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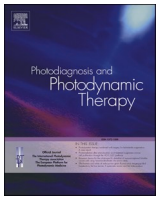

Effect of mechanical debridement with and without adjunct antimicrobial photodynamic therapy for the treatment of peri-implant disease in obese patients: A systematic review and meta-analysis of randomized controlled trials

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ABSTRACT

Objective: The aim of the present systematic review and meta-analysis was to assess the effect of mechanical debridement (MD) with and without adjunct antimicrobial photodynamic therapy (aPDT) for the treatment of peri-implant diseases in obese patients.

Methods: The focused question is "Is MD with adjuvant aPDT more effective than MD alone for treating peri-implant diseases in obese patients?" Indexed databases were searched without time and language barriers up to and including February 2025. Various keywords were used in different combinations using Boolean operators. A forest plot was generated to visually present the results of the meta-analysis. The risk of bias (RoB) within studies was assessed and GRADE analysis was performed.

Results: Three randomized controlled trials (RCTs) were included. The number of participants ranged between 49 and 80 individuals. Patients in the test and control groups underwent MD with and without adjunct aPDT, respectively. In two studies, periimplantitis was treated with MD with and without adjunct aPDT, and in one, MD with and without MD was performed to treat peri-implant mucositis. Follow-up ranged from 3 to 6 months. All RCTs showed that MD+aPDT is more effective in treating peri-implant diseases than MD alone. The RoB was high and unclear in one and two RCTs, respectively. The meta-analysis showed that control intervention provided a more favorable outcome than experimental intervention. The certainty of evidence was low, and the strength of recommendation was weak in all RCTs.

Conclusion: Role of aPDT as an adjunct to MD for treating peri-implant diseases in obese populations remains unclear.

1. Introduction

Dental implants have revolutionized clinical dentistry and related research by offering a more attractive yet reliable substitute for dentures or bridges for patients with missing permanent teeth. However, peri-implant diseases (peri-implant mucositis and peri-implantitis) continue to challenge clinicians and researchers [1,2]. Conventionally, mechanical debridement (MD) of implant surfaces and peri-implant sulci is performed for the treatment of peri-implant diseases (peri-implant mucositis and peri-implantitis) [3–5]. However, studies [6–9] have shown that therapies such as antimicrobial photodynamic therapy (aPDT), when used as an adjunct to SRP, are more effective in reducing periodontal inflammation in contrast to SRP alone. Sculean et al. [10] reviewed results from randomized controlled trials (RCTs), which evaluated the use of MD with adjunct aPDT for managing periodontal and peri-implant infections. The results of this narrative review showed that aPDT, when performed with adjunct MD, is more effective in treating peri-implant diseases compared with MD alone [10]. In addition, the authors proposed that aPDT should be considered as a standard of care in clinical periodontal practice [10]. The most logical justification for such outcomes is linked with the mode of action of aPDT. The aPDT is a therapeutic approach that involves interactions between a chemical dye (photosensitizer) and visible light (usually 660–880 nm wavelength) in an aerobic environment. This interaction results in the formation of reactive oxygen species (ROS) that possess antibacterial, cytotoxic and anti-inflammatory properties [11].

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It is well-documented that a state of immunosuppression not only compromises systemic health but also jeopardizes periodontal and peri-implant tissues [12–14]. Immunosuppression adversely affects periodontal and peri-implant health by impairing the host's ability to mount an effective immune response to microbial biofilms, leading to increased susceptibility to infection and inflammation [15]. Reduced function or number of immune cells, such as neutrophils, T cells, and macrophages, weakens the innate and adaptive immune defenses allowing the proliferation of pathogenic microbes in dental biofilms [16,17]. This dysbiosis results in the release of virulence factors, triggering an excessive inflammatory response characterized by elevated cytokines like interleukin-1β and tumor necrosis factor-alpha, which promote soft and hard tissue destruction [18–20]. Such immunoinflammatory insults, if not diagnosed and treated in a timely manner, can result in dire oral health-related consequences, including tooth and dental implant loosening [21,22]. Obesity is a chronic metabolic condition characterized by excessive accumulation of body fat, resulting in negative health outcomes [23]. It is typically measured using the body mass index (BMI), calculated as weight (kg) divided by height squared (m^2). Individuals with a BMI of 18.5–24.9 kg/m^2 and at least 30 Kg/m2 are categorized as "normal weight" and "obese", respectively [23,24]. In a recent study, Liu et al. [25] assessed the association between periodontitis and obesity using data from the National Health and Nutrition Examination Survey. The results showed that the risk of periodontitis is significantly higher among obese than normal-weight individuals aged between 30 and 44 years [25]. Similarly, Kayal and Rajasekar [26] evaluated peri-implant health parameters among obese and non-obese patients. The results showed that peri-implant probing depth (PD) and crestal bone loss (CBL) were significantly higher in obese than normal-weight individuals [26]. Furthermore, it has been documented that obesity compromises healing after therapeutic interventions primarily due to compromised immunity and an increased expression of proinflammatory cytokines in the serum and gingival crevicular fluid [27,28].

