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SYSTEMATIC REVIEW

Oral health-related quality of life in patients with type II diabetes mellitus: a systematic review and meta-analysis

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Abstract

Background Our study aimed to comprehensively assess the impact of type II diabetes mellitus (T2DM) on oral health-related quality of life (OHRQoL) based on results from the Oral Health Impact Profile (OHIP-14) questionnaire. A secondary objective was to explore how the potential correlation between the OHIP-14 score and T2DM was affected by demographic and clinical characteristics.

Methods We systematically searched the Medline, EMBASE, CINAHL and Scopus databases on January 24, 2024, for evidence starting from database inception. Studies included in the analysis assessed OHRQoL in T2DM patients. We searched trials both with or without comparisons to healthy controls and presenting OHIP-14 results as a severity of impact, namely, the mean OHIP-14 total score. To assess the difference between diabetic and non-diabetic subjects, we calculated weighted mean differences (WMD) with 95% confidence intervals (CI). A meta-analysis of each summary measure was conducted provided that this outcome was evaluated in at least two studies so that model was selected on the basis of heterogeneity assessment. The quality of the included studies was assessed using the tool developed by The National Heart, Lung, and Blood Institute (NHLBI).

Results Seven studies fulfilled the inclusion criteria (1,457 patients diagnosed with diabetes mellitus and 216 healthy controls). In patients with T2DM, the mean OHIP-14 total score was approximately 2.7 points higher (an indication of greater oral problems) than in healthy persons; WMD = 2.68 (95% CI: 0.47–4.89); $p = 0.0176$. Significant differences between diabetic and non-diabetic subjects were also observed for almost all domains of the OHIP-14, except handicap. The calculated average OHIP-14 total score was 12.06 (95% CI: 4.93–19.19), which indicated a slight effect on OHRQoL. Age and sex did not appear to be relevant for assessing the impact of diabetes mellitus on OHRQoL.

Conclusions Our findings confirm that OHRQoL in patients with T2DM is significantly lower and may be influenced by functional problems in addition to various physical and psychological limitations. However, the available data are of low quality and a lack of evidence from high-quality studies with matched control groups exists.

Clinical trial number Not applicable.

Keywords Oral health-related quality of life, OHIP-14, T2DM, Type II diabetes mellitus, Systematic review, Meta-analysis

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Background

Diabetes mellitus type II (T2DM) is a chronic metabolic disease characterized by hyperglycemia, which is caused by defects in insulin secretion, insulin function, or both [1]. Chronic hyperglycemia can lead to complications that affect multiple organ systems, including the nervous, ocular, renal, and cardiovascular systems [2]. Additionally, T2DM is associated with poor oral health and manifests as various dental and oral complications, such as xerostomia, dental caries, oral mucosal diseases, and/or periodontal problems. These complications impact not only physical health but also produce significant emotional and psychosocial consequences [3–5].

Periodontal changes are often among the first clinical manifestation of diabetes mellitus, and affected individuals are more susceptible to infections, oral mucosal disorders, and severe periodontal disease [6, 7]. The issue of diabetes-related periodontal disease is of growing concern given that the International Diabetes Federation estimated that in 2021, 536.6 million adults in 215 countries had diabetes [8].

Several original studies have explored the relationship between diabetes mellitus and oral health-related quality of life (OHRQoL) [9, 10]. OHRQoL is a multidimensional tool encompassing subjective assessments of an individual's oral health, functional well-being, emotional state, treatment expectations and satisfaction, in addition to self-perception [11]. The OHRQoL reflects the extent to which oral health influences daily activities, such as eating, sleeping, and engaging in social interactions in addition to influencing an individual's self-esteem and satisfaction concerning their oral health [12]. Consequently, oral health is closely tied to general well-being, and its impact on QoL is undeniable but often overlooked [9].

Given the significant burden of diabetes and its potential effects on oral health, it is crucial to evaluate whether diabetes substantially influences OHRQoL as is the case with other chronic diseases, such as cancer or cardiovascular diseases [13]. One of the most widely used instruments for quantifying OHRQoL is the Oral Health Impact Profile (OHIP), which assesses seven domains: (1) functional limitations, (2) physical pain, (3) psychological discomfort, (4) physical disability, (5) psychological disability, (6) social disability, and (7) handicap. The original version contained 49 items but was shortened to 14 questions, the OHIP-14, which was introduced in 1997 [14–16]. This convenient, shorter version has proven to be highly reliable and valid with adequate cross-cultural consistency [17–19]. According to various studies, a change of greater than 3 in an OHIP-14 score is considered clinically significant and depends on the disease and oral condition [20].

A previous systematic review examined the impact of diabetes on OHRQoL [4]. However, its findings suggest no statistically significant association between diabetes and oral health conditions. The applicability of these results is limited as the meta-analysis in question combined data from OHIP-14 and GOHAI scales, which is an approach that appears unjustified. OHIP-14 has demonstrated higher internal reliability than GOHAI and provides a more homogenous measure with a greater focus on psychosocial outcomes [21, 22].

Therefore, the primary objective of this study was to conduct a comprehensive assessment using a systematic review and meta-analysis, which included an analysis of its domains, of the impact of type II diabetes mellitus (T2DM) on OHRQoL based on only the OHIP-14 instrument. Additionally, a secondary objective was to investigate whether the OHIP-14 score and its correlation with T2DM were influenced by the demographic and clinical characteristics of the participants included in the selected studies.

Methods

Search strategy

A systematic review was performed using the Medline, EMBASE (via Elsevier), CINAHL (Cumulative Index to Nursing and Allied Health Literature), and Scopus databases. The review was complemented by an analysis of the reference lists of identified trials. The search was performed on January 24, 2024 to find evidence starting from inception of the database. In the search strategies, terms defining diabetes were combined with the Boolean operator "AND" with keywords pertaining to OHRQoL and OHIP-14 (more details in Supplementary Tables S1-S4). Reference lists of previously published reviews with a similar scope in addition to primary studies meeting the inclusion criteria were examined to identify any potentially overlooked studies. The protocol for the systematic review was not pre-registered.

Data analysis

Two independent reviewers screened titles and abstracts followed by full-text articles to determine their suitability for final inclusion. At each stage of the assessment, any discrepancies between the reviewers were discussed with the involvement of a third researcher so that a consensus decision could be reached regarding the eligibility and inclusion of all articles. After duplicate studies were removed from the identified records, the titles and abstracts of the studies were screened according to the eligibility criteria. The remaining full-text articles were subsequently evaluated, and relevant reports were selected. At the full-text selection stage, the reviewers demonstrated a substantial level of agreement as indicated by a Cohen's kappa coefficient of 0.7.

