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# The effects of thyroid function on periodontal status: a systematic review and meta-analysis

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## Abstract

**Background** Thyroid dysfunction causes various oral manifestations, while periodontal disease is a chronic inflammatory condition affecting the supporting structures of teeth. This systematic review and meta-analysis aimed to evaluate the effects of thyroid dysfunction on periodontal disease indices, synthesizing evidence to clarify the relationship between these conditions.

**Methods** A comprehensive search followed PRISMA guidelines across Medline, Scopus, Web of Science, and Google Scholar from inception to September 2024. Studies included adults with diagnosed thyroid dysfunction and healthy controls. Data were extracted on thyroid function tests and periodontal disease indices. The risk of bias and quality of studies were assessed using funnel plots, Begg's and Egger's indices, and the Cochrane tool. Effect sizes were calculated using standard mean difference (SMD) via Comprehensive Meta-Analysis software.

**Results** Eight studies (seven publications) were included. The analysis revealed that patients with thyroid dysfunction exhibited significantly higher periodontal disease indices than controls, with a pooled SMD of 0.369 (95% CI: 0.194–0.545, $p < 0.001$). The effects of thyroid dysfunction were found on clinical attachment level and pocket probing depth, but not on other indices like the gingival and plaque indexes. Sensitivity analysis confirmed the robustness of these findings. The quality of studies was low, with notable risks of bias.

**Conclusions** Thyroid dysfunction is associated with increased periodontal disease indices, highlighting the need for further research to explore the underlying mechanisms and improve clinical management strategies for affected patients. Future studies should aim for higher methodological rigor to enhance the reliability of findings.

**Keywords** Thyroid function, Periodontal status, Meta-analysis, Thyroid dysfunction, Hyperthyroidism, Hypothyroidism, Periodontitis

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## Introduction

The relationship between thyroid function and periodontal health has gained increasing attention in recent years, as both conditions are linked to systemic inflammation and metabolic dysregulation [1]. Periodontitis, a chronic inflammatory disease affecting the supporting structures of the teeth, can lead to tooth loss and has been associated with various systemic diseases, including cardiovascular disease, diabetes, and autoimmune disorders [2]. Conversely, thyroid dysfunction, particularly hypothyroidism and hyperthyroidism, can disrupt metabolic processes and immune responses, potentially exacerbating periodontal conditions [3, 4].

Thyroid hormones, primarily thyroxine (T4) and triiodothyronine (T3) play crucial roles in regulating metabolism, growth, and development. They influence the immune response and inflammatory processes, which are critical in the pathogenesis of periodontal disease [4]. Studies have shown that hypothyroidism may lead to alterations in the oral environment, such as dry mouth, delayed wound healing, and changes in the composition of oral microbiota, which can contribute to periodontal disease progression [1, 5]. Furthermore, the inflammatory response in periodontitis may be intensified in individuals with thyroid dysfunction due to an imbalance in pro-inflammatory and anti-inflammatory cytokines [3, 6].

Recent systematic reviews and meta-analyses have begun to elucidate the connection between thyroid function and periodontal status [4]. For instance, a nationwide cohort study indicated that lower serum levels of thyroid-stimulating hormone (TSH) were significantly associated with a higher prevalence of periodontitis [1]. This finding suggests that even subtle variations in thyroid function can impact periodontal health, highlighting the need for clinicians to consider thyroid function in the management of periodontal disease [1].

The mechanisms by which thyroid hormones affect periodontal health are multifaceted. Thyroid hormones modulate bone metabolism and remodeling, which are essential processes in maintaining the integrity of the periodontium. Research has demonstrated that TSH receptors are present in periodontal tissues, indicating a direct influence of thyroid hormones on periodontal health [6]. Additionally, thyroid dysfunction can lead to systemic changes, such as increased oxidative stress and altered immune responses, which may further exacerbate periodontal disease [7, 8].

Despite the emerging evidence linking thyroid function to periodontal health, there remains a need for more robust, controlled studies to clarify the nature of this relationship. Most existing studies are cross-sectional in design, limiting the ability to draw causal inferences. By systematically synthesizing the existing evidence and quantitatively pooling the results, this review offers a robust assessment of the association between thyroid dysfunction and periodontal disease. The findings highlight the importance of considering thyroid status in the management of periodontal conditions and underscore the need for further research, particularly longitudinal studies and well-controlled prospective trials.

## Materials and methods

### Search strategy

The analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [9]. A comprehensive electronic search was conducted across multiple databases, including Medline via PubMed, Scopus, Web of Science, and Google Scholar, from inception until September 2024. Studies including adults diagnosed with specific thyroid dysfunctions, such as autoimmune thyroiditis, Graves' disease, and Hashimoto's thyroiditis, were considered. This differentiation allowed us to explore the heterogeneity of thyroid disorders and their unique relationships with periodontal health. The search terms utilized were "periodontitis," "periodontal disease," "hyperthyroidism", "hypothyroidism," and "thyroid" structured as follows: ( TITLE-ABS-KEY ( periodontitis ) OR TITLE-ABS-KEY ( periodontal AND disease ) AND TITLE-ABS-KEY ( hypothyroidism ) OR TITLE-ABS-KEY ( hyperthyroidism ) OR TITLE-ABS-KEY ( thyroid ) ). Additionally, references from the identified articles and related meta-analyses were reviewed for further pertinent studies.

