Oral health and sleep disorders: A systematic review and meta-analysis

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Received October 1, 2024; Accepted November 1, 2024

DOI: 10.3892/br.2024.1915

Abstract. Oral health and sleep quality are critical components of overall health, but their relationship remains poorly understood. The present meta-analysis therefore investigates the association between oral health and sleep quality, synthesizing evidence from diverse populations. To this aim, a comprehensive search strategy identified 311 articles, from which 8 studies encompassing 18 comparisons met the inclusion criteria. These studies, conducted between 2015 and 2023, included 36,559 participants across various countries. Oral health was assessed using indices such as the Decayed, Missing, and Filled Teeth Index and gingival indices. At the same time, sleep quality was measured using tools such as the Pittsburgh Sleep Quality Index and Epworth Sleepiness Scale. The results of the meta-analysis revealed a significant association between poorer oral health and poorer sleep quality, with a standardized mean difference of 2.166 [95% confidence interval (95% CI), 0.677-3.655; P=0.004]. Sensitivity analyses confirmed the robustness of the findings, and publication bias assessments indicated no significant bias. Precision interval analysis showed a mean effect size of 2.17 with a 95% CI of -4.83 to 9.16, suggesting variability in the strength of the association across populations. In conclusion, the results of the present meta-analysis provide strong evidence for a significant link between oral health and sleep quality, highlighting the importance of considering oral health in the management of sleep disorders. Future research should focus on longitudinal studies and standardized measurement tools to further elucidate this relationship and inform public health strategies aimed at improving both oral health and sleep quality.

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Key words: oral health, sleep disorders, meta-analysis

Introduction

The relationship between oral health and sleep quality is a complex and bidirectional phenomenon that has garnered significant attention in recent years. This interplay affects not only the quality of life but also has profound implications for overall health and well-being (1). Sleep disturbances can significantly impact oral health (2). Individuals with poor sleep quality often neglect proper oral hygiene practices, increasing the risk of dental issues such as periodontitis and gingivitis (3). A study, using the National Health and Nutrition Examination Survey data, found that individuals with sleep disorders were more likely to report dental pain, periodontal issues and negative emotions regarding their oral health compared with those without sleep disorders (4). Poor sleep quality can also lead to xerostomia, reducing saliva flow and increasing the risk of oral health problems such as tooth decay and gingivitis (4).

Conversely, poor oral health can significantly impact sleep quality. Dental issues such as periodontitis, gingivitis and dental pain can disrupt sleep patterns and lead to restless nights. Thus, periodontal diseases have been identified as risk factors for developing sleep disorders, with inflammation caused by untreated gum disease potentially leading to systemic health issues that can affect sleep quality (5,6). Besides, the Oral Health Impact Profile (OHIP)-14 score, which reflects the subjective interpretation of oral health-related quality of life, was found to be higher in patients with poor sleep quality. This suggests that oral health can significantly affect sleep quality, highlighting the importance of addressing oral health issues to improve sleep (7).

Several mechanisms underlie the relationship between oral health and sleep quality. One key mechanism is the inflammatory pathway (8). Periodontal disease, for instance, leads to chronic inflammation, which can affect systemic health and sleep quality. The release of pro-inflammatory cytokines such as interleukin-6 and tumor necrosis factor-α can disrupt sleep patterns by altering the immune response and affecting the hypothalamic-pituitary-adrenal axis (2,4,9). High cortisol levels can disrupt sleep patterns, and conversely, poor sleep quality can increase cortisol levels (2). This bidirectional relationship is crucial in understanding how sleep disturbances affect the stress response of the body. Studies have shown that elevated cortisol levels are associated with insomnia, waking up during the night, and less sleep time overall (2,4).

However, the aforementioned findings are not universal and certain studies have not found an association between sleep quality and oral hygiene/health (10,11). Given the uncertainty regarding the bidirectional nature of this relationship, a comprehensive meta-analysis is essential to fully understand the magnitude and mechanisms of the interplay between oral health and sleep quality. Such an analysis would help to synthesize data from various studies, providing a clearer picture of how sleep disorders affect oral health and vice versa. Moreover, a meta-analysis could help in addressing the limitations of current studies (12). Therefore, the present systematic review and meta-analysis was performed to assess the relationship between sleep quality/disturbances and oral health/hygiene.

Materials and methods

The present systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (13).

Inclusion and exclusion criteria. Studies were included if they met the following criteria: i) Population: Individuals of any age group, irrespective of sex, in studies assessing oral health status and sleep quality; ii) intervention/exposure: Studies examining the relationship between oral health (such as periodontal disease, dental caries and oral hygiene) and sleep quality; iii) outcomes: Studies reporting on sleep quality using validated tools [such as Pittsburgh Sleep Quality Index (PSQI) and Insomnia Severity Index (ISI)] or on oral health using validated tools [such as Decayed, Missing, and Filled Teeth Index (DMFT) or OHIP]; and iv) study design: Cross-sectional, cohort and case-control studies were included. Review articles, case reports, commentaries and editorials were excluded. Only studies published in English were considered. No time limit was imposed on the publication date. The search was conducted until the end of September 2024.

Search terms and strategy. A comprehensive search of the literature was conducted in September 2024 using the following electronic databases: PubMed (https://pubmed.ncbi.nlm.nih.gov), Embase (https://www.embase.com), Scopus (https://www.scopus.com) and the Cochrane Library (https://www.cochranelibrary.com). Additionally, the references of included studies and relevant review articles were searched to identify any additional studies not captured in the initial database searches. The search strategy was developed using a combination of medical subject headings (MeSH) and free-text terms related to oral health and sleep quality. The search terms included: i) Oral health-related terms: 'Oral health', 'periodontal disease', 'dental caries', 'oral hygiene', 'gingivitis', 'tooth loss' and 'edentulism'; and ii) sleep quality-related terms: 'Sleep quality', 'sleep disturbance', 'insomnia', 'sleep disorders', 'sleep duration', 'Pittsburgh Sleep Quality Index', 'PSQI', 'Insomnia Severity Index' and 'ISI'.