One reviewer (L.K.) extracted the data (details of study design, country, eligibility criteria, baseline characteristics, and predefined outcome data) to data extraction tables in the Microsoft Excel spreadsheets, which was then checked by a second reviewer (M.K.). Missing baseline characteristics or outcomes were calculated from other available numerical data whenever possible. If this step was not feasible, the study was excluded from the respective meta-analysis. We did not impute missing data.

No restrictions on the year of publication were applied. Only publications in English or Polish were examined. The systematic review focused on studies (cohort, case-control, or cross-sectional studies) evaluating the oral health-related quality of life of patients with T2DM with or without comparisons with non-diabetic controls and presented the OHIP-14 results as the severity of impacts, namely the mean OHIP-14 total score (sum of ordinal responses) along with the standard deviation (SD). For a more detailed description of the inclusion and exclusion criteria according to the Population, Exposure, Comparator, Outcome, Study (PECOS) scheme, please refer to Supplementary Table S5. Case reports, reviews, and review protocols were excluded. Studies involving children or adolescents were also not included because the assessed OHIP-14 questionnaire had to be completed by the patient and required proper understanding of the questions contained therein, which might have been difficult in the case of minors.

Two independent reviewers (L.K. and M.K.) assessed the quality of the included studies using the tool developed by the National Heart, Lung, and Blood Institute (NHLBI) for evaluating observational cohort and cross-sectional studies [23]. Each study was rated as 'good', 'fair', or 'poor' on the basis of the items related to the specification of the population, measurement of exposure and outcome measures, and the approach to mitigate the influence of confounding factors. A Grading of Recommendations Assessments, Development, and Evaluation (GRADE) analysis was also performed for the results of meta-analyses regarding OHIP-14 [24].

To assess the difference in continuous outcome measures (the severity of impact) between diabetic and non-diabetic subjects, we calculated weighted mean differences (WMD) with 95% confidence intervals (CI). A meta-analysis of each summary measure was conducted provided that this outcome was evaluated in at least two studies. Both the mean score of the OHIP-14 and the individual domains of this questionnaire were considered and evaluated. The mean OHIP-14 score was calculated using an inverse variance meta-analysis. Furthermore, the potential associations of age, sex, fasting blood glucose, smoking status, and glycated hemoglobin (HbA1c) with differences in OHRQoL were assessed using meta-regression analyses. To explore possible causes of heterogeneity, we conducted subgroup analyses.

The calculations were conducted via the IBM SPSS Statistics for Windows (Version 29.0.2.0; Armonk, NY: IBM Corp.). We selected the meta-analysis model on the basis of the results of the heterogeneity assessment. In cases of statistically significant heterogeneity ($p < 0.1$ in Cochran's Q test), the meta-analysis was conducted via random effects model; otherwise, a fixed effects model was applied. Results of the meta-analyses were presented in forest plots, and meta-regression results were shown in a summary table and bubble plots.

The review was reported according to the PRISMA guidelines [25, 26], with the Preferred Reporting Items for Systemic Reviews and Meta-Analysis (PRISMA) checklist included in the Supplementary materials (Supplementary Table S9).

Results

Data Availability

The dataset analyzed during the current systematic review and meta-analysis is available from the corresponding author upon reasonable request.

Systematic review

From the initial pool of 813 records, 402 duplicates and conference reports were excluded, resulting in 411 records undergoing screening as titles and abstracts. We considered 49 records to be potentially eligible. Of these, 44 were obtained from the full texts for further consideration. We excluded 38 reports, predominantly due to inadequate OHIP-14 data or inadequate study populations. The remaining five publications from five studies met the inclusion criteria: (1) *Nayak 2017* [9], (2) *Khalifa 2020* [27], (3) *Chen 2023* [28], (4) *Tabesh 2023* [29], and (5) *Verhulst 2019* [30]. Supplemental searches of the reference lists of other reviews and included publications yielded two further studies (see also the PRISMA flow diagram in Fig. 1): (1) *Kakoei 2016* [31] and (2) *Mohsin 2017* [32].

Comparison of T2DM versus healthy (non-diabetic) individuals

First, we conducted the meta-analysis comparing OHRQoL in patients with T2DM and non-diabetic controls who did not have dentures or were not edentulous. This comparison was made possible by using data from two studies, *Nayak 2017* [9] and *Khalifa 2020* [27]. Both studies assessed the mean total OHIP-14 score and its individual domains.

In the *Nayak 2017* study [9], a statistically significant difference was found when comparing the mean OHIP-14 total score between the diabetic and non-diabetic group (30.64 [SD: 14.93] versus 25.82 [SD: 14.48];

