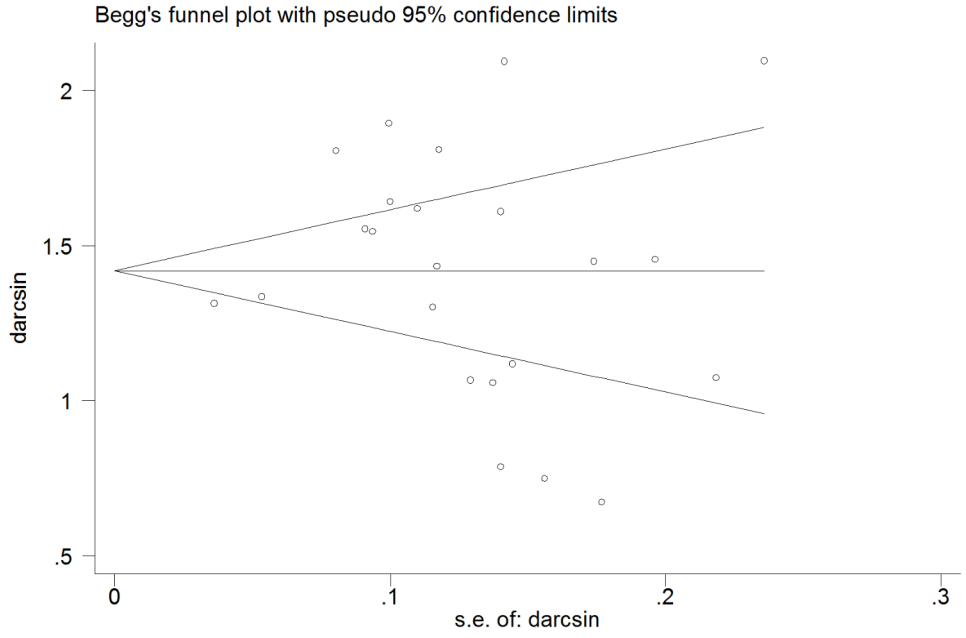

Fig. 6 Publication of risk of bias funnel plots

reduction in salivary flow [1]. The strong correlation between these conditions can lead to misconceptions, thereby complicating accurate assessment of xerostomia prevalence. Consequently, a clear distinction between the two is essential. Our systematic review identified two studies from Spain, one reporting a prevalence of 76.47% using the xerostomia subjective test and another reporting a prevalence of 27.66% using the Dodds xerostomia questionnaire 1997. The latter, adapted from Fox's criteria, has been validated for xerostomia assessment [37], whereas the xerostomia subjective test lacks evidence of reliability and validity. This discrepancy shows that the reliability and validity of the assessment tool influence prevalence estimates. Moreover, the xerostomia assessment tools used in our study included complaints of xerostomia [25], the VAS [32], the Dodds xerostomia questionnaire (1997) [38], and the Fox test [37], indicating a lack of standardization and specificity in assessment methodologies. However, subgroup analysis of evaluation tools revealed no significant difference in xerostomia prevalence as measured by a subjective oral dryness question and Fox criterion-related questionnaires, thus suggesting that the core of xerostomia diagnosis is the subjective sensation of oral dryness. However, subjective sensations can vary, are difficult to quantify, and provide limited practical guidance as they do not offer additional information on the degree and origin of xerostomia. Therefore, future research should focus on establishing a clear definition of xerostomia and developing assessment tools with robust reliability and validity.

Furthermore, our study indicated that research on xerostomia prevalence in T2DM patients was less extensive, older, and had more incomplete data compared to studies on the prevalence of xerostomia due to Sjogren's syndrome or radiation therapy [39]. A correct diagnosis of Sjogren's syndrome requires objective evidence of dry eyes and/or xerostomia along with autoimmunity indicators, with its prevalence reaching up to 100% [40]. A systematic review reported a 93% prevalence of xerostomia during irradiation [41]. Consequently, conditions with high xerostomia incidence, such as Sjogren's syndrome and radiation therapy, may attract more research attention than studies on patients with T2DM. Although xerostomia is significantly associated with dental caries [42], quality of life, and negative mood in diabetic patients [10], it remains the most overlooked symptom among the various oral manifestations of diabetes. A systematic review [43] of 53 observational studies demonstrated that T2DM patients had significantly worse periodontal status. A meta-analysis [44] involving 3092 diabetic patients and 23,494 controls revealed that the overall prevalence of (combined) periodontitis in diabetic patients was 67.8%. In contrast, a literature review indicated that the number of updated studies and available meta-analyses on xerostomia prevalence in T2DM patients was suboptimal, which suggested that xerostomia in patients with T2DM may not have received sufficient attention as a research topic. The possible reasons include inadequate awareness among healthcare professionals and the subjective nature of symptoms of xerostomia as well as its multifactorial influences, which make assessment challenging [45]. The lack of a clear treatment protocol, with mostly palliative approaches such as salivary replacement therapy and mouthwash, is another factor that limits the evaluation of xerostomia in patients with T2DM [46, 47]. In conclusion, xerostomia in T2DM patients warrants greater attention, necessitating more high-quality research to improve recognition and management of this condition.