With this background, the objective of the present systematic review and meta-analysis was to evaluate the influence of MD with and without adjunct aPDT for the treatment of peri-implant diseases in obese individuals.

2. Methods

2.1. Ethical approval

The present study systematically reviewed studies published in indexed databases. Therefore, the study protocol was exempted from attaining prior ethical approval from an institutional review committee.

2.2. Focused question

The focused question addressed in the present systematic review and meta-analysis is ""Is MD with adjuvant aPDT more effective than MD alone for treating peri-implant diseases in obese patients?"

2.3. Population, intervention, control, outcome

The population, Intervention, Control, Outcome (PICO) parameters were as follows: *P*=Obese patients diagnosed with peri-implant diseases (peri-implant mucositis or peri-implantitis); *I*=MD with adjunct aPDT; C=MD alone; *O*=Reduction in peri-implant PD.

2.4. Inclusion and exclusion criteria

The inclusion criteria were as follows: (a) original studies; (b) clinical studies; (c) presence of a control group (MD alone); (d) assessment of peri-implant clinical parameters; (e) statistical analysis. Letters to the Editor, dissertations/thesis, studies on animal models, in-vivo/ex-vivo/in-silico studies, case reports, case series, review articles, commentaries, perspectives, book chapters and expert opinions were excluded.

2.5. Literature search protocol

The literature search protocol for the present systematic review and meta-analysis was developed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to ensure a comprehensive and unbiased selection of studies [29]. Indexed electronic databases, namely PubMed/MEDLINE, EMBASE, Scopus, Web of Science, and Google Scholar, were searched by two investigators (SA and RA) without time and language restrictions. Disagreements related to study selection were resolved via discussion. The literature search was performed up to and including February 2025. The following keywords were used in different combinations using Boolean operators ("AND," "OR"): Alveolar bone loss, Antimicrobial photodynamic therapy, Obesity, Probing depth, and mechanical debridement. Duplicates were removed, and an independent reviewer screened titles and abstracts to exclude irrelevant studies based on eligibility criteria referenced above. Full-text articles of potentially relevant studies were assessed for inclusion. Hand searching of the reference lists of review articles was also performed to identify studies that could have been missed during the initial search.

2.6. Risk of bias assessment

Two investigators (SA and RA) assessed the risk of bias (RoB) using the Cochrane RoB 2.0 (RoB 2) tool, which evaluates the quality of evidence across five key domains [30]. These domains included (1) random sequencing, (2) allocation concealment (AC), (3) blinding of operator, (4) blinding of outcome assessment, (5) incomplete outcome data, (6) Selective reporting, and (7) other sources of bias. Two independent reviewers (SA and RA) evaluated each trial, assigning judgments of "low risk," "Unclear," or "high risk" for each domain, followed by an overall RoB judgment for each study. The process involved reviewing the study protocols, methods, and reported outcomes to ensure transparency and minimize subjective interpretations. Disagreements were resolved via discussion. A summary plot of RoB assessments was generated, highlighting domain-specific concerns for each trial to guide the synthesis of evidence.

2.7. Grading of recommendations, assessment, development, and evaluation

The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) methodology was employed to assess the overall quality of evidence for each outcome included in the present systematic review and meta-analysis [31]. Studies were evaluated by two investigators (SA and RA) across four levels: high, moderate, low, and very low quality. The authors independently assessed the quality of evidence for each outcome across five key domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias [31].

2.8. Meta-analysis

Calculation of change scores for both the experimental and control groups were calculated as the difference between follow-up and baseline means. The standard deviations of the change scores were calculated assuming no covariance data. Both fixed-effect and random-effects models were computed. A forest plot was generated to visually present the results of the meta-analysis. The meta-analysis was conducted using the meta package in Posit Software (2024, Posit Software, PBC, Boston, MA, USA).