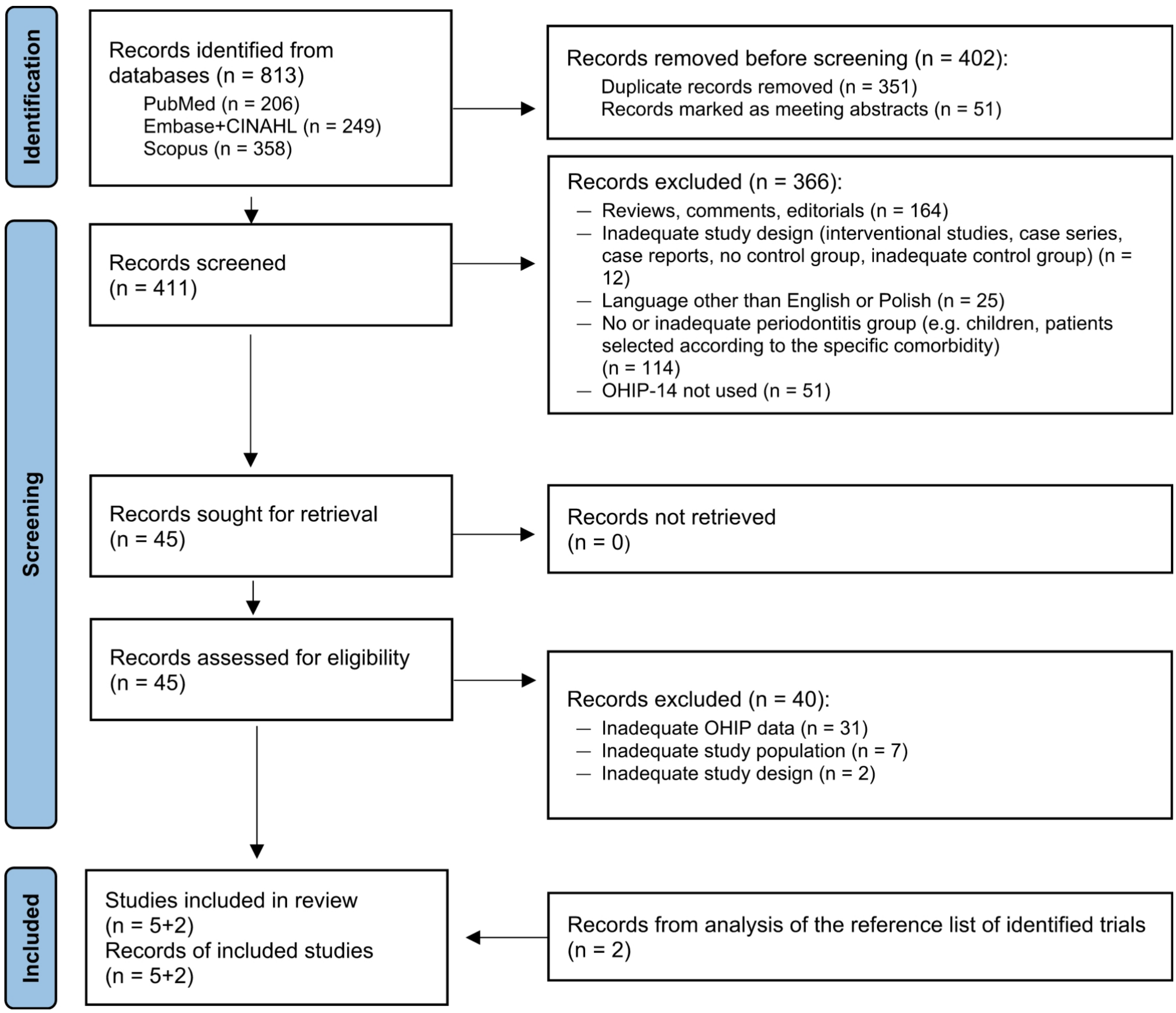

Fig. 1 Flow chart of search results.
(adapted from Preferred Reporting Items for Systemic Reviews and Meta-Analysis [PRISMA] 2020 Flow Diagram [25]).

$p = 0.008$). Conversely, in the *Khalifa 2020* study [27], the differences between these groups did not reach statistical significance (13.7 [SD: 9.7] versus 12.4 [SD: 9.5]; $p = 0.37$). However, the numerical results indicate a poorer quality of oral health in patients with diabetes mellitus than in non-diabetics in both studies. Additionally, the *Khalifa 2020* study [27] found no significant differences between diabetics and non-diabetic patients across individual OHIP-14 domains. In contrast, the *Nayak 2017* study [9] reported significant differences that were unfavourable to diabetic patients in almost every domain (except for the assessment of functional limitations). Detailed results are presented in Supplementary Table S6.

According to Fig. 2, the mean OHIP-14 total score was approximately 2.7 points higher in patients with T2DM than in those without diabetes, indicating greater oral health problems for which WMD = 2.68 (95% CI: 0.47–4.89). This result was statistically significant ($p = 0.0176$), suggesting that periodontal health was poorer among diabetic patients than among non-diabetic subjects.

Significant differences between diabetic and non-diabetic patients were also observed in almost all domains of the OHIP-14, except for handicap. The calculated WMD values for individual domains are listed: (1) functional limitations, 0.26 (95% CI: 0.02–0.49), $p = 0.0317$; (2) physical pain, 0.32 (95% CI: 0.06–0.58), $p = 0.0142$; (3) psychological discomfort, 0.34 (95% CI: 0.09–0.58), $p = 0.0065$; (4) physical disability, 0.34 (95% CI: 0.10–0.57), $p = 0.0051$; (5) psychological disability, 0.31 (95% CI: 0.07–0.55), $p = 0.0105$; (6) social disability, 0.34 (95% CI: 0.11–0.58), $p = 0.0041$; and (7) handicap, 0.17 (95%

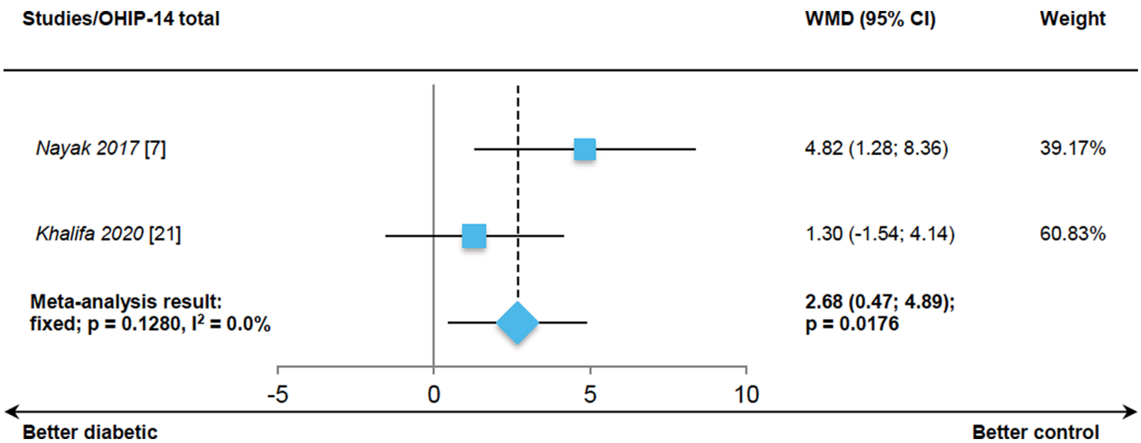

Fig. 2 Weighted mean difference in severity of impacts (mean Oral Health Impact Profile [OHIP]-14 total score) in diabetic patients compared to control subjects, meta-analysis of the results from the *Nayak 2017* [9] and *Khalifa 2020* [27] studies

CI: -0.27–0.60), $p = 0.4557$. The detailed results for the OHIP-14 domains are presented in Fig. 3.

Average OHIP-14 score in diabetic patients

The average OHIP-14 score in diabetic patients was calculated using data from the case-control trials described above [9, 27] along with five additional studies that did not have a control group (Chen 2023 [28], Kakoei 2016 [31], Mohsin 2017 [32], Tabesh 2023 [29], and Verhulst 2019 [30]). The objective was to assess potential correlation of age, sex, fasting blood glucose, smoking, and HbA1c with OHRQoL using meta-regression analyses.

The mean OHIP-14 total score across the included studies ranged from 2.5 [30] to 30.64 [9] in the diabetic patients. The calculated average OHIP-14 total score was 12.06 (95% CI: 4.93–19.19), suggesting a slight effect on OHRQoL.