The specific search strategy for PubMed was as follows: ('oral health'[MeSH Terms] OR 'periodontal disease'[MeSH Terms] OR 'dental caries'[MeSH Terms] OR 'oral hygiene'[MeSH Terms] OR 'gingivitis'[MeSH Terms] OR 'tooth loss'[MeSH Terms] OR 'edentulism'[MeSH Terms] OR 'oral health'[Title/Abstract] OR 'periodontal disease'[Title/Abstract] OR 'dental caries'[Title/Abstract] OR 'oral hygiene'[Title/Abstract] OR 'gingivitis'[Title/Abstract] OR 'tooth loss'[Title/Abstract] OR 'edentulism'[Title/Abstract]) AND ('sleep quality'[MeSH Terms] OR 'sleep disturbance'[MeSH Terms] OR 'insomnia'[MeSH Terms] OR 'sleep disorders'[MeSH Terms] OR 'sleep duration'[MeSH Terms] OR 'Pittsburgh Sleep Quality Index'[Title/Abstract] OR 'PSQI'[Title/Abstract] OR 'Insomnia Severity Index'[Title/Abstract] OR 'ISI'[Title/Abstract] OR 'sleep quality'[Title/Abstract] OR 'sleep disturbance'[Title/Abstract] OR 'insomnia'[Title/Abstract] OR 'sleep disorders'[Title/Abstract] OR 'sleep duration'[Title/Abstract]).

Study selection and data extraction. The studies identified through the database search were imported into EndNote X9 (Clarivate) and duplicates were removed. In total, two independent reviewers screened the titles and abstracts of the remaining studies. Full texts of potentially eligible studies were retrieved and assessed according to the inclusion criteria. Any disagreements between the reviewers were resolved through discussion or consultation with a third reviewer. Data were extracted independently by two reviewers using a standardized data extraction form. Extracted data included: i) Study characteristics: Author, year of publication, country and study design; ii) population characteristics: Sample size, age, sex and oral health status; iii) sleep quality assessment: Tools used (such as PSQI and ISI) and definitions; and iv) results: Mean ± standard deviation (SD).

Risk of bias assessment. In total, two independent reviewers assessed the risk of bias of each study using the Newcastle-Ottawa Scale (NOS) for observational studies. The NOS evaluates studies based on selection, comparability and exposure or outcome assessment (14). Each study was rated as low (score, 7-9), moderate (score, 4-6) or high (score, 0-3) risk of bias (14). Discrepancies in the assessments were resolved through discussion or by consulting a third reviewer.

Statistical analysis. Meta-analyses were performed using Comprehensive Meta-Analysis version 3 software (https://meta-analysis.com). The relationship between oral health and sleep quality was synthesized using Standardized Mean Differences (SMDs) to compare outcomes across studies with different measurement scales. The choice between a fixed-effect and a random-effects (in this case) meta-analysis should never be made on the basis of a statistical test for heterogeneity. In addition, since heterogeneity is expected for the intervention effects among multiple studies from different groups and geographical locations, a random effects model was used to calculate the SMDs. Heterogeneity among the studies was assessed using the precision interval approach, which examines the variability in effect sizes across studies. Unlike the I^2 statistic, the precision interval provides a range of plausible true effects, giving a more direct interpretation of heterogeneity. This method was chosen due to its robustness in handling the diverse study designs and populations included in the analysis (15). Publication bias was assessed through Egger's, and Begg and Mazumdar rank correlation tests and visually using funnel plots. Begg's test evaluates the asymmetry

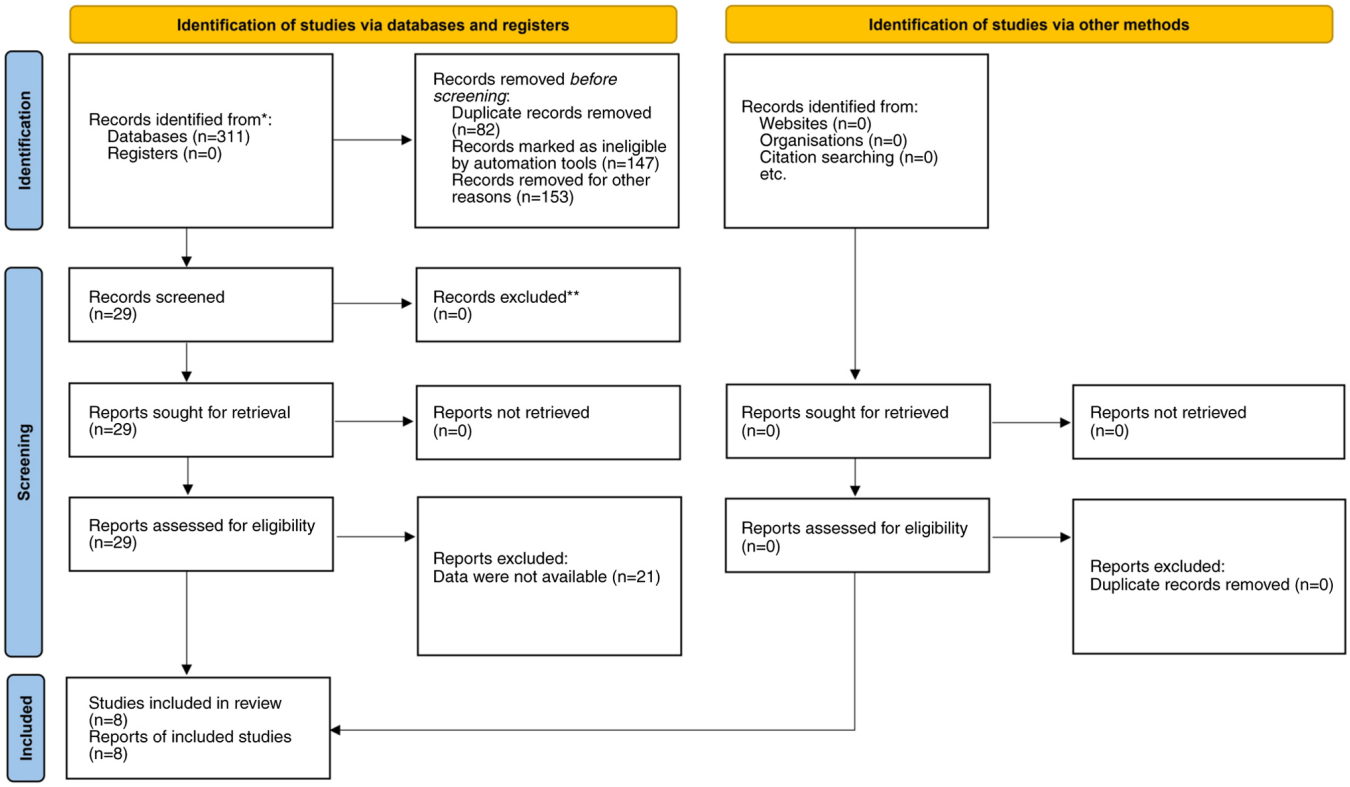

Figure 1. Flow diagram of study selection. Flow diagram illustrating the process of study selection for the meta-analysis. The diagram shows the number of articles identified, duplicates removed, irrelevant studies excluded and the final number of studies included in the analysis.

of the funnel plot, with P<0.05 indicating potential publication bias. In cases where publication bias was suggested, the trim-and-fill method was applied to estimate the impact of missing studies on the overall effect size.