3. Results

3.1. General characteristics of studies

Through the initial literature search, a total of 141 potentially relevant articles were identified (Supplementary Table A). Duplicates (n = 109) and review articles (n = 12) were removed and full texts of the remaining studies (n = 12) were vigilantly reviewed. Of these, 17 studies that did not abide by the PICO were removed. In total, three RCTs [3–5] were included and processed for data extraction (Fig. 1). There was no statistically significant difference in the mean age of individuals in the test and control groups in all studies [3–5]. All studies [3–5] were performed in obese patients with a BMI of at least 30 Kg/m^2. The number of participants ranged between 49 and 80 individuals. In the included RCTs [3–5], patients in the test and control groups underwent MD with and without adjunct aPDT, respectively. In two studies [4,5], peri-implantitis was treated with MD with and without adjunct aPDT, and in the study by Alasqah MH [3], MD with and without MD was performed to treat peri-implant mucositis. The follow-up duration ranged between three and six months [3–5] (Table 1). A prior sample size estimation (SSE) or power analysis (PA) was performed in one [5] of the three RCTs [3–5].

3.2. Photodynamic therapy related characteristics

In two RCTs [3,4], a 670 nm diode laser was used and Elsadek and Almoajel [5] used the diode laser at 660 nm wavelength. In all RCTs [3–5], the laser was used at a power of 150 mW. None of the RCTs [3–5] reported the power density and energy fluence of the diode laser. In studies by Alasqah MN [3] and Elsadek and Almoajel [5], the laser was delivered with a flexible tip having a diameter of 300 and 600 μm, respectively. In two studies 0.05 % methylene blue was used as photosensitizer. In the study by Alresayes et al. [4], the type an concentration of photosensitizer used was not reported. In all RCTs [3–5], aPDT was performed once after MD (Table 2).

3.3. Outcomes

Results from all RCTs [3–5] showed that MD when performed with adjunct aPDT is more effective in treating peri-implant diseases in contrast to when MD is performed as the sole treatment protocol.

3.4. Risk of bias

The RoB was unclear in the RCTs by Alasqah MN [3] and Elsadek and Almoajel [5]. The study by Resayes et al. [4] had a high RoB. A summary plot representing the RoB within the included RCTs [3–5] is shown in Fig. 2.