Variability among studies

The highest OHIP-14 score, indicating the worst OHRQoL, was reported in the *Nayak 2017* study in which it was reported that patients exhibited poor oral health conditions, including the presence of tooth stones (scores greater than or equal to 2 based on the Community Periodontal Index of Treatment Needs [CPITN]), moderate plaque accumulation on the tooth surface, in the gingival pocket, and/or on the gum, and moderate inflammation [9].

The higher OHIP-14 scores reaching approximately 14 points were observed in three studies: (1) Chen 2023 [33], (2) Khalifa 2020 [27], and (3) Tabesh 2023 [29]. These studies included diabetic patients with oral health conditions, such as decayed teeth (mean: 3.8) [27], moderate xerostomia (mean xerostomia inventory score: 22.27) [29], and chronic periodontitis [33], all of which contribute to OHRQoL deterioration. Notably, in Tabesh 2023, the duration of diabetes was long with an average of 11 years [29].

Lower OHIP-14 Scores (approximately 3–6 points) were found in the *Kakoei 2016* [31] and *Mohsin 2017* [32] studies. Both studies were conducted in hospital settings, which made it challenging to generalize the results to every diabetic patient. Additionally, results from the Kakoei 2016 study were questionnaire-based, and no clinical examinations had been performed. Moreover, the duration of diabetes, previous dental visits, or oral hygiene of the included patients were not considered when the study subjects were selected, and nearly 50% of patients scored zero on the OHIP-14 scale with 44% being edentulous [31].

The lowest OHIP-14 Score was reported in the study by *Verhulst 2019*. This study was conducted in Europe unlike the other included studies [30]. This result may initially report a better OHRQoL as reflected in more developed countries [34–36].

Sensitivity analysis

Given the above results, a sensitivity analysis was conducted using only data from more homogenic studies, *Khalifa 2020*, *Chen 2023*, and *Tabesh 2023* [27, 29, 33], and yielded an average OHIP-14 score of 14.61 (95% CI: 14.16–15.06) via inverse variance meta-analysis. This analysis showed lower heterogeneity compared to the full meta-analysis, but the overall OHIP-14 scores remained consistent. The results of both meta-analyses are presented graphically in Fig. 4.

Correlation of baseline characteristics with OHRQoL

Five included studies analyzed the impact of sociodemographic and clinical factors on OHRQoL using various statistical methods, including linear regression [27], Pearson's correlation and t-tests [31], Kendall's Tau-b and

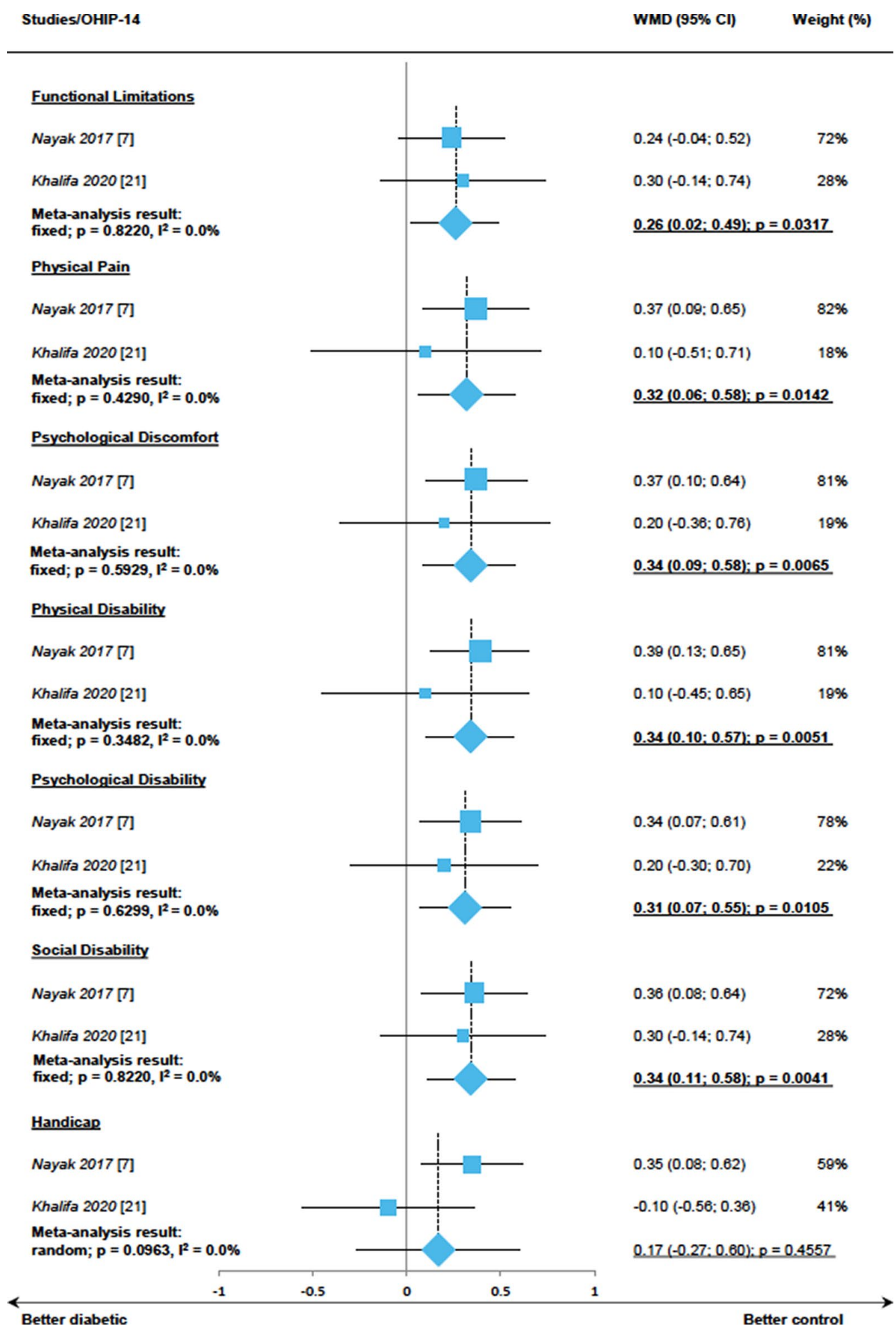

Fig. 3 Weighted mean difference in severity of impact (mean score in OHIP-14 domains) in diabetic patients compared to control subjects, meta-analysis of the results from the *Nayak 2017* [9] and *Khalifa 2020* [27] studies