### Selection criteria

The study population included adults diagnosed with thyroid dysfunction (hypothyroidism or hyperthyroidism) of any cause (particularly autoimmune thyroiditis, Graves' disease, and Hashimoto's thyroiditis, as their potential for immune dysregulation may influence periodontal outcomes) according to the clinical findings and biochemical tests (T3, T4, and TSH). The control group was composed of healthy volunteers without thyroid dysfunction. The American Association of Clinical Endocrinology states that low/high levels of circulating free T4 and increased/decreased TSH are suggestive of hypo/hyperthyroidism [10]. The definition of periodontitis was different between studies. These criteria are presented as comparators in the analysis section of the results. For instance, Saraswathi et al., defined chronic periodontitis as attachment loss greater than 5 mm at more than 30% of the site and bleeding during probing [11]. However, we prioritized studies that adhered to established diagnostic criteria for periodontitis, focusing on definitions that align with or build upon the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions. This ensured a baseline

consistency in case definitions, while also allowing for broader data synthesis. While definitions varied, inclusion was determined based on their clinical relevance and methodological rigor. This variability was managed by employing comparative analyses in the results section to harmonize findings. Smokers and patients who took antibiotics or anti-inflammatory drugs 3 months before the study were excluded [12]. The exclusion criteria were expanded to include participants with coexisting systemic diseases such as diabetes and cardiovascular conditions, which could affect periodontal status. This ensured that the analysis focused solely on the impact of thyroid dysfunction. Only full-text studies published in English and involving human subjects were included, while in-vivo, in-vitro, and in-silico studies were excluded.

### Data extraction

The full-text publications were carefully assessed based on predetermined exclusion criteria after abstracts were first screened for inclusion criteria. This approach ensured minimum heterogeneity and good quality. A kappa measure of agreement ($\kappa = 1.00$) was determined to guarantee consistency between the two reviewers who independently classified the research. The study authors were contacted in case of missing data. Study authors, publication date, type of thyroid dysfunction, thyroid function tests, and periodontal disease indicators and indices (papillary bleeding index (PBI), clinical attachment level (CAL), pocket probing depth (PPD), plaque index, gingival index, and blood and salivary inflammatory cytokine levels) were extracted from the studies. Standard deviations (SDs), means, and sample sizes for both case and control groups were extracted to determine the effect size. Research articles that lacked the requisite outcome data were eliminated by the authors.

### Outcome

The primary outcome of interest was the effect of thyroid dysfunction on periodontal disease activity in the case group compared to the control group.

### Risk of bias assessment

The risk of bias (RoB) for included studies was independently assessed by two authors using the Cochrane RoB assessment tool, focusing on aspects such as sequence generation, allocation concealment, blinding, selective reporting bias, and attrition bias. Funnel plots were employed to visually assess the potential for publication bias, complemented by trim and fill analysis.

### Statistical analysis

Effect size (ES) estimations and publication bias testing were calculated using Comprehensive Meta-Analysis (CMA) software (Version 2; Biostat Inc., Englewood, NJ, USA). For periodontal disease indices (see above), the standard mean difference (SMD) and corresponding 95% confidence intervals (CIs) were calculated. SMD is commonly computed using Cohen's d or Hedges' g. By dividing it by the pooled standard deviation, Cohen's d calculates the difference between sample means of a continuous variable. On the other hand, small sample numbers might lead to a large bias in Cohen's d. Consequently, Hedges' g was employed in this study, which tackles this problem by lowering the bias using a correction factor [13].

A fixed-effects model was utilized to account for heterogeneity in ES estimations, with the $I^2$ statistic applied to quantify the degree of heterogeneity across studies. In this study, it was not opted to use prediction interval analysis to determine the heterogeneity of the data as $I^2$ was equal to null (in cases where $I^2$ equals null, it can be considered a measure of heterogeneity) [14]. The analysis considered $p < 0.05$ as statistically significant. The calculations for multiple outcomes within a single study were performed using established statistical formulas (1) and (2) [15].

$$\overline{Y} = \frac{1}{m}\left(\sum {}_{j}^{m} Y_j\right) \tag{1}$$

where "m" is the number of means and "Y" is the average of the effect sizes from the various outcomes. The entire variance of these means was nonetheless determined as follows:

$$\begin{aligned} V_{\overline{Y}} &= \left(\tfrac{1}{m}\right)^2 var\left(\sum {}_{j=1}^{m} Y_i\right) \\ &= \left(\tfrac{1}{m}\right)^2 \left(\sum {}_{j=1}^{m} V_i + \sum {}_{j \neq k} \left(r_{jk} \sqrt{V_j}\, \sqrt{V_k}\right)\right) \end{aligned} \tag{2}$$

## Results

The search strategy yielded a total of 437 records from various databases. After the removal of duplicates and irrelevant records, 431 studies were excluded based on predefined eligibility criteria, resulting in 6 reports sought for retrieval. All 6 reports were successfully retrieved and assessed for eligibility. Via the manual search of the references of existing scoping reviews and systematic reviews, 6 other studies were found. Out of these 12 studies, 3 were duplicates and were excluded. Upon evaluation, 1 report was excluded due to the unavailability of data, leading to a final inclusion of 8 studies (7 publications) in the meta-analysis [6, 8, 11, 12, 16–18]. The selection process is illustrated in the PRISMA flow diagram (Fig. 1), which details the identification, screening, and inclusion of studies. The included studies encompassed a range of methodologies and sample sizes, providing a comprehensive overview of the effects of thyroid function on periodontal disease. General characteristics of the included