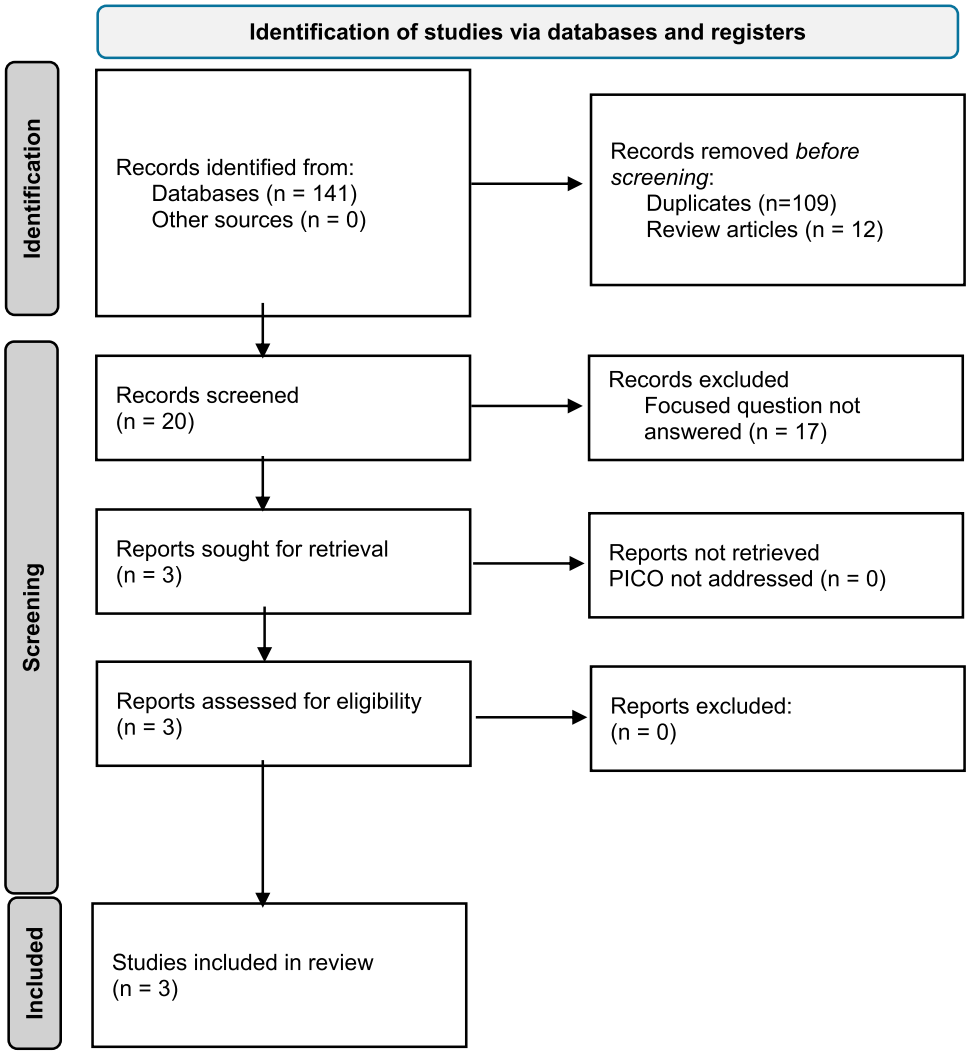

Fig. 1. PRISMA flowchart.

Table 1
Characteristics of included studies.

Authors et al.	Study design	Peri-implant disease	Participants (n)	Gender	Study groups (n)	Age in years	Follow-up
Alasqah MN [3]	RCT	Peri-implant mucositis	51	Male	Control-group: MD alone (25) Test-group: MD + aPDT (26)	Control-group: 40.5 ± 5.2 years Test-group: 42.1 ± 3.9 years	6 months
Alresayes et al. [4]	RCT	Peri-implantitis	49	22 males 27 females	Control-group: MD alone (25) Test-group: MD + aPDT (24)	Control-group: 49.4 ± 9.9 years Test-group: 45.8 ± 9.2 years	6 months
Elsadek and Almoajel [5]	RCT	Peri-implantitis	80	55 males 25 females	Control-group: MD alone (40) Test-group: MD + aPDT (40)	Control-group: 41.4 ± 2.5 years Test-group: 43.4 ± 5.2 years	3 months

Table 2
Photodynamic therapy-related parameters.

Authors et al.	Diode laser	Power	Power density	Energy fluence	Diameter of fiber tip	Photosensitizer	Frequency of aPDT
Alasqah MN [3]	670 nm	150 mW	NR	NR	300μm	0.05 % methylene blue	Once
Alresayes et al. [4]	670 nm	150 nm	NR	NR	NR	NR	Once
Elsadek and Almoajel [5]	660 nm	150 mW	NR	NR	600 μm	0.05 % methylene blue	Once

NR: Not reported.

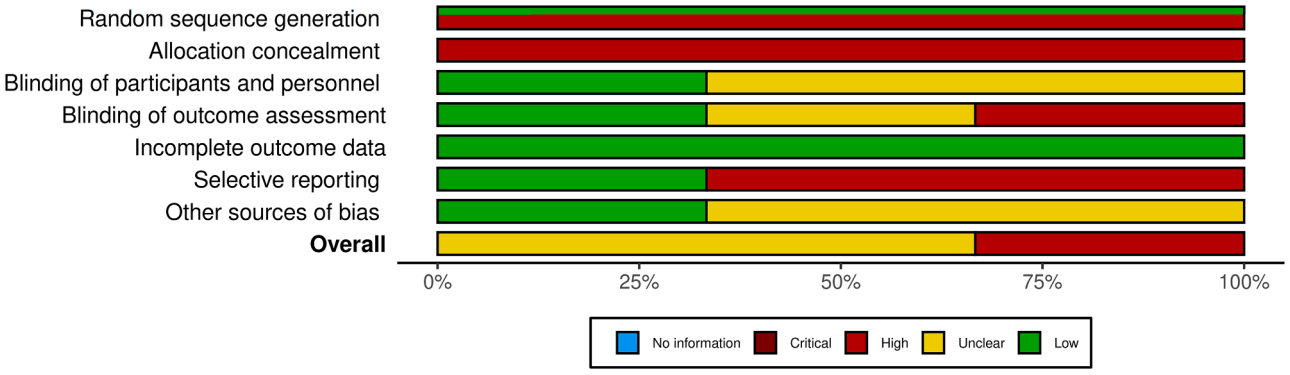

Fig. 2. Summary plot for the risk of bias within studies.