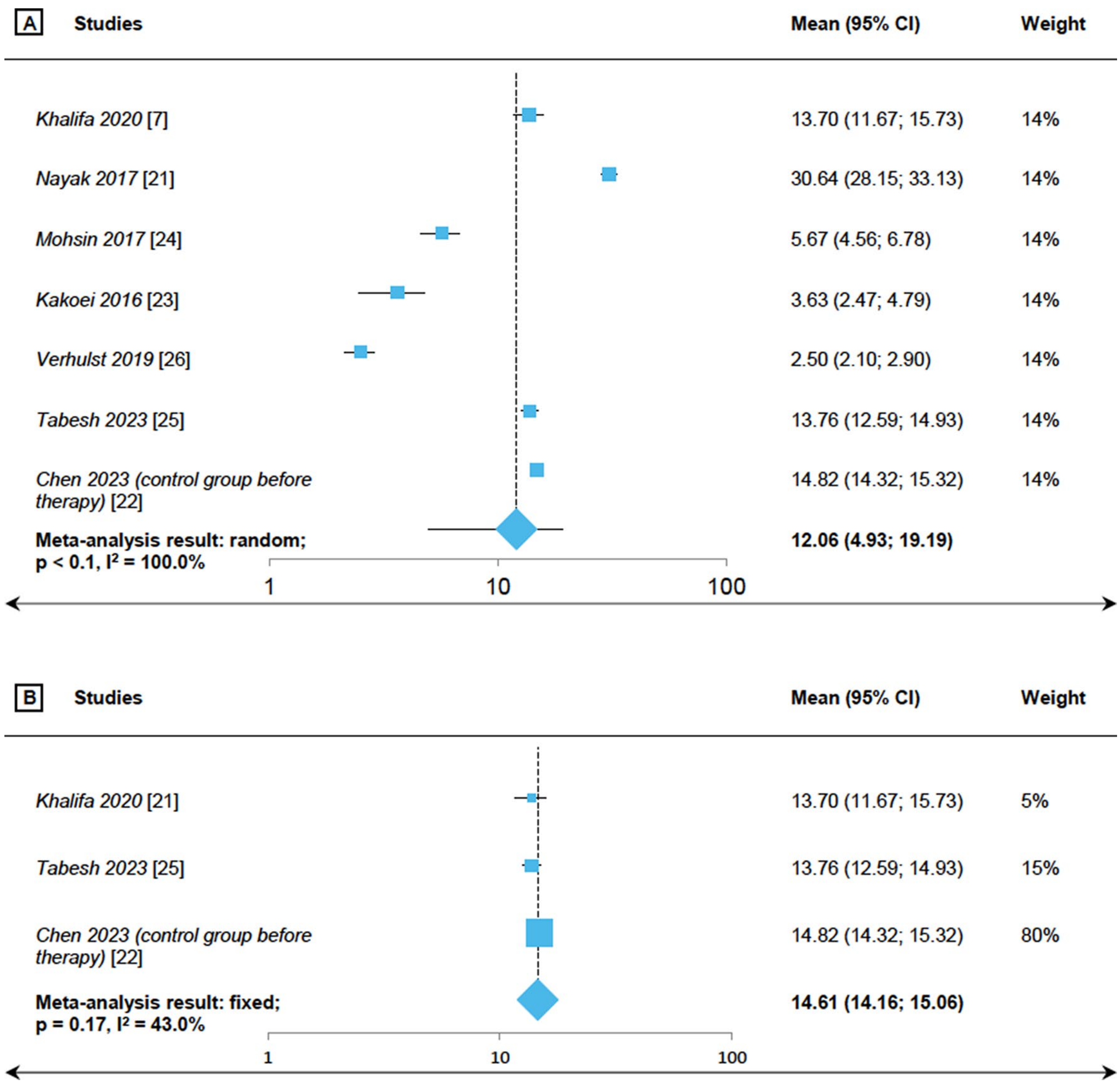

Fig. 4 (**A**) Average OHIP-14 score in diabetic patients– inverse variance meta-analysis of all included studies. (**B**) Average OHIP-14 score in diabetic patients, sensitivity analysis– inverse variance meta-analysis based on the the results from the *Khalifa 2020* [21], *Tabesh 2023* [25], and *Chen 2023* [22] studies

Mann–Whitney tests [32], Pearson's correlation [29], and Mann–Whitney test [30].

Key findings from individual studies

The *Khalifa 2020* study revealed that among diabetic patients, clinical attachment loss (CAL) was significantly associated ($p < 0.05$) with the social disability and handicap domains, whereas the decayed, missing, and filled teeth (DMFT) score was not [27].

In the *Kakoei 2016* study, no significant relationships between the mean OHRQoL score and sex, education, affliction with candidiasis, or history of frequent abscess were observed [31]. However, weak, but significant correlations, were found between OHRQoL and blood glucose levels ($p = 0.002$) and age ($p = 0.016$), indicating worse OHRQoL with increasing age and glucose levels. The mean OHRQoL score was significantly related to xerostomia, which is a subjective feeling of dry mouth (yes: 7.75 [SD: 5.22] versus no: 3.25 [SD: 1.45]; $p = 0.005$), tongue blade signs (yes: 7.92 [SD: 5.32] versus no: 4.29 [SD: 2.03]; $p = 0.031$), and burning sensations in the oral cavity (yes: 6.50 [SD: 3.10] versus no: 6.16 [SD: 6.02]; $p = 0.003$). Notably, in the study by *Kakoei 2016* [31], the results concerning individual subgroups were incorrectly shown in relation to their description; in this paragraph, they are presented correctly.

A significant impact of xerostomia on the deterioration of OHRQoL as assessed using the OHIP-14 questionnaire (total score) was also demonstrated in other studies: (1) in *Tabesh 2023* [29] with a correlation of $r = 0.444$; $p < 0.001$, a significant impact was also observed for all domains of the OHIP-14 questionnaire and (2) in the

Verhulst 2019 trial [30], yes: 3.0 [SD: 5.7] versus no: 2.2 [SD: 4.9]; $p < 0.05$ was reported.

In the *Tabesh 2023* study [29], significant relationships were observed between the mean OHRQoL scores and age, fasting blood glucose, HbA1c, disease duration, and denture wearing, but not with sex.

In the *Verhulst 2019* trial [30], a significantly worse mean OHIP-14 total score was found in patients with pain in the mouth (5.1 [SD: 7.4] versus 2.0 [SD: 4.6]; $p < 0.001$), bad breath (3.5 [SD: 6.1] versus 2.3 [SD: 5.1]; $p < 0.01$), periodontitis (2.6 [SD: 4.7] versus no: 0.8 [SD: 3.4]; $p < 0.001$), and edentulous patients (5.1 [SD: 7.4] versus no: 2.0 [SD: 4.6]; $p < 0.001$).