Results

Using the predefined search strategy, a total of 311 articles were identified. After removing duplicates, irrelevant studies, reviews and editorials, 29 articles were deemed eligible for full-text assessment. Of these, 8 articles, encompassing 18 different comparisons, met the criteria for inclusion in the meta-analysis (Fig. 1) (5,6,16-21). Some studies included multiple comparisons with different populations and have therefore been split into multiple studies in the present analysis. The characteristics of the included studies are presented in Table I. The table includes 8 cross-sectional studies conducted between 2015 and 2023 in countries such as Greece, India, Spain, Italy, France, South Korea and the United States. Sample sizes ranged from 60 to 29,870 participants, with age groups spanning from young children (2-5 years) to adults. The total number of patients included across all the studies was 36,559. Oral health assessments used various indices, including the DMFT, Community Periodontal Index and gingival indices. Additionally, sleep quality was measured using tools such as the PSQI, Pediatric Sleep Questionnaire and Epworth Sleepiness Scale. The results showed that poorer oral health, such as higher DMFT scores and gingival inflammation, was often associated with poorer sleep quality, including increased sleep disturbances and reduced sleep duration.

The results of the present study showed a significant association between oral health and sleep quality [SMD, 2.166; confidence interval (95% CI), 0.677-3.655; P=0.004; Fig. 2]. The Leave-One-Out sensitivity analysis showed that the exclusion of no single study significantly affected the total effect size of the studies and its significance (Fig. 3). Additionally, the funnel plot was reasonably symmetric and showed no evidence of publication bias (Fig. 4). The observed and adjusted point estimates were also the same (point estimate: 0.387). In the present analysis, the trim-and-fill method was applied to assess potential publication bias by evaluating the symmetry of the funnel plot. This method involves 'trimming' asymmetric studies and 'filling' in estimated missing studies to achieve symmetry. The results indicated that no studies needed to be trimmed or imputed on either side of the mean, suggesting an absence of publication bias. Consequently, both the observed and adjusted point estimates remained consistent, with a fixed-effect estimate of 0.387 and a random-effect estimate of 2.166. This consistency implies that the data distribution is symmetric, and the influence of publication bias on the present findings is minimal. Regarding the funnel plot visualization, it is important to note that the plot displays the original studies without any imputed data points, as no imputations were necessary. The appearance of points outside the funnel could be attributed to factors such as heterogeneity among studies or variations in study precision. While the trim-and-fill method did not identify missing studies, the presence of points outside the funnel suggests that other factors, such as study heterogeneity, may be influencing the plot's appearance. Therefore, while the trim-and-fill results suggest minimal

Table I. Characteristics of the included studies, population characteristics, sleep quality assessment and the results.

First author/s, year	Study characteristics	Population characteristics	Sleep quality assessment	Results, Mean ± SD	(Refs.)
Apessos *et al*, 2020	Country: Greece; study design: Cross-sectional observational clinical study.	Sample size: 177; age: 18-30 years; sex: Male; oral health status: Good general health, no medical problems.	Tools used: ESS, PSQI, BQ, SB questionnaire and XI.	Age: 23.10±2.86 years; BMI: 25.43±3.69; MST: 24.97±10.61; XI: 19.41±5.88; ESS: 6.97±3.50; PSQI: 5.91±3.17	(16)
Arroyo Buenestado and Ribas-Pérez, 2023	Country: Spain; Study design: Analytical cross-sectional study.	Sample Size: 80; age: 2-5 years; sex: Male (50%) and female (50%); oral health status: Evaluated using DMFT index, with a mean of 1.73±2.34	Tools Used: PSQ and AAPD guideline-based questionnaire.	Occasional snorers: DMFT, 2.63±2.50; non-snorers: DMFT, 1.02±1.96; Significant relationships with noisy breathing, sleepwalking and nightmares.	(17)
Grillo *et al*, 2019	Country: Italy; study design: . Cross-sectional study	Sample size: 122; age: 8-17 years; sex: Male (54.1%) and female (45.9%); oral health status: Evaluated using DMFS, PPD and BOP indices	Tools used: (PSQ) and COHIP.	DMFS: SDB+ (13.6±4.7) andSDB- (3.5±2.2); COHIP (parent): SDB+ (24.5±5.6) and SDB- (16.7±4.3); COHIP (child): SDB+ (23.2±4.6) and SDB- (15.9±3.8)	(5)
Carra *et al*, 2017	Country: France; study design: Cross-sectional epidemiological study.	Sample size: 29,870; mean age: 45.3 years; sex: Male (47.9%) and female (52.1%); oral health status: Evaluated using plaque index, calculus index, gingival inflammation and masticatory function.	Tools used: Self-reported questionnaire on sleep disorders and sleep duration.	Age: 45.3±15.19 years; BMI: 25.73±4.93; sleep duration: 6.02±1.48 h; gingival inflammation: Higher in individuals with sleep disorders [AOR 1.22 (1.13-1.32)]	(6)
Chacko *et al*, 2021	Country: India; study design: Cross-sectional study.	Sample size: 85; age: 15-60 years; sex: Male (65.9%) and female (34.1%); oral health status: Categorized into clinically healthy, gingivitis and periodontitis groups.	Tools used: PSQI.	PSQI: Healthy (3.03±1.14), gingivitis (4.44±1.28) and periodontitis (9.03±2.17). GI: Healthy (0.67±0.44), gingivitis (1.31±0.19) and periodontitis (2.05±0.51); PD: Healthy (2.16±0.33), gingivitis (2.73±0.38) and periodontitis (5.19±1.31).	(18)
Grover *et al*, 2015	Country: India; study design: Cross-sectional study.	Sample size: 60; age: 25-50 years; sex: Male (43.3%) and female (56.7%); oral health status: Categorized into clinically healthy, gingivitis and periodontitis groups.	Tools used: PSQI.	PSQI: Healthy (1.20±0.83), gingivitis (1.88±0.18) and periodontitis (7.39±1.33); GI: Healthy (0), gingivitis (1.39±0.32) and periodontitis (1.88±0.18). PD: Healthy (2.08±0.06), gingivitis (2.34±0.17) and periodontitis (3.58±0.63).	(19)

Table I. Continued.