3.5. GRADE analysis

The certainty of evidence was low and strength of recommendation was weak in all RCTs (Table 3).

3.6. Meta-analysis

The meta-analysis yielded a significant overall effect size. The fixed-effect model indicated a weighted mean difference (WMD) of −0.51 (95 % CI: −0.67 to −0.35, $p < 0.05$), while the random-effects model yielded a WMD of −0.60 (95 % CI: −0.77 to −0.43, $p < 0.05$). The prediction interval was [−1.88 to 1.23]. These results suggest that the control intervention showed a more favorable outcome compared to the experimental intervention. The heterogeneity analysis revealed a τ^2 (Tau-squared) value of 0.0878, with a Chi-squared statistic of 6.79 (df = 2, $P = 0.0335$), and an I^2 of 70.6 %, indicating substantial heterogeneity among the included studies. The forest plot (Fig. 3) illustrates the effect sizes and confidence intervals for each study. Most studies favored the control intervention over the experimental, confirming a significant reduction in outcomes for the control group compared to the experimental group.

4. Discussion

An individual assessment of the results of each of the three RCTs [3–5] included in the present systematic review and meta-analysis showed that aPDT when performed as an adjuvant to MD is more effective in reducing peri-implant soft tissue inflammation (PD) in contrast to MD alone in obese populations. It is, therefore, tempting to conclude that a PDT is a reliable therapeutic strategy for managing per-implant diseases in patients with a BMI of 30 Kg/m^2. Nevertheless, the author of the present study perceives that such a conclusion should

Table 3
GRADE analysis.

Study	Participants	Study Design	Outcome Measures	Certainty of Evidence (GRADE)	Strength of Recommendation
Alasqah MN [3]	51	RCT	Probing depth	Low ⊕⊕ ●●	Weak
Alresayes et al. [4]	49	RCT	Probing depth and crestal bone loss	Moderate ⊕⊕ ●●	Weak
Elsadek and Almoajel [5]	80	RCT	Probing depth and crestal bone loss	Low ⊕⊕ ●●	Weak

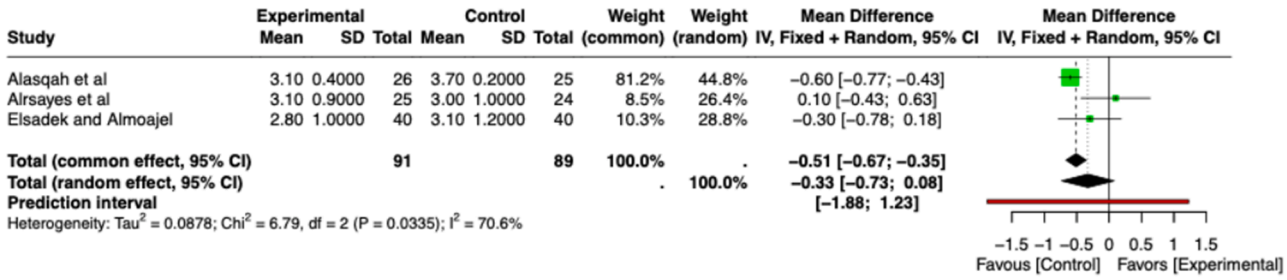

Fig. 3. Forest plot representing quantitative assessment of the included randomized controlled trials.