The *Moshin 2017* study noted that the mean score of the OHIP-14 in females was greater than that in males in terms of the total score (6.5 [SD: 5.93] versus 4.35 [SD: 5.14]; $p = 0.012$), functional limitations domain (1.51 [SD: 1.11] versus 1.00 [SD: 1.21]; $p = 0.012$) and physical pain domain (1.35 [SD: 1.33] versus 0.76 [SD: 1.01]; $p = 0.019$). These differences were statistically significant. No correlation was found between glycemic control (HbA1c) and other biochemical parameters [32]. The detailed results are presented in Supplementary Table S7.

Meta-regression analysis

In our study, neither age nor sex had a significant impact on diabetes-related OHRQoL as none of the univariate or bivariate meta-regression results were statistically significant (Supplementary Table S8). However, a slightly positive trend suggested that a higher proportion of males or older age groups was associated with better OHRQoL (Supplementary Figures S1 and S2). Due to insufficient data, assessing the impact of fasting blood glucose, smoking, and HbA1c on OHRQoL via meta-regression was not possible.

The detailed results are presented in Supplementary Table S7.

Characteristics of the included studies are summarized in Tables 1 and 2 and Supplementary Table S6.

Two studies were case-control designs (*Nayak 2017* [9] and *Khalifa 2020* [27]); however, only the *Khalifa 2020* study [27] included a control group matched to the exposed group in terms of age, marital status, and level of education. The *Nayak 2017* study [7] included patients who had been recruited from the monthly diabetic outpatient clinic of a private hospital in addition to T2DM who visited the outpatient department of the dental college during the study period (October 2013–March 2014). No additional inclusion/exclusion criteria were specified, except that the population included subjects

Table 1 Characteristics of included studies

Study	Country	Study period	Type of the sample (representativeness)	Sample size/ power calculation?	Sampling method	Matched controls?	*N*	Quality rating (Good, Fair or Poor) [23]
Nayak 2017 [9]	India	October 2013– March 2014	Convenience (diabetic outpatient clinic of a private hospital and the outpatient department of the dental college during the study period)	No	Not described	No	266	Fair
Khalifa 2020 [27]	The United Arab Emirates	March 2016–May 2018	Convenience (University Dental Hospital Sharjah and University Hospital Sharjah)	Yes, based on a previous study	Not described	Yes	176	Fair
Chen 2023 [33] (control group before therapy)	China	January 2020–October 2022	Convenience (Department of Stomatology in Hainan Medical College Second Affiliated Hospital, China)	No	Not described	NA	45	Fair
Kakoei 2016 [31]	Iran	NR	Convenience (public hospitals in Kerman, Iran)	No	Not described	NA	121	Fair
Mohsin 2017 [32]	Pakistan	January 2015–March 2015	Convenience (Diabetic Clinic at Baqai Institute of Diabetology and Endocrinology, Karachi)	No	Not described	NA	101	Fair
Tabesh 2023 [29]	Iran	September 2020–February 2021	Convenience (Department of Oral Medicine at the School of Dentistry of Isfahan University of Medical Sciences, Iran)	No	Not described	NA	200	Fair
Verhulst 2019 [30]	The Netherlands	March 2015–September 2016	Convenience (family physician offices)	No	Not described	NA	764	Fair

Abbreviations: NA– not applicable; NR– not reported

Table 2 Main characteristics and severity of impacts (the mean OHIP-14 total score), reported in the included studies (we reported characteristics presented in at least two studies)

Study/Group	*N*	Age (years), mean (SD)	Males, *n* (%)	Fasting blood glucose [mg/dl], mean (SD)	Smoking, *n* (%)	HbA1c (%), mean (SD)	Dentures (complete or removable partial), *n* (%)	Duration of T2DM [years], mean (SD)	Higher education, *n* (%)	OHIP-14 total score, mean (SD)
Nayak 2017 (D vs. C) [9]	138 versus 128	53 (10.23) versus 52 (10.59)	NR	NR	NR	NR	NR	NR	67 (48.6%) versus 74 (57.8%)	30.64 (14.93) vs. 25.82 (14.48)
Khalifa 2020 (D vs. C) [27]	88 vs. 88	43.1 (1.5) versus 43.0 (1.5)	32 (36%) vs. 48 (55%)	NR	25 (28%) versus 22 (25%)	NR	NR	7.3 (6.4) vs. NR	55 (63%) vs. 56 (64%)	13.7 (9.7) versus 12.4 (9.5)
Chen 2023 [33] (control group before therapy) (D)	45	NR	NR	NR	NR	7.16 (0.42)	NR	NR	NR	14.82 (1.71)
Kakoei 2016 (D) [31]	121	52.07 (11.35)	31 (25.6%)	284 (106)	NR	NR	NR	NR	8 (6.6%)	3.63 (6.5)
Mohsin 2017 (D) [32]	101	53.3 (11)	39 (38.6%^)	180.24 (89.36)	3 (3%)	9.25 (2.07)	NR	NR	NR	5.67 (5.71)
Tabesh 2023 (D) [29]	200	64.42 (10.04)	73 (36.5%)	161.23 (49.14)	NR	7.9 (1.12)	90^ (45%)	11.02 (7.78)	NR	13.76 (8.41)
Verhulst 2019 (D) [30]	764	65.9 (10.7)	426/763 (55.8%)	NR	112 (15.8%)	NR	345/759 (45%)^	NR	272/518 (52.5)	2.5 (5.2). $n=640$

Abbreviations: C– control group; D– diabetic group; NA– not applicable; NR– not reported; SD– standard deviation; T2DM– type II diabetes mellitus; OHIP: Oral Health Impact Profile

^ calculated using the available data

with decayed teeth. In contrast, the *Khalifa 2020* study [27] selected adults with T2DM from a list of patients attending the clinics at the University Dental Hospital Sharjah and University Hospital Sharjah. The diagnosis of T2DM was based on the patients' existing medical records and patients had to have at least 10 natural teeth. Additional criteria that were included were absence of major medical complications, such as coronary heart disease, no antibiotic use during the last three months, no steroidal or nonsteroidal anti-inflammatory medication use over the last three weeks, no treatment with immunosuppressive chemotherapy, and no professional periodontal treatment over the last six months.