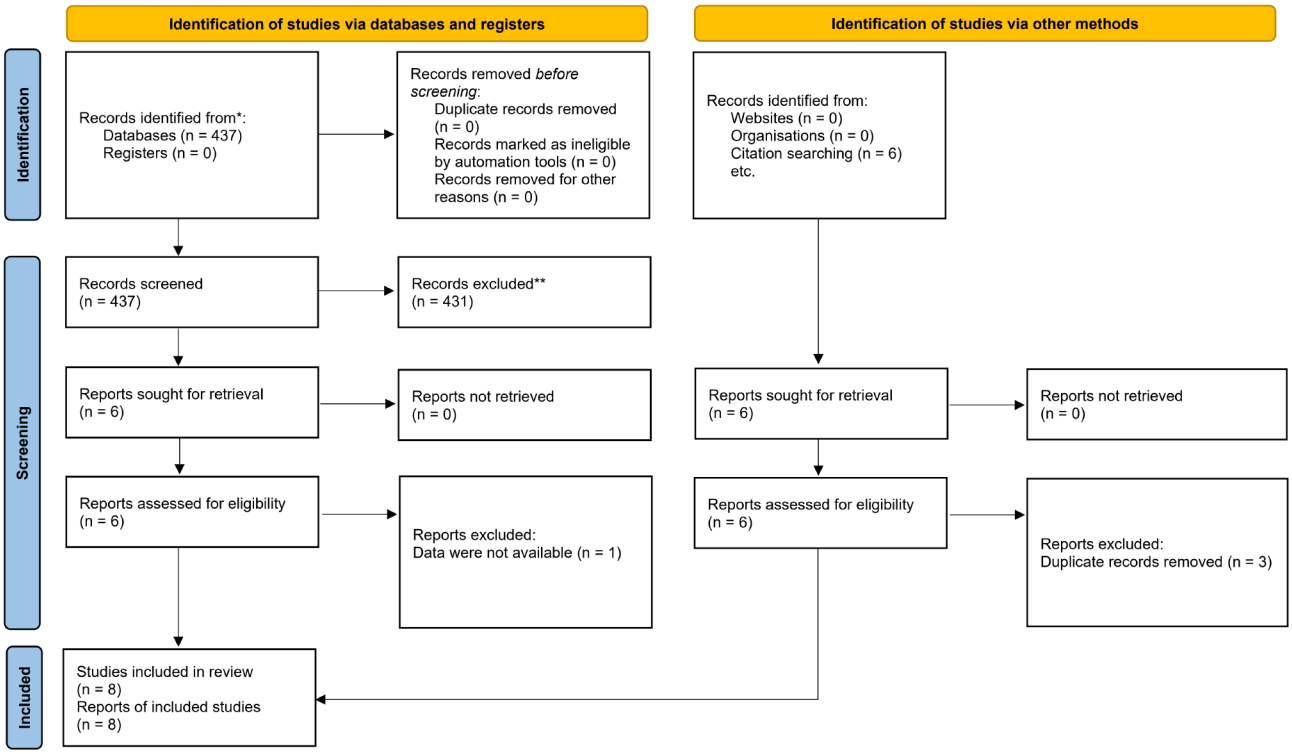


**Fig. 1** PRISMA flow diagram depicting the study selection process for the systematic review and meta-analysis. Several databases were thoroughly searched to find the relevant articles. Duplicates and irrelevant research were eliminated during the preliminary screening process. After identifying potentially relevant papers by title and abstract screening, full-text screening was conducted to decide final inclusion. Every step of the selection process included a record of the reasons for elimination

studies are presented in Table 1. The individual data from the studies are summarized in Table 2.

### The effect of thyroid dysfunction on periodontal disease indices

Our results revealed that patients with thyroid dysfunction (hyper- or hypothyroidism) had significantly higher periodontal disease indices compared to the control group (0.369 SMD, 95%CI: 0.194–0.545, $p < 001$). The heterogeneity of the included data was found to be low ($I^2 = 0.00$) (Fig. 2).

### Leave-one-out sensitivity analysis

A leave-one-out sensitivity analysis was performed, recalculating the overall SMD after removing one study at a time in order to assess the robustness of the association results. The results of this analysis were found to be stable, indicating that the removal of any one study would not alter the overall pooled results (Fig. 3).

### The effect of thyroid dysfunction on individual periodontal disease indices

All the comparisons mentioned here are against a control group. Three studies assessed the effects of thyroid dysfunction on the gingival index. The analysis showed no significant effect of thyroid dysfunction on the gingival index though (0.388 SMD, 95%CI: -0.230 to 1.007, $p = 0.218$) (Fig. 4). Similarly, no significant impacts of thyroid function on the serum IL-6 nor the salivary IL-6 were detected ($n = 4$, 0.649 SMD, 95%CI: -0.045 to 1.343, $p = 0.067$ and $n = 4$, 0.404 SMD, 95%CI: -0.313 to 1.120, $p = 0.269$, respectively) (Fig. 4). Besides, no significant effects of thyroid function on mean plaque index ($n = 4$), papillary bleeding index ($n = 2$), serum TNF-α ($n = 4$), nor salivary TNF-α ($n = 3$) were detected ($p > 0.05$ for all comparisons; Fig. 4). However, it was demonstrated that the effects of thyroid dysfunction on mean CAL and mean PPD reached a statistical significance ($n = 3$, 2.339 SMD, 95%CI: 0.589 to 4.088, $p = 0.009$ and $n = 2$, 0.454 SMD, 95%CI: 0.159 to 0.748, $p = 0.003$, respectively) (Fig. 4).

### Publication bias

The funnel plot showed three missing studies to the left of the mean (Fig. 5). Accordingly, Begg and Mazumdar rank correlation revealed a significant publication bias in the included studies (2-tailed $p = 0.004$). Egger's regression intercept confirmed these findings (2-tailed $p = 0.011$). After including the ES of the missing studies, the overall SMD was shifted from 0.369 to 0.284 (95%CI: 0.126–0.442).

**Table 1** The characteristics of the studies included in the systematic review and meta-analysis. SD, standard deviation; DMFT, the sum of the number of Decayed, Missing due to caries, and Filled Teeth in the permanent teeth