The metabolic state and duration of diabetes are closely associated with its progression [48]. Our study revealed that xerostomia prevalence was lower in patients with short disease duration than in those with long disease duration (48.96% vs. 53.46%), which is consistent with the findings of previous studies and may be attributed to increased salivary gland damage due to prolonged hyperglycemia [8, 9]. Additionally, previous studies [20, 29] have indicated that patients with low HbA1c levels have a reduced risk of xerostomia, whereas our study revealed a low incidence of xerostomia with high HbA1c levels (53.46% vs. 46.96%), which may be related to the limited extraction of HbA1c data. The metabolic control and duration of diabetes are crucial indicators of disease progression [8], and understanding their influence on xerostomia prevalence will enhance awareness among healthcare professionals, enabling them to better manage the progression of symptoms. However, the relevant data are currently limited. In addition, our study found that the prevalence of xerostomia in patients with T2DM was very poorly studied, with only 5 out of 23 studies, which may have led to an overestimate of the prevalence of xerostomia in patients with T2DM. Hence, targeted high-quality prevalence studies should be conducted for the above diabetes-related indicators to provide relevant epidemiological data.

Limitations

For our study methodology, we employed a double arcsine-transformed proportional meta-analysis, which can mitigate potential small study effects and offers the advantage of variance stabilization [49]. However, the present study has several limitations. First, substantial heterogeneity remained unexplained even after accounting for hypothesized factors from existing epidemiologic literature. Second, although both Begg's test and Egger's test P values were >0.05 and the funnel plots were largely symmetrical, numerous studies still had values outside the CIs. Third, additional factors affecting xerostomia,

such as medications and head and neck radiation, may independently influence oral health and potentially bias the prevalence results of xerostomia in T2DM patients. However, because of the limited number of articles on xerostomia prevalence in T2DM patients, most studies did not report these exclusion criteria or general information. This study did not exclude diabetic patients with these combined factors, which may introduce bias and requires further investigation. Considering these limitations, we should approach the results with caution and maintain a skeptical perspective.

Conclusion

Xerostomia, a discomforting symptom frequently experienced by individuals with T2DM, is strongly associated with their quality of life and adverse health outcomes. This study revealed a high overall prevalence of xerostomia among T2DM patients. However, this topic has probably not have received sufficient attention. Research examining the prevalence of xerostomia in T2DM patients faced challenges such as a lack of large sample prevalence studies and standardized assessment tools, and inadequate data extraction, thereby limiting the accurate evaluation of xerostomia prevalence and heterogeneity in this population. Future high-quality epidemiological studies are anticipated to provide more precise epidemiological data, potentially increasing awareness and attention to xerostomia in T2DM patients.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Not Applicable.

Author contributions
SQ H and X Z with equal contributions as co-first authors.SQ H: Conceptualization (supporting); Methodology(lead); Formal Analysis(lead); Data Curation(equal); Writing – Review & Editing(equal); Visualization(lead); Project Administration(supporting). X Z: Writing – Original Draft Preparation(lead); Methodology(supporting); Data Curation(equal); Formal Analysis(supporting); Writing – Review & Editing(equal), Project Administration(supporting), Visualization(supporting). SC D, SX H: Methodology(supporting); Formal Analysis(supporting); Writing – Review & Editing(equal). F L: Conceptualization(lead); Project Administration(lead); Supervision(lead); Writing – Review & Editing(equal); Methodology(supporting); Formal Analysis(supporting).

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Data availability
All data generated or analysed during this study are included in this published article and its supplementary information files.

Declarations

Ethics approval and consent to participate
Not applicable.

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