The *Nayak 2017* study [9] was conducted in India, whereas the *Khalifa 2020* [27] was carried out in the United Arab Emirates. In the first study, the mean age of the analyzed patients was approximately 52–53 years, whereas in the second study, it was approximately 43 years. The *Nayak 2017* study [9] included 266 patients (138 with diabetes and 128 healthy persons), whereas the *Khalifa 2020* study [27] included 176 persons (88 persons in each group). In *Nayak 2017* [9], no significant differences were found between the groups in terms of the assessment of plaque presence and gum condition. A score of around 2 indicated moderate plaque accumulation on the tooth surface, in the gingival pocket, and/or on the gum in addition to moderate inflammation. Overall, patients most frequently exhibited moderate gingivitis, and the difference in the severity of gingivitis was not statistically significant. However, significant differences ($p=0.03$) were noted to the disadvantage of diabetic patients in terms of the CPITN, which indicated the presence of tooth stones (scores greater than or equal to 2). Most patients in the *Nayak 2017* study [9] had a degree qualification (48.6% in the diabetic patients and 57.8% in the group of healthy persons). Similar results were noted in the *Khalifa 2020* study [27] in which 63% and 64% of individuals had completed university education, respectively. A significantly higher proportion of female diabetic patients was noted ($p=0.02$). Additionally, a significantly greater ($p=0.01$) proportion of diabetic patients had a clinical attachment loss (CAL) ≥ 3 mm compared to non-diabetic subjects (23% versus 10%). The *Nayak 2017* study [9] did not report sex proportions or CAL analysis. Furthermore, none of the case-control studies provided detailed information on the severity of T2DM, its duration, or treatment regimens.

Among the seven included studies, six were conducted in Asia [9, 27, 29, 31–33] (including two in Iran), and one in Europe [30]. One study [33] was a randomized trial, but because only data from the control group (prior to applying the investigated therapy) were used, this study was described as a single-arm study. The remaining four studies [29–32] were cross-sectional, and one of them was also a part of a cluster-randomized controlled trial [30].

All included studies primarily used convenience samples drawn from patient populations in dental and/or diabetic clinics. In most studies, participants were adults as determined by inclusion criteria (17–75 years of age in the inclusion criteria, but the age range of the subjects was 18–78 years [31], aged ≥ 30 years [32], or ≥ 18 years [30]) or the mean age reported in the baseline characteristics [9, 27, 29]. Some studies required a minimum number of teeth (at least 10 in [27] or ≥ 15 in [33]). In most of the analyzed studies, the inclusion and exclusion criteria were very limited, when specified, and these mainly related to permitted or prohibited comorbidities, prior treatments, or smoking history. Only two studies [27, 31] provided a detailed definition of T2DM in their inclusion criteria.

The total population across the seven analyzed studies consisted of 1,457 patients diagnosed with diabetes. The studies varied in terms of the demographic and clinical characteristics of the analyzed samples (Table 2). However, incomplete reporting has hindered a comprehensive assessment of the existing differences. The mean age reported in eight studies ranged from 43.0 years [27] to 65.9 years [30], and the percentage of men reported in six studies ranged from 25.6% [31] to 55.8% [30]. The proportion of smokers ranged from 3 to 28%; however, four studies did not report smoking status. The mean fasting blood glucose across the three studies ranged from 161 mg/dl [29] to 284 mg/dl [31], whereas the mean Hb1Ac, which is presented in three studies, varied from 7.16% [33] to 9.25% [32], and may indicate suboptimal diabetes control.

Reliability of included studies

The quality of all studies was assessed as 'fair' (Supplementary Table S7). The most common limitations were the inability to determine diabetes duration, ability to determine whether the diabetes diagnosis preceded the OHRQoL assessment, and whether the outcome assessors were blinded to diabetes duration of the participants. In 75% of the analyzed trials, the relationships between OHRQoL and confounding variables were measured and/or reported in sufficient detail. The GRADE analysis for the results of meta-analyses regarding OHIP-14 indicates that the level of certainty of the presented scientific evidence is low (Supplementary Table S10).

The number of studies fulfilling the inclusion criteria was too low to conduct publication bias analysis on the basis of funnel plots or multivariate meta-regression considering multiple sociodemographic and clinical factors.

Discussion

The aim of our study was to conduct a meta-analysis comparing OHRQoL in patients with T2DM and non-diabetic subjects who did not have dentures or were not edentulous. A meta-analysis of the data from the two case-control studies, *Nayak 2017* and *Khalifa 2020* [9, 27], revealed that the mean total score on the OHIP-14 questionnaire was significantly higher by nearly 3 points in diabetic patients. These findings indicate that periodontal status and perceived OHRQoL were worse among diabetic individuals than among healthy persons.

Our result differed from those of a previously published systematic review [4] in which no statistically significant association between DM and OHRQoL was found. However, the prior review included studies using various questionnaires (OHIP-14 and Geriatric Oral Health Assessment Index [GOHAI]), whereas our study focused solely on OHIP-14 as it was the most widely used and reliable tool for assessing OHRQoL. We intentionally did not pool results from assessments conducted with different tools, such as alternative versions of OHIP-14 or GOHAI. The OHIP-14 has higher internal reliability than GOHAI and is a more homogenous measure in which psychosocial outcomes are emphasized. In contrast, GOHAI assigns greater weight to immediate outcomes, such as functional limitations and pain rather than psychological and behavioral aspects [21, 22]. This distinction is significant because diabetic patients often prioritize managing their primary disease over oral health and potentially overlook symptoms of periodontitis or gingivitis [37]. Allowing various measurement methods for OHRQoL would lead to an increase in the heterogeneity of the results, thus consequently reducing their reliability. To ensure consistency, only studies reporting the total OHIP-14 score (ranging from 0 to 56 points) were included in our analysis.

Our observations that periodontal health is poorer among diabetic patients align with previous research studies [3, 38–41]. However, some studies suggest that elderly individuals with diabetes may experience better OHRQoL than their non-diabetic counterparts [10, 42].

Although the overall results indicate a significant disadvantage for diabetic patients, it remains unclear whether the differences are clinically significant. After adopting a conservative MCID value of 4.45 points, which is within the published range of 1.68 to 4.45 points [20, 28, 43–47], it was found that the unadjusted mean OHIP-14 score difference (WMD = 2.68 points) in our study did not meet the threshold for clinical significance.

Nevertheless, the statistically significant results of the meta-analysis regarding the mean OHIP-14 total score are reinforced by significant differences across almost all questionnaire domains, except the handicap assessment. This finding suggests that diabetes has a substantial impact on physical and psychological aspects of OHRQoL. The absence of significant differences in the handicap domain may be because diabetic patients prioritize other health concerns over oral health [39].