be interpreted with extreme caution. A critical appraisal of the RCTs [3–5] included in this systematic review and meta-analysis revealed several shortcomings in the design of the individualistic studies. A prior SSE or PA analysis is crucial in RCTs as it determines the minimum sample size required to detect an effect ensuring that the study is adequately powered to avoid false negatives [32,33]. Usually, a power of at least 80 % is targeted, indicating an 80 % probability of correctly rejecting a false *null* hypothesis [32]. Insufficient power can lead to inconclusive results, misinterpretation of treatment effects, and wasted resources [32]. In this regard, comprehensive planning and power calculations significantly enhance the validity and reliability of a study ultimately contributing to better clinical outcomes and informed decision-making [32]. It is imperative to emphasize that a prior SSE or PA was performed in only one [5] of the three RCTs [3–5] that fulfilled the eligibility criteria. In this context, the statistical comparisons and their corresponding probability values may not necessarily reflect a true comparison between the study groups. Another factor that could have potentially biased the results is the lack of AC. The AC is a critical methodological feature in a RCT designed to prevent selection bias ensuring that the process of assigning participants to different intervention groups is not influenced by knowledge of the treatment allocation [34]. This practice is essential for maintaining the integrity and credibility of trial results. Moreover, AC enhances the internal validity of a trial by ensuring that the treatment groups are comparable at baseline [34]. This comparability strengthens the ability to attribute differences in outcomes solely to the interventions being tested, rather than to pre-existing differences A vigilant overview of the methodology of the included RCTs [3–5] revealed that this parameter remained unaddressed in all studies. Furthermore, quantitative assessment (meta--analysis) of the included RCTs [3–5] favored the control intervention over the experimental, confirming a significant reduction in outcomes for the control group compared to the experimental group.

The author of the present systematic review and meta-analysis has several concerns related to the methodology of the RCTs [3–5] included. The diameter of the laser fiber tip (FT) plays a significant role in the delivery of light energy during photobiomodulation, influencing factors such as the area of tissue irradiated, power density (irradiance), and energy distribution [35]. For instance, a smaller FT diameter focuses the laser beam on a smaller area, resulting in higher power density but a limited treatment area [35]. Moreover, a smaller-diameter FT tips often allow for deeper penetration due to concentrated energy delivery in contrast to wider tips [35]. Alasqah MN [3] used a FT with a diameter of 300 300μm whereas another RCT [5] used a 600 nm FT. It is, therefore, likely that essential laser parameters such as energy fluence as well as power density varied during a PDT. The possibility of these factors influencing the overall efficacy of aPDT cannot be overlooked. It is also noteworthy that aPDT was done once throughout the study duration. According to Muzaheed et al. [36] at least two sessions of aPDT following MD are more effective in reducing the severity of oral inflammatory conditions in contrast to a single session. Likewise, in another RCT, Aabed et al. [37] reported that at least two sessions of aPDT following scaling and root planing (SRP) significantly reduces counts of periodontopathogenic bacteria (such as *Aggregatibacter actinomycetemcomitans* and *Porphyromonas gingivalis*) in the subgingival biofilm in contrast to a single session of aPDT after SRP. The author of the present systematic review and meta-analysis proposes that at least two sessions of aPDT (with standardized laser delivery parameters) following MD is more effective in treating peri-implant diseases in contrast to a single aPDT application. Further studies are needed to test this hypothesis.

It is worth mentioning that in all the RCTs [3–5] included in the present systematic review, the patients underwent non-surgical MD with or without adjunct aPDT. To the authors' knowledge from pertinent indexed literature, there is a lack of consensus as to whether surgical or non-surgical MD is most appropriate for the management of peri-implant inflammatory conditions. In a systematic review, Kotsailidi et al. [38] reviewed scientific databases to identify studies that had compared surgical and non-surgical MD protocols for managing peri-implantitis. Astoundingly, only one study performed on animal models was included and processed for data extraction [38]. Kotsailidi et al. [38] concluded that, to date, there is a lack of consensus on whether MD should be performed non-surgically or following the reflection of a surgical flap for managing peri-implantitis. Further well-designed and power-adjusted RCTs are needed in this regard. Future RCTs should focus on long-term follow-ups to evaluate the sustained efficacy of aPDT in managing peri-implant disease in obese individuals. It is also recommended that future investigations should assess obesity-related inflammatory markers (e.g., C-reactive protein and destructive inflammatory cytokines) in biological fluids (such as peri0implant sulcular fluid and unstimulated whole saliva) in relation to the treatment of peri-implant diseases using MD with and without adjunct aPDT. Furthermore, additional investigations on subgingival microbial shifts following MD with and without aPDT in obese and non-obese patients with peri-implant diseases.

5. Conclusion

The role of aPDT as an adjunct to MD for the management of peri-implant diseases in obese populations remains unclear. Further well-designed and power-adjusted clinical trials are needed.

CRediT authorship contribution statement

Sultan Albeshri: Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Raed AlRowis:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.pdpdt.2025.104510.

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