| Study Name | Study Design | Number of Patients | Number of Controls | Mean Age ± SD | Mean TSH Level | Measures to Assess Periodontitis | Conclusion |
|---|---|---|---|---|---|---|---|
| Bhankhar et al., 2017 | Case-control | 15 | 15 | 18–50 | Baseline: 3.48 ± 1.41 uIU/ml<br>> 3 months: 2.31 ± 1.24 uIU/ml | Oral hygiene index-simplified (OHI-S), papillary bleeding index (PBI), periodontal screening and recording index (PSR), clinical attachment level (CAL), radiographic assessment of bone loss | NSPT improves periodontal conditions and reduces inflammatory markers, influencing thyroid hormone levels. |
| Kadhom et al., 2023 | Cross-sectional study | 45 | 45 | 25–45 | Not specified | Plaque index (PLI), gingival index (GI), periodontal pocket depth (PPD), and CAL | Individuals with hyperthyroidism are at risk for periodontal disease and have high levels of IL-6. |
| Monea et al., 2014 | Case-control | 28 | 24 | 23–53 years | Hyperthyroidism: 0.069 ± 0.09 uUI/mL<br>Hypothyroidism: 17.64 ± 7.78 uUI/mL | Serum and salivary levels of TNF-a and IL-6, clinical examination of periodontal tissues | Thyroid dysfunction can co-induce periodontal disease by raising cytokine levels, leading to tissue destruction. |
| Rahangdale et al., 2018 | Comparative cross-sectional study | 52 | 50 | 37.40 ± 11.27 | 0.35-5 uIU/mL | PLI, PBI, probing pocket depth (PPD), CAL, mandibular cortical width (MCW), panoramic mandibular index (PMI) | Hypothyroid patients on thyroxine therapy are at increased risk for periodontal destruction, indicated by increased probing depth and attachment loss. |
| Al-Hindawi et al., 2019 | Cross-sectional study | 30 | 30 | 39.88 ± 1.423 | Elevated TSH, low T4, low/normal T3 | Clinical examination, ELISA for cytokine levels in serum and saliva | Hypothyroidism may cause periodontitis development; serum and salivary IL-1ß, and salivary IL-6 are important biomarkers for early detection of periodontitis in hypothyroid patients. |
| Saima et al., 2016 | Comparative cross-sectional study | 40 | 40 | 3–15 years | Not specified | PLI, GI, DMFT, dmft index | Children with thyroid disorders have poorer oral health compared to healthy children, with higher plaque and gingival index scores. |
| Saraswathi et al., 2020 | Comparative interventional study | 20 | 20 | 18–60 years | Elevated TSH (> 5.5 uIU/mL) | PLI, GI, PPD, and CAL | Nonsurgical periodontal therapy reduces serum levels of IL-6 and TNF-a in chronic periodontitis patients with and without hypothyroidism |

### Quality of studies

RoB assessment showed the low quality of the included studies. None of the included studies was blinded (performance and detection bias) nor randomized (selection bias). On the other hand, selective reporting (reporting bias) and incomplete outcome data (attrition bias) were not discernible in the included studies.

## Discussion

The findings of our systematic review and meta-analysis indicate a significant association between thyroid dysfunction and increased periodontal disease indices. Specifically, patients with thyroid dysfunction, whether hyperthyroid or hypothyroid, exhibited higher periodontal disease indices compared to control groups, with a pooled SMD of 0.369 (95% CI: 0.194–0.545, $p < 0.001$). This suggests that thyroid dysfunction may exacerbate periodontal disease, highlighting the importance of monitoring oral health in patients with thyroid disorders. However, it is important to note that the studies included in this analysis were of low quality and exhibited a significant risk of bias. This raises concerns about the reliability of the findings and suggests that the observed associations may not accurately reflect the true relationship between thyroid dysfunction and periodontal disease. The heterogeneity of the included studies was low ($I^2$ = 0.00), indicating that the results are consistent across the studies analyzed.

The association between thyroid dysfunction and periodontal disease has been a focal point of research in recent years, with several studies supporting this connection [1, 7, 19]. Thyroid hormones play a crucial role in regulating immune responses [20]. Dysregulation of thyroid function, particularly hypothyroidism, can lead to an altered immune response, making individuals more susceptible to periodontal disease. Studies indicate that patients with hypothyroidism often exhibit deeper periodontal probing depths and increased periodontal attachment loss compared to those without thyroid dysfunction [7, 20]. Evidence also suggests that individuals with lower TSH levels have a higher prevalence of periodontitis, suggesting that thyroid hormone levels may influence inflammatory processes within periodontal tissues [1, 20]. The imbalance of pro-inflammatory and anti-inflammatory cytokines due to thyroid dysfunction can further contribute to periodontal tissue destruction. While T3 and T4 levels influence various metabolic processes, the etiology of thyroid disorders, particularly autoimmune conditions like Hashimoto's thyroiditis and Graves' disease, is crucial in understanding the cytokine imbalance. These autoimmune disorders inherently involve immune dysregulation, leading to elevated levels of pro-inflammatory cytokines such as TNF-α, IL-1β, and IFN-γ, which can exacerbate periodontal tissue destruction [1]. Further, patients with thyroid dysfunction may experience impaired wound healing, which can hinder the recovery of periodontal tissues following inflammation or infection. This impairment can lead to more severe periodontal disease progression [21]. There is evidence suggesting a bidirectional relationship between thyroid disease and periodontal disease. While thyroid dysfunction can worsen periodontal health, periodontal disease may also impact thyroid function, highlighting the need for comprehensive management of both conditions in affected individuals [20].

Our findings align with previous scoping reviews and meta-analyses that have explored this relationship [1, 7, 19]. For instance, a scoping review by Aldulaijan et al. (2020) demonstrated a positive correlation between hypothyroidism and the severity of periodontitis, suggesting that altered thyroid hormone levels may exacerbate periodontal conditions [7]. Similarly, a meta-analysis conducted by Ortarzewska et al. (2024) reported that patients with thyroid dysfunction exhibited significantly higher odds of developing periodontitis compared to healthy controls [4]. In comparison to this meta-analysis, our study included a more extensive selection of studies, providing a broader overview of the relationship between various thyroid dysfunctions (both hyperthyroidism and hypothyroidism) and periodontal disease. Previous investigations have predominantly focused on patients with hypothyroidism, often overlooking the effects of hyperthyroidism. Although Ortarzewska et al. (2024) employed inclusive search terms for thyroid diseases, the composition of their included studies was predominantly focused on hypothyroidism [4]. In contrast, our analysis included both hyperthyroid and hypothyroid patients, providing a more comprehensive understanding of how thyroid dysfunction in its various forms influences periodontal health. By integrating Hedges' g for effect size calculations and conducting rigorous sensitivity analyses, our study ensures a comprehensive and unbiased evaluation. This not only aligns with but extends existing literature, offering valuable insights into clinical implications and supporting a call for targeted longitudinal studies to further define the interplay between thyroid health and periodontal outcomes.