First author/s, year	Study characteristics	Population characteristics	Sleep quality assessment	Results, Mean ± SD	(Refs.)
Romandini *et al*, 2017	Country: South Korea; study design: Cross-sectional study.	Sample size: 5,812; Age: Adults (≥19 years); sex: Not specified; oral health status: Evaluated using Community Periodontal Index.	Tools used: Self-reported average daily sleep duration.	Sleep duration: 6.89±0.004 h; Periodontitis prevalence: Higher in those with longer sleep duration.	(20)
Tamasa *et al*, 2018	Country: United States; study design: Cross-sectional study.	Sample size: 123; age: 8-17 years; sex: Male (52%) and female (48%); Oral health status: Evaluated using COHIP, DMFS and periodontal indices.	Tools Used: PSQ.	COHIP: SDB+ (24.5±12) and SDB- (11.6±9.2); DMFS: SDB+ (15.7±15.7) and SDB- (3.7±6.2); Periodontal PD: SDB+ (2.0±1.0) and SDB- (0.0±0.7); Bleeding on probing: SDB+ (90%) and SDB- (20%).	(21)

ESS, Epworth Sleepiness Scale; PSQI, Pittsburgh Sleep Quality Index; BQ, Berlin Questionnaire; SB, Sleep Bruxism (questionnaire); XI, Xerostomia Inventory; SVS, Subjective Vitality Scale; FAS, Fatigue Assessment Scale; DMFT, Decayed, Missing, and Filled Teeth Index; PSQ, Pediatric Sleep Questionnaire; COHIP, Child Oral Health Impact Profile; GI, Gingival Index; PD, pocket depth; AAPD, American Academy of Pediatric Dentistry; MST, modified Schirmer test; PPD, periodontal probing depth; BOP, bleeding on probing; SDB, sleep-disordered breathing; AOR, adjusted odds ratio.

Table II. Begg and Mazumdar's rank correlation and Egger's regression intercept.

Measure	Value
Kendall's S statistic (P-Q)	33.000
Kendall's tau without continuity correction	
Tau	0.215
Z-value for tau	1.249
P-value (1-tailed)	0.105
P-value (2-tailed)	0.211
Kendall's tau with continuity correction	
Tau	0.209
Z-value for tau	1.212
P-value (1-tailed)	0.112
P-value (2-tailed)	0.225
Egger's regression intercept	
Intercept	13.578
Standard error	6.871
95% Lower limit (2-tailed)	-0.987
95% Upper limit (2-tailed)	28.144
t-value	1.976
Degrees of freedom	16.000
P-value (1-tailed)	0.032
P-value (2-tailed)	0.065

The first part of the table presents Kendall's S statistic and Kendall's tau values (both with and without continuity correction), along with their associated Z-values and P-values. These metrics provide insights into rank correlation and potential publication bias. The second part of the table provides the results of Egger's regression intercept, which includes the intercept value, standard error, 95% confidence intervals (lower and upper limits), t-value, degrees of freedom, and associated P-values. This analysis evaluates the asymmetry in funnel plots to further detect publication bias.

publication bias, the funnel plot should be interpreted with caution, considering these potential influences (Fig. 4). Begg and Mazumdar rank correlation confirmed these findings by showing no evidence of publication bias (two-tailed P=0.225). Similarly, Egger's regression intercept revealed no evidence of publication bias (two-tailed P=0.065) (Table II).

The precision interval analysis yielded a mean effect size of 2.17 with a 95% confidence interval (CI) ranging from 0.68 to 3.66. This suggests that, based on the present sample data, it is with 95% confidence that the true effect size lies between 0.68 and 3.66. Additionally, the analysis provided a prediction interval from -4.83 to 9.16, indicating that in 95% of comparable populations, the true effect size is expected to fall within this range. The broader prediction interval reflects the variability observed across different populations, highlighting the potential for diverse outcomes in similar studies (Fig. 5).

Due to the high heterogeneity of the included studies, a moderator analysis was conducted to examine the effects of age (mean ± SD) and sex (percentage of male participants) on the overall effect size. The analysis revealed that the mean age of participants significantly influenced the study outcomes, with higher ages associated with lower SMDs (slope,

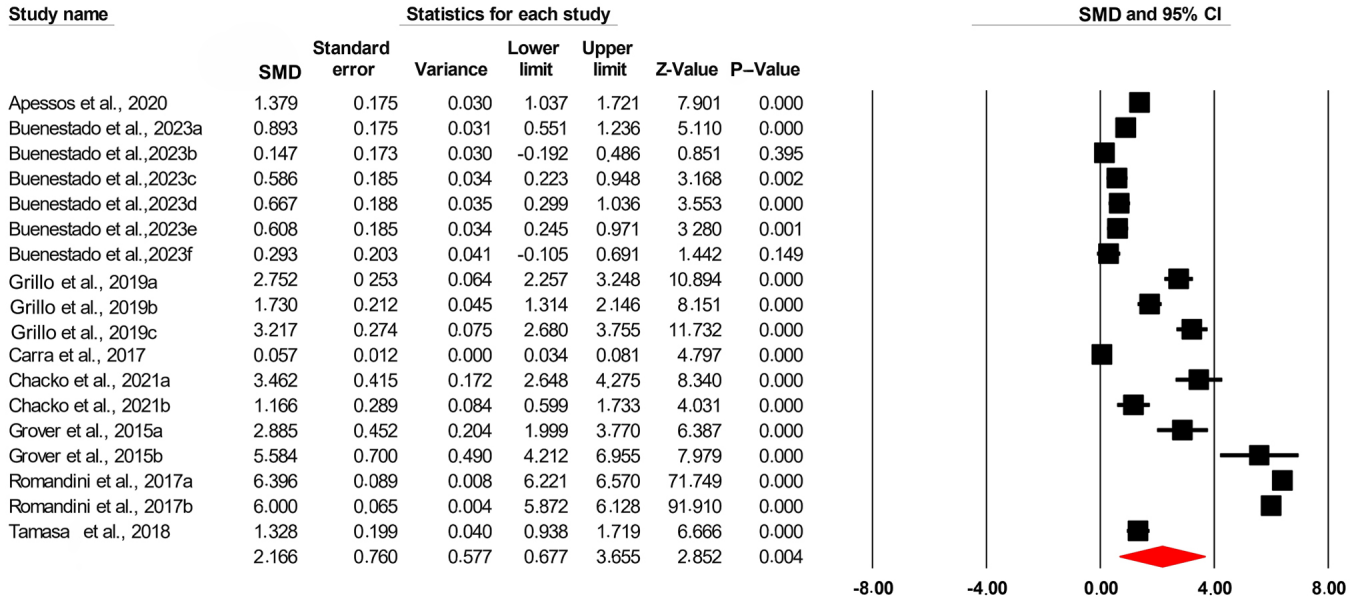

Figure 2. Forest plot of SMD. Forest plot displaying the SMD and 95% CI for the association between oral health and sleep quality. Each study is represented by a square, with the size of the square indicating the weight of the study in the meta-analysis. The horizontal line represents the 95% CI for each study, and the diamond at the bottom represents the overall effect size and its 95% CI. CI, confidence interval; SMD, standardized mean difference..