The two case-control studies included in our analysis varied in terms of the average age of participants. The *Nayak 2017* study, which reported significantly worse OHRQoL among diabetic patients, included an older population [9]. In contrast, the *Khalifa 2020* study, which found no statistically significant differences, studied on average ten years younger population.[27]. This difference may translate into a shorter duration of diabetes and consequently, a lower frequency of complications related to this condition, which may have an impact on oral health. A shorter duration of diabetes also means a shorter period during which patients experience the characteristic for the previously described disease impairment of salivary gland function and increased glucose levels in the blood and saliva, which results in a lower risk of bacterial growth in the oral cavity and tooth decay [48, 49]. Additionally, cultural differences in interpreting the impact of diabetes on OHRQoL should not be overlooked. Furthermore, the *Khalifa 2020* study [27] included nearly 100 fewer participants than the *Nayak 2017* study [9], potentially contributing to the lack of significant differences. Notably, the *Khalifa 2020* study found no significant difference in dental decay between diabetic and non-diabetic patients [27].

A major limitation of the studies included in our analysis is the lack of detailed information on the severity, duration, and/or treatment of T2DM in the control groups. Given these considerations, the results of our meta-analysis should be interpreted conservatively.

Among the most significant factors affecting OHRQoL deterioration in diabetic patients were xerostomia and age. Xerostomia, a common side effect of diabetes mellitus, leads to social and clinical complications [3, 50]. Its presence increases the risk of periodontal disease, which has a further impact on OHRQoL. One of the included studies, *Verhulst 2019* [30] in addition to previous research [51, 52], demonstrated that diabetic patients with periodontitis had lower OHRQoL than those without periodontitis. Furthermore, another included study, *Khalifa 2020* [27], reported that while the mean age of diabetic and non-diabetic participants was similar (43 years), diabetic patients had a longer duration of periodontal disease (>7 years), which could explain the greater prevalence of severe periodontal disease among diabetics.

The relationship between OHRQoL and socio-demographic features is complex. Some studies found no correlation [53], while others suggest that age is positively associated with better OHRQoL, even in diabetic patients. Younger patients may prioritize aesthetics more than older ones, whereas older individuals may adapt better to diabetes over time [10]. An unfavorable body mass index (BMI) was also linked to poorer OHRQoL, particularly in the physical pain domain of OHIP-14 [54]. Interestingly, individuals with T2DM were more likely to rate their oral health as poor compared to the general population with lower education levels further strengthening this association [55]. Functional limitations associated with diabetes, such as oral discomfort or toothache, can negatively impact social interactions and mental well-being [56].

The average OHIP-14 total score for diabetic patients across all included studies was approximately 12 points, indicating these domains overall had a slight effect on OHRQoL. However, study diversity, as outlined in our results, should be considered when interpreting this result.

Our results also have important clinical implications. The significant deterioration of periodontal health and OHRQoL in diabetic patients underscores the need for comprehensive oral healthcare in this population. Improving diabetic patients' oral health may not only prevent or delay complications but also enhance their overall QoL [3, 22, 23, 43–45].

We also attempted to evaluate the impact of confounding variables on our meta-analysis through meta-regression. However, none of the results reached statistical significance, likely due to the small number of studies (up to six) included in the models. Therefore, conclusions drawn from these analyses should be considered exploratory. We observed a non-significant trend suggesting that an increasing proportion of males or older age was associated with improved OHRQoL, consistent with one of the included studies [32], which reported that the mean OHIP-14 score of females was significantly higher than that of males in terms of the total score and functional limitations and physical pain domains. However, the conclusions drawn from the available literature are ambiguous. Women usually take better care of oral hygiene and generally have better overall oral health [57], but this level of care does not necessarily translate into a more positive perception of OHRQoL in this group. Several previous studies have demonstrated that women may have worse OHRQoL than men [58–60]. Alternatively, men more frequently reported poor self-rated oral health than women [61], or no statistically significant differences were found between sexes, although numerical trends suggested poorer self-assessment results among females [62, 63].

Similarly, the impact of age on OHIP-14 remains debatable. Contrary to our observations from the meta-regression analysis, one of the included studies [31] noted that with increasing age, the OHRQoL score increased, reflecting a decrease in OHRQoL. Similar conclusions were drawn from the other studies [29, 64, 65] in which aging results in more oral problems for different reasons, including decreased attention to oral hygiene status by patients. Conversely, some studies reported that elderly people with T2DM experienced better OHRQoL [10, 42]. Due to insufficient sample size and lack of comprehensive patient data, we could not perform a meta-regression analysis on other predictors, such as fasting blood glucose, smoking, and/or HbA1c levels.

Our review also has certain additional limitations beyond those already mentioned. We assessed the quality of all studies included in the review as 'fair'. Unfortunately, the number of studies meeting the inclusion criteria was too low to conduct publication bias analysis on the basis of funnel plots or multivariate meta-regression considering multiple sociodemographic and clinical factors. Moreover, in this conducted systematic review, we included only studies with full-text publications. This criterion may have introduced bias, as it excluded studies conducted on smaller samples or those that did not yield statistically significant results. However, grey literature, such as conference abstracts and letters, was unlikely to contain sufficiently precise numerical data to be deemed eligible for our meta-analyses. In some included studies, various OHIP-14-derived indices were available (such as prevalence and extent of impact), which could allow for a more comprehensive description of the influence of diabetes on OHRQoL. Nevertheless, ultimately, only the severity of impacts (total OHIP-14 score) was consistently measured and uniformly reported in the available studies.

Conclusion

While our study provides evidence for an association between diabetes and oral health-related quality of life, the limited data do not allow clear conclusions to be drawn regarding causality. Diabetes can lead to functional problems in addition to different physical and psychological limitations, which results in poorer periodontal health among diabetic patients than non-diabetic individuals and requires more attention from physicians. Our results can be considered important baseline data for further trials in this area, which should be based on more homogenous populations and larger sample sizes.

Abbreviations

C	Control group
CAL	Clinical attachment loss
CI	Confidence interval
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CPITN	Community Periodontal Index Of Treatment Needs
D	Diabetic group
DMFT	Decayed, Missing, and Filled Permanent Teeth
GOHAI	Geriatric Oral Health Assessment Index
MCID	Minimal clinically important difference
NA	Not applicable
NHLBI	National Heart, Lung, and Blood Institute
NR	Not reported
OHIP	Oral Health Impact Profile
OHRQoL	Oral Health–related Quality of Life
PECOS	Population, Exposure, Comparator, Outcome, Study
SD	Standard deviation
T2DM	Type II diabetes mellitus type
WMD	Weighted mean difference

Supplementary Information

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Supplementary Material 1

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Author contributions

JS made substantial contribution to the conception, design of the work, interpretation of data, and drafted the work. LK made substantial contribution to the analysis, interpretation of data, and drafted the work. MK made substantial contribution to the analysis, interpretation of data, and drafted the work. MW substantively revised the drafted work and supervised it. All authors have approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Data availability

The dataset analyzed during the current systematic review and meta-analysis is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
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Competing interests
The authors declare no competing interests.

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