Despite the consistent findings, our study presents specific nuances that differentiate it from prior research. Notably, while we found significant effects of thyroid dysfunction on CAL and PPD, we did not observe significant impacts on other periodontal indices such as the gingival index and plaque index. Among the included studies, several studies utilized less rigorous definitions of periodontitis, relying heavily on serum/salivary markers, gingival indices, or self-reported measures, which may not accurately reflect disease severity [16–18].

**Table 2** Comparative presentation of Periodontal Disease Indicators and Indices in Studies of Thyroid Dysfunction. This table provides data from seven studies on patients with thyroid disorders. It includes measurements of periodontal disease indicators such as Decayed, Missing, and Filled Teeth index (DMFT) for permanent teeth and dmft for deciduous teeth, Plaque Index (PI), Gingival Index (GI), Papillary Bleeding Index (PBI), Pocket Probing Depth (PPD), and Clinical Attachment Level (CAL). Additionally, inflammatory markers like Interleukin (IL) cytokine levels and Tumor Necrosis Factor-alpha (TNF-α) were analyzed. Each value is presented as a mean with a standard deviation (SD) for both the case and control groups

| Study Authors | Date Publication | Type of Thyroid Dysfunction | Thyroid Function Tests | Periodontal Disease Indicators and Indices | Case Group (Mean ± SD, *n*) | Control Group (Mean ± SD, *n*) |
|---|---|---|---|---|---|---|
| Bhankhar et al. | 2017 | Hyperthyroidism | TSH, T3, FT4 | PBI, CAL, PPD, GI | TSH: 3.48 ± 1.41 µIU/ml, CAL: 2.5 ± 0.5 mm, PPD: 3.1 ± 0.4 mm, *n* = 15 | *n* = 15 (Healthy individuals, TSH: 2.1 ± 0.3 µIU/ml) |
| Kadhom et al. | 2023 | Hyperthyroidism | TSH, T3, FT4 | PI, GI, PPD, CAL, IL-6 | PI: 1.9 ± 0.7, PPD: 3.4 ± 0.5 mm, CAL: 3.2 ± 0.6 mm, IL-6: 150 ± 15 pg/ml, *n* = 45 | PI: 1.2 ± 0.4, PPD: 2.6 ± 0.4 mm, CAL: 2.3 ± 0.4 mm, IL-6: 90 ± 10 pg/ml, *n* = 45 |
| Monea et al. | 2014 | Hypo-/Hyperthyroidism | TSH, T3, FT4 | Salivary/serum IL-6, TNF-α | Hypo: IL-6 (99.39 ± 54.41 pg/ml), TNF-α (132.29 ± 91.26 pg/ml), *n* = 13; Hyper: IL-6 (32.24 ± 29.46 pg/ml), TNF-α (45.30 ± 28.10 pg/ml), *n* = 15 | IL-6: 11.23 ± 2.14 pg/ml, TNF-α: 10.5 ± 3.2 pg/ml, *n* = 24 |
| Rahangdale et al. | 2018 | Hyperthyroidism | TSH, T3, FT4 | PI, BI, PPD, CAL | PPD: 3.2 ± 0.6 mm, CAL: 2.7 ± 0.5 mm, BI: 0.8 ± 0.2, *n* = 52 | PPD: 2.5 ± 0.4 mm, CAL: 2.1 ± 0.3 mm, BI: 0.5 ± 0.1, *n* = 50 |
| Sahar et al. | 2019 | Hyperthyroidism | TSH, T3, FT4 | IL-1β, IL-6, TNF-α in serum/saliva | IL-1β: 277.83 ± 21.49 pg/ml, IL-6: 105.25 ± 12.34 pg/ml, TNF-α: 75.62 ± 8.45 pg/ml, *n* = 30 | IL-1β: 80.58 ± 13.75 pg/ml, IL-6: 42.17 ± 6.92 pg/ml, TNF-α: 35.78 ± 4.32 pg/ml, *n* = 30 |
| Saraswathi et al. | 2020 | Hyperthyroidism | TSH, T3, FT4 | PI, GI, PPD, CAL, IL-6, TNF-α | PPD: 3.5 ± 0.5 mm, CAL: 3.3 ± 0.6 mm, IL-6: 120 ± 10 pg/ml, TNF-α: 85 ± 12 pg/ml, *n* = 20 | PPD: 2.9 ± 0.4 mm, CAL: 2.7 ± 0.5 mm, IL-6: 78 ± 8 pg/ml, TNF-α: 55 ± 7 pg/ml, *n* = 20 |
| Saima et al., | 2016 | Congenital hypothyroidism, thyroid agenesis, thyroid dysmorphogenesis, secondary hypothyroidism, thyroiditis | Not specified in detail | DMFt, dmft, PI, GI | DMFT: 0.65 ± 1.185, dmft: 2.14 ± 2.12, PI: 1.316 ± 0.616, GI: 0.876 ± 0.623 | DMFT: 0.31 ± 0.664, dmft: 1.86 ± 2.085, PI: 0.763 ± 0.404, GI: 0.34 ± 0.373 |