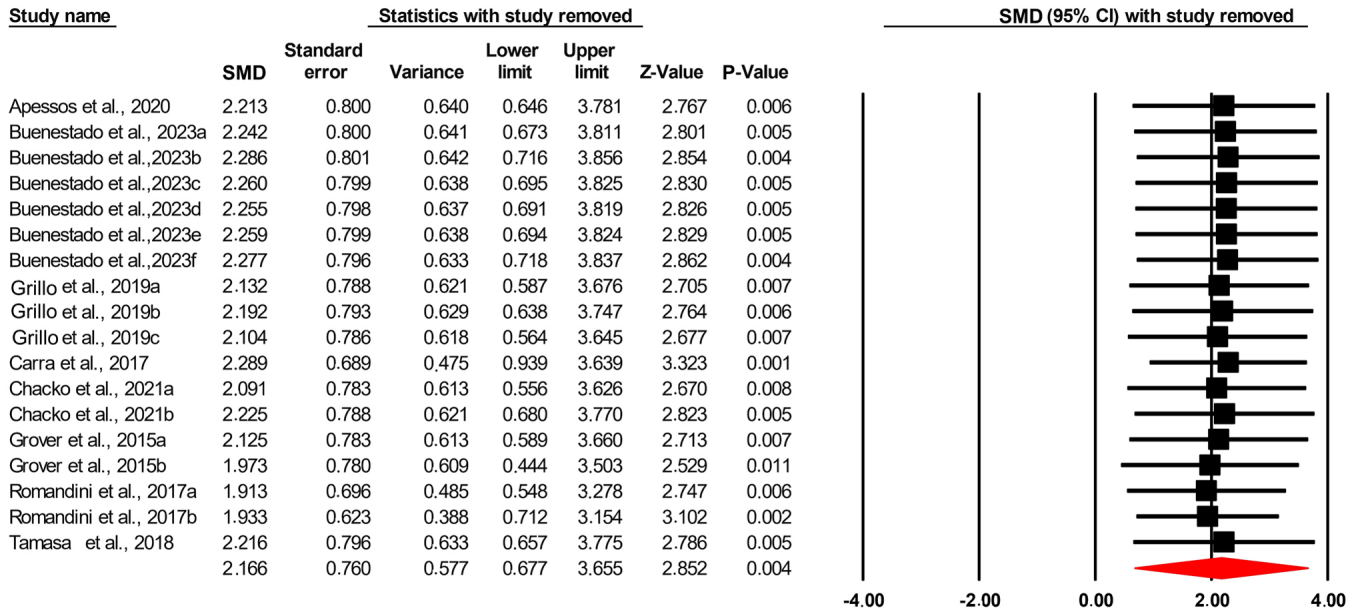

Figure 3. Leave-One-Out sensitivity analysis. Leave-One-Out sensitivity analysis plot showing the effect of excluding each study on the overall SMD and its 95% CI. The plot indicates that no single study significantly affects the overall effect size or its significance. CI, confidence interval; SMD, standardized mean difference.

P<0.00001; Fig. 6A). Conversely, an increase in the proportion of male participants was associated with a higher SMDs (slope, P<0.00001; Fig. 6B). To address this issue further, subgroup analyses based on the continent of origin (Europe, Asia and North America) and year of publication of the studies were performed. However, the heterogeneity of the subgroups remained high even at subgroup level (data not shown).

Based on the NOS study quality appraisal, 2 studies were deemed to have low quality while others were found to be of high quality (Table III). The decision to include the 2 studies of low quality was made to provide a comprehensive overview of the existing literature on the topic. Excluding these studies could have led to an incomplete synthesis of available evidence, potentially omitting valuable insights.

Discussion

The meta-analysis conducted in the present study on the association between oral health and sleep quality yielded significant findings, highlighting a robust link between these two critical aspects of overall health. The results indicated that individuals with poorer oral health, as measured by indices