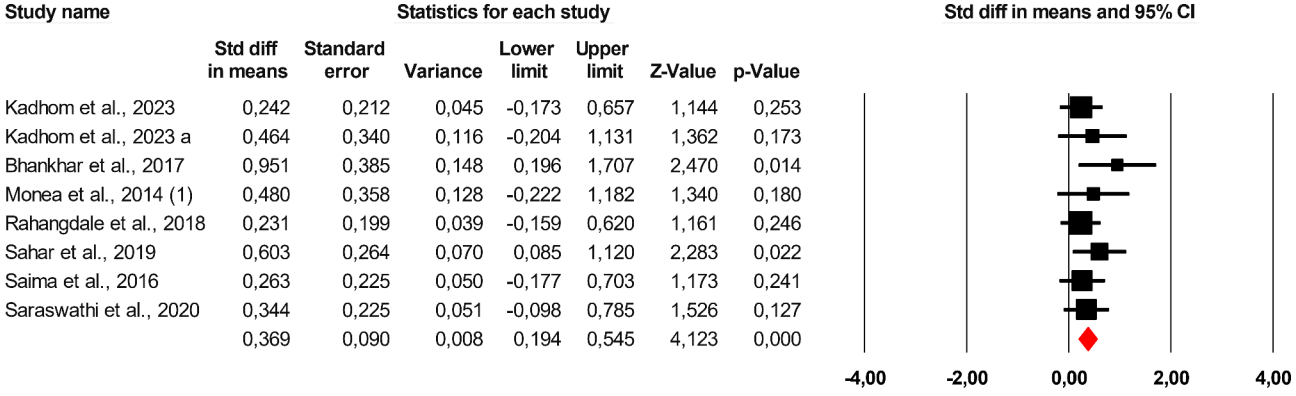


**Fig. 2** Forest plot summarizing the standardized mean difference (SMD) for each study included in the meta-analysis. The SMD, shown as a square on the plot, serves as a gauge of the impact size for every study. The 95% confidence interval for the effect size estimate is shown by the horizontal line that extends from each square. The 95% confidence interval and the overall effect size estimate are shown by the red diamond at the bottom of the figure. CAL, clinical attachment level; PPD, pocket probing depth

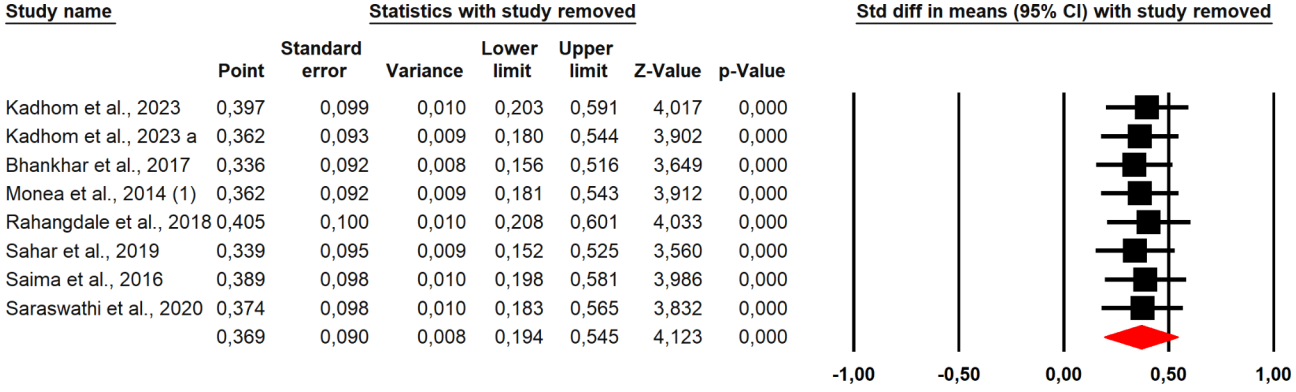


**Fig. 3** Forest plot depicting the results of the leave-one-out analysis for the studies included in the meta-analysis based on the standardized mean difference (SMD). The SMD, shown as a square on the plot, serves as a gauge of the impact size for every study. The 95% confidence interval for the effect size estimate is shown by the horizontal line that extends from each square. The 95% confidence interval and the overall effect size estimate are shown by the red diamond at the bottom of the figure

Additionally, the multifactorial nature of periodontal disease must be considered when interpreting these findings. Factors such as smoking, diabetes, and other inflammatory conditions can significantly influence periodontal health and may confound the relationship between thyroid dysfunction and periodontal disease. We excluded patients who used antibiotics in the past 3 months or were smokers. However, it was not possible to account for all these confounding factors in our meta-analysis.

Despite the valuable insights gained from our systematic review and meta-analysis, several limitations must be acknowledged. First, the overall quality of the included studies was low, which raises concerns about the reliability of the findings. The absence of randomization and blinding in the studies could introduce biases that affect the outcomes measured. Second, the relatively small number of studies included in the meta-analysis limits the generalizability of our findings. Although we aimed for a comprehensive search strategy, the final inclusion of only eight studies may not fully represent the breadth of research available on this topic. Furthermore, the studies varied in their definitions of thyroid dysfunction and the specific periodontal indices assessed, which complicates the comparison of results across studies. Future research should aim to standardize the assessment of periodontal disease and thyroid function to facilitate more accurate comparisons and conclusions. Third, the presence of publication bias, as indicated by our funnel plot analysis, suggests that the findings may not accurately reflect the true relationship between thyroid dysfunction and periodontal disease. This bias could lead to an overestimation of the effect size and may obscure the nuances of the relationship.

| Group by Comparison | Study name | Subgroup within study | Comparison | Std diff in means | Standard error | Variance | Lower limit | Upper limit | Z-Value | p-Value |
|---|---|---|---|---|---|---|---|---|---|---|
| Gingival index | Kadhom et al., 2023 a | Hyperthyroid | Gingival index | 0,033 | 0,211 | 0,044 | -0,381 | 0,446 | 0,154 | 0,877 |
| Gingival index | Saima et al., 2016 | Hypothyroid | Gingival index | 1,044 | 0,238 | 0,057 | 0,577 | 1,511 | 4,380 | 0,000 |
| Gingival index | Saraswathi et al., 2020 a | Hypothyroid | Gingival index | 0,110 | 0,224 | 0,050 | -0,329 | 0,549 | 0,491 | 0,623 |
| Gingival index | | | | 0,388 | 0,316 | 0,100 | -0,230 | 1,007 | 1,231 | 0,218 |
| IL-6-Blood | Monea et al., 2014 (2) a | Hyperthyroid | IL-6-Blood | 0,679 | 0,338 | 0,114 | 0,016 | 1,341 | 2,008 | 0,045 |
| IL-6-Blood | Monea et al., 2014 (1) b | Hypothyroid | IL-6-Blood | 0,590 | 0,351 | 0,123 | -0,098 | 1,278 | 1,681 | 0,093 |
| IL-6-Blood | Sahar et al., 2019 c | Hypothyroid | IL-6-Blood | -0,089 | 0,258 | 0,067 | -0,596 | 0,417 | -0,345 | 0,730 |
| IL-6-Blood | Saraswathi et al., 2020 b | Hypothyroid | IL-6-Blood | 1,404 | 0,250 | 0,062 | 0,915 | 1,894 | 5,626 | 0,000 |
| IL-6-Blood | | | | 0,649 | 0,354 | 0,125 | -0,045 | 1,343 | 1,832 | 0,067 |
| IL-6-Salivary | Kadhom et al., 2023 b | Hyperthyroid | IL-6-Salivary | 0,849 | 0,220 | 0,048 | 0,417 | 1,280 | 3,856 | 0,000 |
| IL-6-Salivary | Monea- et al., 2014 (2) d | Hyperthyroid | IL-6-Salivary | 0,682 | 0,338 | 0,114 | 0,019 | 1,344 | 2,017 | 0,044 |
| IL-6-Salivary | Monea et al., 2014 (1) c | Hypothyroid | IL-6-Salivary | 0,700 | 0,354 | 0,125 | 0,007 | 1,394 | 1,979 | 0,048 |
| IL-6-Salivary | Sahar et al., 2019 d | Hypothyroid | IL-6-Salivary | -0,583 | 0,264 | 0,069 | -1,099 | -0,066 | -2,211 | 0,027 |
| IL-6-Salivary | | | | 0,404 | 0,366 | 0,134 | -0,313 | 1,120 | 1,105 | 0,269 |
| Mean CAL | Bhankhar et al., 2017 | Hypothyroid | Mean CAL | 8,764 | 1,189 | 1,413 | 6,434 | 11,094 | 7,372 | 0,000 |
| Mean CAL | Rahangdale et al., 2018 a | Hypothyroid | Mean CAL | 0,434 | 0,200 | 0,040 | 0,041 | 0,827 | 2,166 | 0,030 |
| Mean CAL | Saraswathi et al., 2020 c | Hypothyroid | Mean CAL | 0,372 | 0,226 | 0,051 | -0,070 | 0,814 | 1,649 | 0,099 |
| Mean CAL | | | | 2,339 | 0,893 | 0,797 | 0,589 | 4,088 | 2,620 | 0,009 |
| Mean plaque index | Kadhom et al., 2023 c | Hyperthyroid | Mean plaque index | 0,593 | 0,215 | 0,046 | 0,171 | 1,015 | 2,754 | 0,006 |
| Mean plaque index | Rahangdale et al., 2018 c | Hypothyroid | Mean plaque index | 0,046 | 0,198 | 0,039 | -0,343 | 0,434 | 0,231 | 0,818 |
| Mean plaque index | Saima et al., 2016 a | Hypothyroid | Mean plaque index | 1,016 | 0,238 | 0,056 | 0,551 | 1,482 | 4,278 | 0,000 |
| Mean plaque index | Saraswathi et al., 2020 d | Hypothyroid | Mean plaque index | 0,000 | 0,224 | 0,050 | -0,438 | 0,438 | 0,000 | 1,000 |
| Mean plaque index | | | | 0,406 | 0,235 | 0,055 | -0,054 | 0,866 | 1,729 | 0,084 |
| Mean PPD | Rahangdale et al., 2018 e | Hypothyroid | Mean PPD | 0,540 | 0,202 | 0,041 | 0,145 | 0,935 | 2,678 | 0,007 |
| Mean PPD | Saraswathi et al., 2020 e | Hypothyroid | Mean PPD | 0,346 | 0,225 | 0,051 | -0,095 | 0,788 | 1,538 | 0,124 |
| Mean PPD | | | | 0,454 | 0,150 | 0,023 | 0,159 | 0,748 | 3,021 | 0,003 |
| Papillary bleeding index | Bhankhar et al., 2017 a | Hypothyroid | Papillary bleeding index | 5,463 | 0,794 | 0,631 | 3,907 | 7,020 | 6,879 | 0,000 |
| Papillary bleeding index | Rahangdale et al., 2018 f | Hypothyroid | Papillary bleeding index | 0,226 | 0,199 | 0,039 | -0,163 | 0,616 | 1,138 | 0,255 |
| Papillary bleeding index | | | | 2,788 | 2,618 | 6,854 | -2,343 | 7,920 | 1,065 | 0,287 |
| TNF-a-Blood | Monea et al., 2014 (2) b | Hyperthyroid | TNF-a-Blood | 0,354 | 0,339 | 0,115 | -0,310 | 1,018 | 1,044 | 0,297 |
| TNF-a-Blood | Monea et al., 2014 (1) a | Hypothyroid | TNF-a-Blood | 0,687 | 0,363 | 0,132 | -0,024 | 1,398 | 1,894 | 0,058 |
| TNF-a-Blood | Sahar et al., 2019 e | Hypothyroid | TNF-a-Blood | -0,134 | 0,258 | 0,067 | -0,641 | 0,372 | -0,520 | 0,603 |
| TNF-a-Blood | Saraswathi et al., 2020 f | Hypothyroid | TNF-a-Blood | 0,105 | 0,224 | 0,050 | -0,334 | 0,543 | 0,468 | 0,640 |
| TNF-a-Blood | | | | 0,179 | 0,160 | 0,026 | -0,134 | 0,493 | 1,122 | 0,262 |
| TNF-a-Salivary | Monea et al., 2014 (2) c | Hyperthyroid | TNF-a-Salivary | 0,129 | 0,354 | 0,125 | -0,565 | 0,822 | 0,364 | 0,716 |
| TNF-a-Salivary | Monea et al., 2014 (1) d | Hypothyroid | TNF-a-Salivary | 0,081 | 0,354 | 0,125 | -0,612 | 0,774 | 0,229 | 0,819 |
| TNF-a-Salivary | Sahar et al., 2019 f | Hypothyroid | TNF-a-Salivary | -0,121 | 0,258 | 0,067 | -0,627 | 0,386 | -0,468 | 0,640 |
| TNF-a-Salivary | | | | -0,004 | 0,180 | 0,032 | -0,357 | 0,348 | -0,024 | 0,981 |
| Overall | | | | 0,312 | 0,079 | 0,006 | 0,157 | 0,468 | 3,944 | 0,000 |