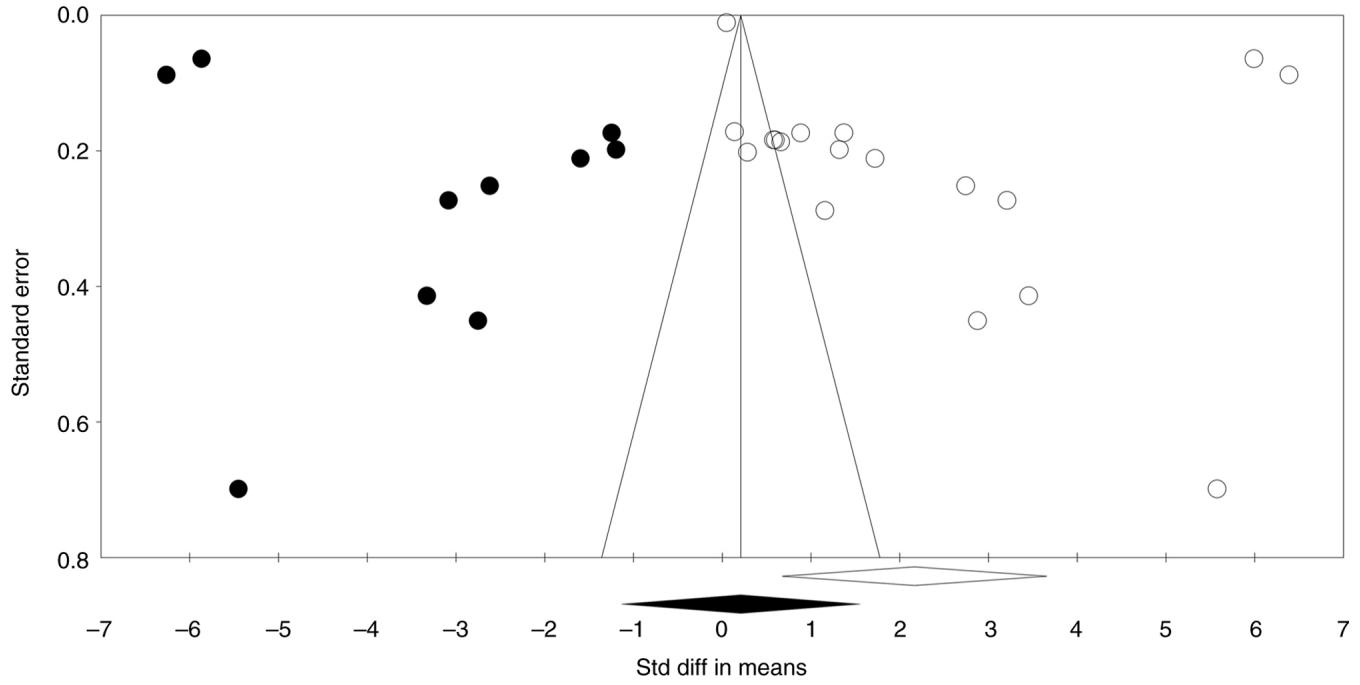

Figure 4. Funnel plot for publication bias assessment. Funnel plot assessing publication bias in the meta-analysis. The plot shows the distribution of the effect sizes of the studies against their standard errors. The symmetry of the plot indicates no evidence of publication bias. The trim and fill analysis is also shown, indicating no missing studies to the right or left of the mean.

such as the DMFT and gingival indices, were more likely to experience sleep disturbances and reduced sleep duration. The Leave-One-Out sensitivity analysis showed that the exclusion of any single study did not significantly affect the total effect size, suggesting that the findings were robust and not heavily influenced by any one study. This consistency was further supported by the symmetry of the funnel plot and the absence of evidence for publication bias, as confirmed by the Begg and Mazumdar rank correlation and Egger's regression intercept. The absence of adjusted values indicated that the observed distribution of studies was balanced around the pooled effect size. Therefore, the results of the trim and fill analysis supported the robustness of the study findings, reinforcing that the significant association between oral health and sleep quality (SMD, 2.166; 95% CI, 0.677-3.655; P=0.004) was not notably impacted by potential publication bias.

A wide precision interval, as observed in the present study, suggests variability in the strength of the association across different populations, indicating that the true effect size may vary depending on the specific characteristics of each study. This reflects a high degree of heterogeneity, which the moderator analysis performed in the present study aimed to address (15). For instance, the analysis revealed that age played a significant role, with studies involving older populations tending to show lower SMDs. This finding suggests that age-related factors may influence the strength of the association between oral health and sleep quality. Additionally, the moderator analysis highlighted that the proportion of male participants also affected the results, with a higher percentage of males associated with larger SMDs. These findings indicate that demographic factors such as age and sex contribute to the observed variability, leading to the wide precision interval. This variability could arise due to different age groups and sex distributions responding differently to the factors influencing both sleep quality and oral health.

The association between sleep disorders and oral health is well-documented in the literature. For instance, a study using self-reported questionnaires found that individuals with sleep disorders reported worse self-perceived oral health, including a higher prevalence of tooth and temporomandibular joint pain (22). Another study highlighted that both short and long sleep durations are significantly associated with poor oral health status. Specifically, sleep durations of ≤5 h and ≥9 h per night were linked to higher odds of poor oral health compared with a normal sleep duration of 6-8 h (23). This supports the results of the present meta-analysis, suggesting that sleep quality and duration are critical factors influencing oral health. Additionally, a study examining the relationship between sleep duration and dental caries found a statistically significant negative relationship, indicating that individuals who sleep ≥7 h per night are less likely to experience dental caries compared with those who sleep <7 h (24). This finding is consistent with the broader theme that adequate sleep is essential for maintaining good oral health.

Poor oral health can directly affect sleep quality through various mechanisms. For instance, dental issues such as tooth decay, gum disease and oral infections can cause discomfort, leading to difficulty falling asleep or frequent awakenings (25). Additionally, conditions such as sleep apnea, which can be linked to oral health issues such as misalignment of the jaw or the tongue falling back into the throat, further disrupt sleep patterns (25). Poor sleep quality can exacerbate stress and inflammation, which in turn can worsen oral health. Chronic sleep deprivation is known to increase levels of inflammatory markers, which can contribute to conditions such as periodontitis and other oral health issues (22). The

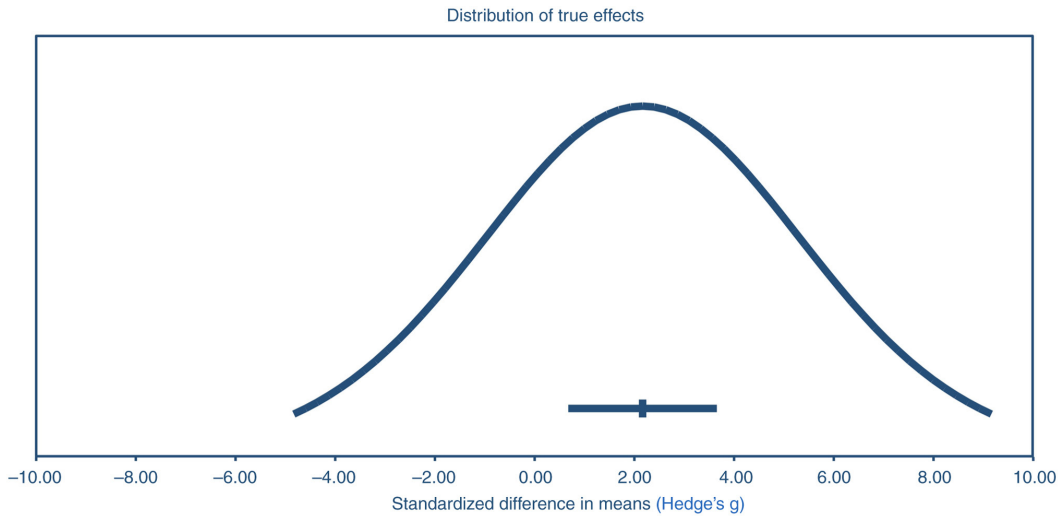

Figure 5. Precision interval analysis. Precision interval analysis plot showing the mean effect size and its 95% confidence interval for the association between oral health and sleep quality. The plot also displays the precision interval, indicating the range within which the true effect size is likely to fall in 95% of comparable populations.