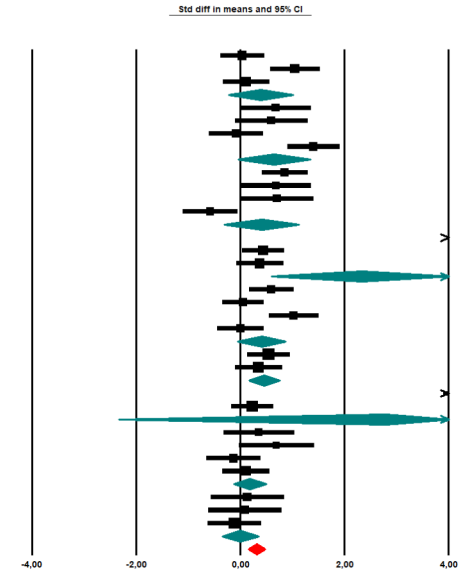


**Fig. 4** Forest plot summarizing the standardized mean difference (SMD) for each comparator included in the meta-analysis. The SMD, shown as a square on the plot, serves as a gauge of the impact size for every study. The 95% confidence interval for the effect size estimate is shown by the horizontal line that extends from each square. The 95% confidence interval and the overall effect size estimate are shown by the red diamond at the bottom of the figure

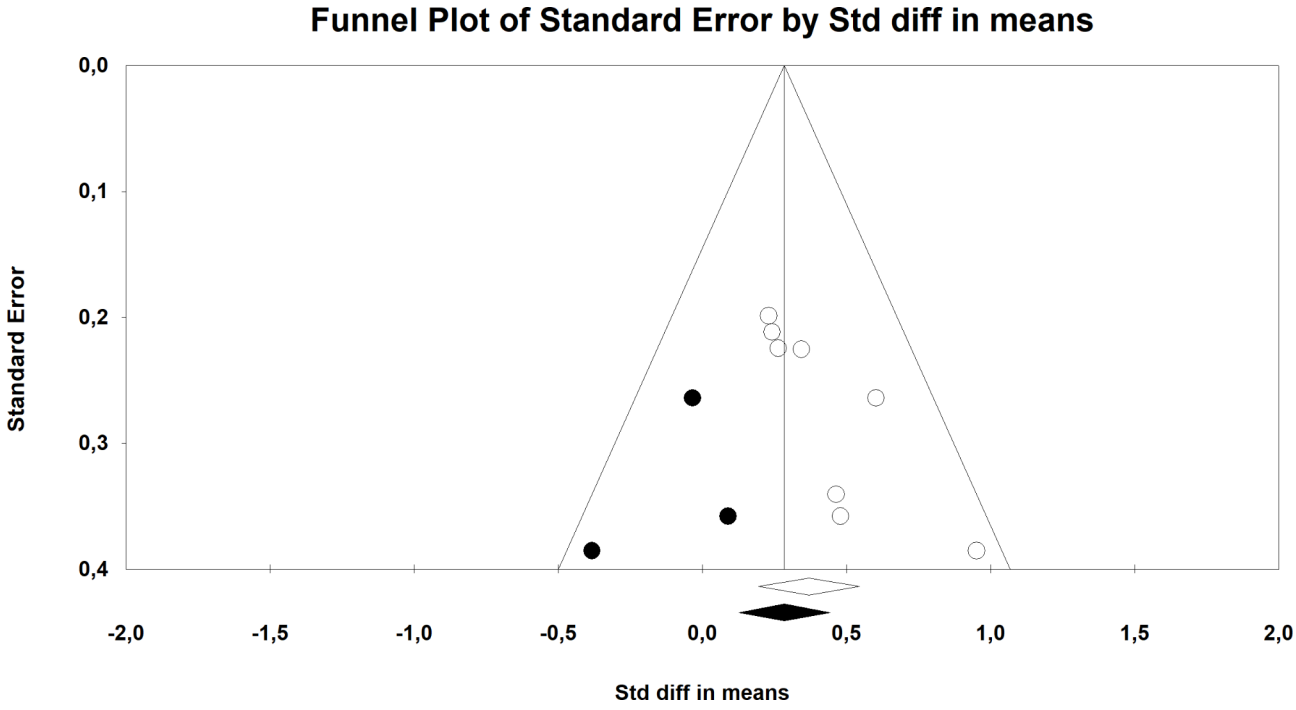


**Fig. 5** Funnel plot. The link between the standard error and the standardized mean difference (SMD) for the studies that were included in the meta-analysis is shown by a funnel plot. The funnel plot is a useful tool for visually examining the meta-analysis for publication bias and asymmetry

## Conclusion

Our systematic review and meta-analysis provide evidence of a significant association between thyroid dysfunction and increased periodontal disease indices. While our findings align with some existing literature, discrepancies in specific outcomes highlight the need for further research to clarify the relationship between thyroid function and periodontal health. Addressing the limitations of the current studies and standardizing methodologies will be crucial for advancing our understanding of this important connection. Future investigations should also explore the underlying mechanisms by which thyroid dysfunction may influence periodontal disease, ultimately contributing to improved management

strategies for patients with coexisting thyroid and periodontal conditions.

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This study is a systematic review and meta-analysis of the existing studies. This is not a clinical trial so clinical trial is not applicable.

**Author contributions**
Conceptualization, J,N and F, L; Methodology and Software, J,N; Validation, J,N; Formal Analysis, J,N; Investigation, J,N; Resources, F,L; Data Curation, F,L; Writing—Original Draft Preparation, J,N and B, D; Writing—Review & Editing, F,L; Visualization, F,L; Supervision, F,L; Project Administration, F,L; Funding Acquisition, F,L. All authors have reviewed and approved the submitted version. All authors have read and agreed to the published version of the manuscript.

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**Data availability**
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**
Not applicable.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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