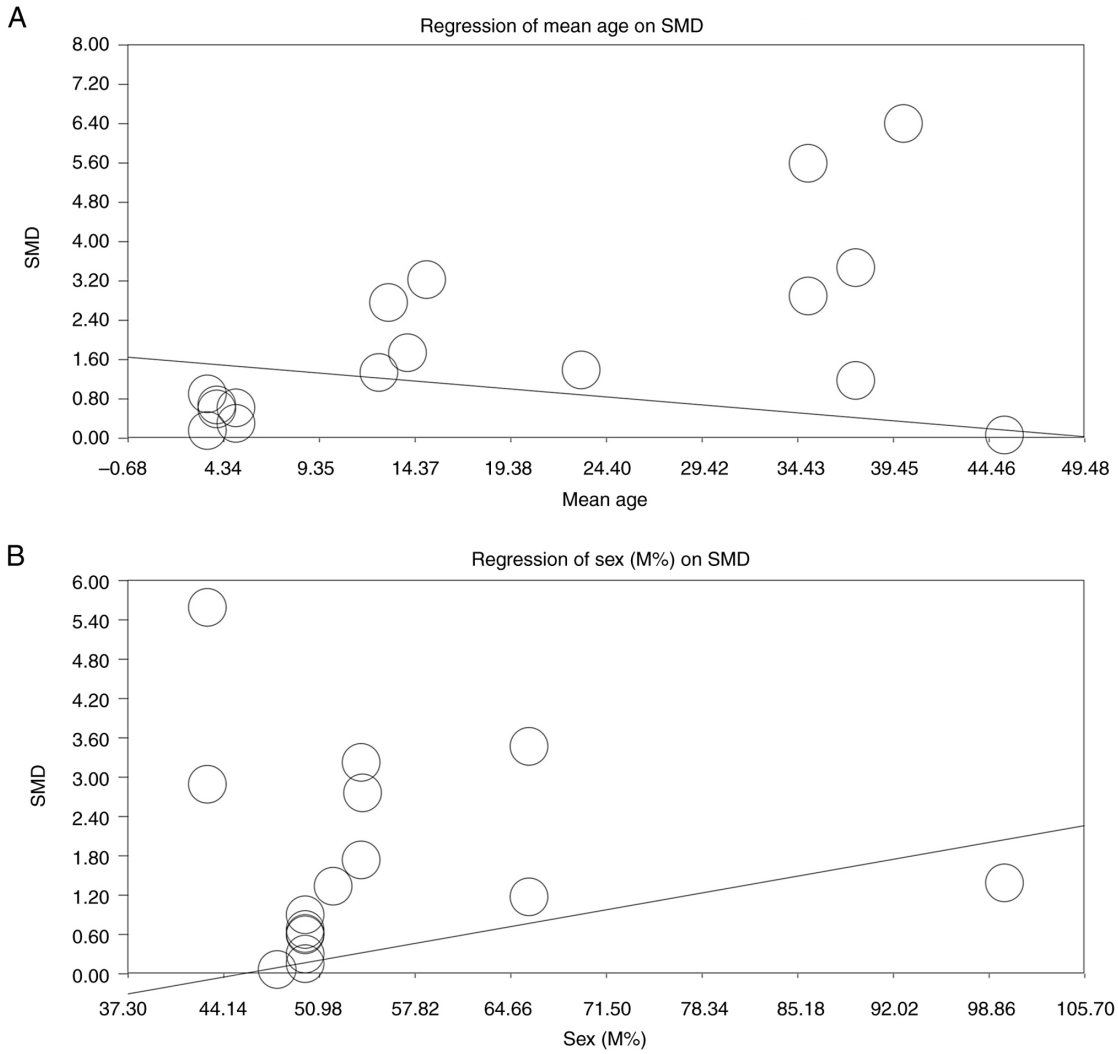

Figure 6. Moderator analysis of mean age and sex proportion on SMD. (A) Regression of mean age on SMD. This panel illustrates the relationship between the mean age of participants and the SMDs across studies. The negative slope indicates that a higher mean age is associated with a lower SMD, suggesting that older populations may exhibit smaller effect sizes. (B) Regression of sex (male) proportion on SMD. This panel shows the relationship between the proportion of male participants in the studies and the SMDs. The positive slope suggests that a higher proportion of male participants is associated with larger SMDs, indicating stronger effects in studies with more male-dominated samples. The bubble size indicates the relative weight of each study in the analysis. SMD, standardized mean differences; M, male.

Table III. Methodological quality assessment of cross-sectional studies using the Newcastle-Ottawa Scale[a].

	Criteria									
	Selection				Comparability		Outcome			
First author/s, year	Representativeness of the sample	Non-respondents	Sample size	Ascertainment of the exposure (risk factor)	The study controls for the most important factor	The study control for any additional factor	Assessment of the outcome	Statistical test	Total score	(Refs.)
Apessos, *et al*, 2020	The study sample consisted of 177 Greek male soldiers without medical problems, ensuring a homogenous population.	Four participants did not agree to undergo the specific test and were excluded.	177 participants, divided into a study group (n=63) and a control group (n=110).	Morning hyposalivation was assessed using the MST.	Age and BMI were controlled, showing no significant difference between the study and control groups.	Smoking status was considered, with smokers prevailing in the study group.	Sleep quality, daytime sleepiness, risk of OSA, and sleep bruxism were assessed using validated questionnaires (PSQI, ESS and BQ, SB questionnaire).	The correlation between variables was tested using the Pearson χ^2 test, Mann-Whitney U test and Kruskal-Wallis test. The level of significance was set at $P<0.05$, with Bonferroni correction applied for multiple tests.	8	(16)
Buenestado and Ribas-Pérez, 2023	Included healthy children aged 2-5 years from Pozoblanco, Córdoba.	40 children did not meet inclusion criteria.	80	Sleep disorders. assessed using the PSQ	Age and BMI were controlled.	Exclusion of children with regular medication or orthopedic treatment.	Caries risk factors and DMFT index evaluated using clinical examination and questionnaires.	Mann-Whitney U test, Kruskal-Wallis test, Spearman's correlation and two-way ANOVA	8	(17)

Table III. Continued.

	Criteria								
	Selection				Comparability		Outcome		
First author/s, year	Representativeness of the sample	Non-respondents	Sample size	Ascertainment of the exposure (risk factor)	The study controls for the most important factor	The study control for any additional factor	Assessment of the outcome	Statistical test	Total score	(Refs.)
Grillo *et al*, 2019	Included children aged 8-17 years from a university-based dental clinic.	Not explicitly mentioned.	122	Sleep-disordered breathing assessed using the PSQ.	Sex, caregiver's.	None mentioned. education, family social class, obesity, Mallampati classification, Brodsky score and Angle's malocclusion classification were controlled	Oral health status and oral health-related quality of life evaluated using dental exams and the COHIP questionnaire.	χ^2 test, Mann-Whitney test, Student t-test and regression analysis.	6	(5)
Carra *et al*, 2017	Included a French cohort of individuals who underwent medical and oral examinations between 2012 and 2013.	Not explicitly mentioned.	29,870	Sleep disorders assessed based on self-reported data.	Age, sex and BMI were controlled.	Smoking status, diabetes, EPICES score, depression and stress were also considered.	Oral health variables such as plaque, calculus, gingival inflammation and masticatory function were evaluated.	Multivariate logistic regression and general linear models.	7	(6)
Chacko *et al*, 2021	Included subjects. from SMBT Dental College & Hospital, Sangamner, Maharashtra, India	Not explicitly mentioned.	85	Sleep deprivation assessed using the PSQI.	Age, sex and. socioeconomic status were controlled	Exclusion of subjects with systemic diseases, recent periodontal therapy or medication use.	Periodontal status assessed using GI and pocket probing depth.	ANOVA F test, Tukey's post hoc test, χ^2 test, Pearson correlation coefficient.	7	(18)

Table III. Continued.

	Criteria									
	Selection				Comparability		Outcome			
First author/s, year	Representativeness of the sample	Non-respondents	Sample size	Ascertainment of the exposure (risk factor)	The study controls for the most important factor	The study control for any additional factor	Assessment of the outcome	Statistical test	Total score	(Refs.)
Romandini *et al*, 2017	Representative sample of the South Korean population.	Not explicitly mentioned.	5,812	Sleep duration assessed through self-reported average daily sleep duration.	Age, sex, education, smoking status, alcoholism and consumption frequency of coffee, tea, chocolate and red wine were controlled.	None mentioned.	Periodontal status assessed using the CPI.	Multivariate logistic regressions.	6	(20)
Tamasa *et al*, 2018	Included children aged 8-17 years from a university-based pediatric dental clinic.	Not explicitly mentioned.	123	Sleep-disordered breathing assessed using the PSQ.	Age, sex and parental education were considered.	Exclusion of subjects with craniofacial diagnoses, systemic conditions, neurologic disease or cognitive impairment.	Oral health status assessed using dental examinations and the COHIP questionnaire.	χ^2 tests, t-tests and linear and logistic regression analyses.	7	(21)

[a]Each item accounts for 1 point. Studies with <7 star items were considered low quality and those with ≥7 star items were considered high quality. ESS, Epworth Sleepiness Scale; PSQI, Pittsburgh Sleep Quality Index; BQ, Berlin Questionnaire; SB, Sleep Bruxism (questionnaire); XI, Xerostomia Inventory; SVS, Subjective Vitality Scale; FAS, Fatigue Assessment Scale; DMFT, Decayed, Missing, and Filled Teeth Index; PSQ, Pediatric Sleep Questionnaire; COHIP, Child Oral Health Impact Profile; GI, Gingival Index; PD, pocket depth; MST, modified Schirmer test; CPI, Community Periodontal Index; OSA, obstructive sleep apnea; EPICES, Évaluation de la Précarité et des Inégalités de santé pour les Centres d'Examen de Santé.

relationship between oral health and sleep quality may also be influenced by behavioral factors. For instance, individuals with poor sleep quality might have reduced motivation or ability to maintain good oral hygiene practices, leading to a vicious cycle of deteriorating oral health and sleep quality (25).

The present meta-analysis included a diverse range of studies conducted across different countries and populations, providing a comprehensive overview of the association between oral health and sleep quality. The use of SMD and sensitivity analyses ensured that the findings were robust and not unduly influenced by any single study. The absence of publication bias further strengthens the reliability of the results. The majority of the included studies were deemed to be of high quality according to the NOS study quality appraisal, which enhances the credibility of the findings. However, the present study had several shortcomings. The wide precision interval (-4.83 to 9.16) indicated significant variability in the strength of the association across different populations. This variability could be due to differences in study designs, population demographics and the measurement tools used. A key limitation is the reliance on self-reported sleep measures in a number of the included studies. Self-reported data can be prone to recall and social desirability biases, leading to possible misclassification of sleep quality or disorders, which may underestimate the true impact of sleep disturbances on oral health. Moreover, self-reports often lack the precision of objective measures (including polysomnography or actigraphy), which are more accurate in diagnosing conditions such as obstructive sleep apnea. This could result in the underreporting of certain sleep disorders, further influencing the observed association between sleep quality and oral health. The included studies were predominantly cross-sectional, which limits the ability to establish causality between oral health and sleep quality. Longitudinal studies are necessary to determine the temporal relationship between these variables. The use of various indices for oral health and sleep quality might also introduce some heterogeneity in the results. Therefore, standardization of measurement tools across studies could help in reducing this variability. While the present study adjusted for several covariates, there could be other unmeasured confounding variables that influence the relationship between oral health and sleep quality. Future studies should aim to control for a broader range of potential confounders.

Several gaps in knowledge remain in the field of oral health and sleep quality. One key area is the mechanistic pathways through which sleep quality impacts oral health, such as the role of inflammatory processes and immune responses. Additionally, more research is needed to understand the impact of specific sleep disorders, such as obstructive sleep apnea, on various oral health conditions beyond periodontitis

The findings of the present meta-analysis highlight important clinical implications. Clinicians should consider incorporating basic sleep assessments into routine dental check-ups, as poor sleep quality is linked to worsened oral health outcomes. Collaboration with sleep specialists for patients with severe oral health issues and suspected sleep disorders can help optimize patient care. Additionally, educating patients about the relationship between sleep and oral health can encourage improved sleeping habits, which may improve oral health maintenance and recovery. For older patients and those with chronic oral conditions, screening for sleep issues may be particularly beneficial in managing their overall health.

In conclusion, the present meta-analysis provided strong evidence for a significant association between poorer oral health and poorer sleep quality. This relationship is supported by various studies in the literature, which highlight the direct and indirect mechanisms through which oral health can impact sleep and vice versa. The robust statistical analysis and the high quality of the included studies are notable strengths of the present study. However, the variability in study populations and the cross-sectional nature of the included studies are limitations that need to be addressed in future research. Understanding this association can inform public health strategies aimed at improving both oral health and sleep quality, ultimately contributing to improved overall health outcomes. Given the cross-sectional nature of most included studies, future research should focus on longitudinal studies to establish causality between oral health and sleep quality. Long-term studies that follow individuals over time can clarify whether poor sleep quality leads to deteriorating oral health, or if existing oral health issues contribute to sleep disturbances.

Acknowledgements

Not applicable.

Funding

No funding was received.

Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

XH conceived, designed, revised, supervised and edited the manuscript, as well as analyzed and interpreted the data. FL acquired the data. FL and XH confirm the authenticity of the data. Both authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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